PROTEIN AND ENERGY UTILISATION IN TWO MEKONG CATFISHES, *PANGASIUS BOCOURTI* AND *PANGASIUS HYPOPHTHALMUS*

Le thanh Hung [1,2], Jérôme Lazard [2], Huynh thi Tu [3] and Yann Moreau [4]

(1) College of Agriculture and Forestry, National University of Ho Chi Minh city, Vietnam
(2) Aquaculture Research Unit, CIRAD-EMVT, GAMET, BP 5095, 34033 Montpellier Cedex 1, France
(3) Department of Aquaculture, Can Tho University, Vietnam
(4) IRD (ex ORSTOM)-GAMET, BP 5095, 34033 Montpellier, France

Abstract

Fish unlike terrestrial animal, use a large amount of protein as an energy source for their energy metabolism. When fed on a high protein ration, the fish itself may choose which amount of protein in food will be converted into body growth and which will be burned through the catabolism. Therefore, in the study one diet was designed with a high protein content and fed to fish with different levels: 0, 5, 15, 25, 35 and 45g crude protein $kg^{-1}.d^{-1}$.

P. bocourti has a higher growth rate than *P. hypophthalmus* at the same food intake. However, the higher growth observed in *P. bocourti* is obviously associated to higher fat accumulation in the body. The protein efficiency, NPU and PER, tends to be reduced at higher protein intake in both species.

Energy and protein requirements for maintenance were calculated to be 128 and 92 $kJ.kg^{-1}.day^{-1}$, and 5.16 and 3.24 $g.kg^{-1}.day^{-1}$, in *P. bocourti* and *P. hypophthalmus*, respectively. *P. bocourti* has nearly a double protein and energy requirement for maintenance. The event may be linked to the fact that *P. bocourti* has higher growth rate and higher ability to synthesise a large amount of body lipid than *P. hypophthalmus*.

An estimate of protein requirement was in range of 12-13 and 11-12 $g.kg^{-1}.day^{-1}$ in *P. bocourti* and *P. hypophthalmus*, respectively. The DP/DE ratio was estimated to be 18 and 17 $mg.kJ^{-1}$ in *P. bocourti* and *P. hypophthalmus*, respectively. These low DP/DE ratios may be related to the fact that the protein requirement was relatively low in the two species.

INTRODUCTION

Pangasius bocourti Sauvage, 1880 and *Pangasius hypophthalmus* Sauvage, 1887 are two indigenous fish species living in the Mekong River (Roberts & Vidthayanon, 1991). The culture of *P. bocourti* in floating cages represents a production with an annual figure of 13 000 tons (Cacot, 1994). The culture of *P. hypophthalmus*, done mainly in earthen ponds, has been a long traditional activity with an estimated production of several ten thousand tons a year.

Optimal protein requirement for growth was estimated for some catfishes reared in Asia (Madu & Tsumba, 1989; Degani *et al.*, 1989). Optimal dietary levels of crude protein ranged from 25% in *Pangasius sutchi* (Chuapoehuk & Pothissong, 1985) to 50% in *Clarias gariepinus* (Henken *et al.*, 1986). Even in the same species, there are also differences from one author to another. One of reason for such discrepancies may lie in the level of feed intake, amount of non-protein energy in the feed and also the quality of the dietary protein (Wilson & Moreau, 1996).

When feed quality and quantity are not limiting factors, three main factors have an influence on growth rate: feeding rate, protein level and energy content in the diet. They are all related and influenced by each other. Therefore, optimal level of protein may be defined for one feeding rate with a fixed energy level. Thus, requirement must be define using consecutive experiments where one of the factor is fixed in each case. To reduce the influence of feeding rate, absolute ration which is the combination of feeding rate with nutrient content, may be used (Moreau *et al*, 1995).

In attempt to install an experiment with the aim to determine protein-energy requirement, the best way is to avoid any interference between protein and energy content in the feed. Fish unlike terrestrial animal, use a large amount of protein as an energy source for their energy metabolism (Velas, 1981). Therefore, fish may be fed on a high protein ration as it is commonly done when trash fish is provided. In this case, the fish may choose itself which amount of protein in food will be converted into body increase and which will be burned through the catabolism. Fish will be fed on a diet where the content could be used either for protein supply or energy supply. Thus, the diet was designed with a very high protein content and gave varying amount to the fish. Then, fish itself could select and determine which ratio of energy to protein to be fixed or burned. The sum of a nutrient amount fixed for optimal growth and a nutrient amount required for maintenance (i.e. situation with no increase in body weight) has been defined as the protein and energy requirement for optimal growth.

Therefore, the objective of the present study is to estimate the protein and energy requirement for optimal growth in *P. bocourti* and *P. hypophthalmus* using a single diet formulation with only one experiment for each species, and to compare their growth performance as well.

MATERIAL AND METHODS

Fish and facilities

Experimental fish were obtained from sexually mature broodfish cultured in earthen ponds. The fish were induced to spawn using human gonadotropin hormone injection. The fish selection for a homogenous population was done and then fish were acclimatised to experimental facilities during one week for *P. bocourti* and two weeks for *P. hypophthalmus* since the later species is more sensitive to confined condition. *Pangasius bocourti* and *P. hypophthalmus* were on average 6.68 g and 7.69 g at initial day of the experiment, respectively.

Pangasius bocourti fingerlings were cultured in 50-liter aquarium in a recirculating water system at a stocking density of 20 fish per aquarium. *Pangasius hypophthalmus* fingerlings were cultured in concrete tank (1 x 1 x 0.6 m) at a density of 20 fish per tank. Water in tanks was supplied from a deep well. Water in aquarium was aerated and exchanged at a flow rate of 2-3 L. min^{-1}. Dissolved oxygen and pH, monitored twice a week, ranged between 3.5-5.5 $mg.L^{-1}$ and 7.0-7.5, respectively. Ammonia and nitrite in aquarium were measured once a week, varied from 0.1 to 0.8 $mg.L^{-1}$ and 0.01 to 0.03 $mg.L^{-1}$, respectively. Aquarium temperature ranged from 28 to 30°C. Water in tanks was exchanged at a flow rate of 10-15 $L.min^{-1}$. Dissolved oxygen was monitored twice a week and ranged from 3.0 to 3.5 $mg.L^{-1}$, pH ranged 7.0-7.2. Ammonia and nitrite ranged 0.1-0.4 $mg.L^{-1}$ and from 0.01 to 0.03 mg. L^{-1}, respectively. Temperature in tanks varied between 28 and 32°C.

Feed and feeding

A high protein diet was designed in which vitamins, minerals as well as essential fatty acids were added to avoid any nutrient deficiency. Therefore, fish were fed a pelleted feed containing high amount of fishmeal plus vitamin and mineral premix as well as soybean oil. Ingredients and composition are given in Table 1.

Ingredients	**% dry matter**
Fish meal (70% crude protein)	91
Vitamin premix	1
Mineral premix	4
Soybean oil	3
Sodium alginate (as binder)	1

Feed composition for each species (% dry matter)		
	P. hypophthalmus	*P. bocourti*
Crude protein	65.7	63.0
Crude fat	10.9	10.4
Ash	17.2	16.3

Table 1: Formulation of the diet and composition obtained for each species.

In the present study, six rations (0, 5, 15, 25, 35 and 45 g protein per kg of fish per day) were chosen in order to provide different amounts of protein and then energy intake. The protein amount is given with the aim to provide protein and energy as well. Therefore, presenting result only in term of amount of protein intake, may lead to confusion even if it is done this way. So, treatments will be referred later as R0, R5, R15, R25, R35 and R45 for convenience. Each treatment had three replications. Fish were fed twice a day at 8:00 and at 18:00. The experiment lasted for 4 weeks.

Sampling and data analysis

Fish were weighed individually every week to adjust the feeding at a precision of 0.1g. Initially 10 fishes were kept in freezer and at the end of the experiment 10 fishes in each tank or aquarium were also kept in freezer for carcass analysis.

Carcass and feed composition were determined for crude protein (Kjeldahl, nitrogen x 6.25), crude lipid (Soxhlet, chloroform extract), ash (residue after burning 4-5 hours at 550°C) and moisture (weight loss after drying at 105°C for 4-5 hours).

Growth performances and feed efficiency were expressed using usual parameters as following:

- Specific growth rate: SGR= (Ln(final weight) - Ln(initial weight)) / number of days.
- Food conversion ratio: FCR = dry food intake / increase in body weight.
- Protein efficiency ratio: PER = increase in body weight / protein intake.
- Net protein utilisation: NPU = increase in body protein / protein intake.
- For the purpose of this experiment and to match NPU, a new index regarding fat utilisation was introduced as followed: net fat utilisation: NFU = increase in body fat / fat intake.

Data analysis was done using SAS GLM and MIXED procedures.

RESULTS

Growth performance and feed utilisation of **Pangasius bocourti** *and* **Pangasius hypophthalmus**

Higher level of diet intake induces higher increase in body weight for both species (Figure 1). As intake is equal to R25 and above, the growth reaches a plateau for *P. hypophthalmus*. Meanwhile the fish growth in *P. bocourti* is still increasing until the ration R35. Comparing growth rate between the two species shows that *P. bocourti* has higher growth than *P. hypophthalmus* for the same intake. It can be seen also from Figure 1 that variation in body weight, obtained with treatment R5, is not or slightly different from zero, for both species.

Variation in the amount of food intake induces changes in body composition. Considering an

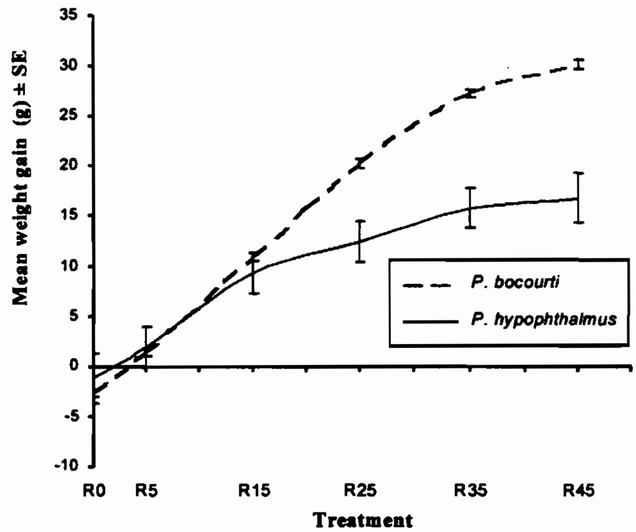
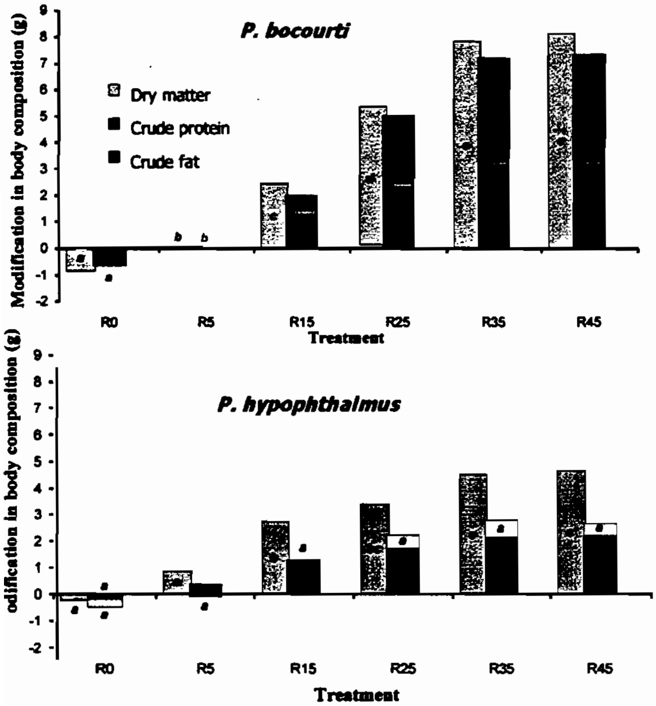


Figure 1: Mean weight gain of *P. bocourti* and *P. hypophthalmus* in response to treatments.

average fish for each treatment, changes in body composition such as dry matter, protein and fat may be calculated from difference between initial and final body composition (Figure 2). Similarly to growth performance, body dry matter and body protein increased with higher diet intake. However, body dry matter and body protein did not increase more when feed intake is over treatment R35 and R25, for *P. bocourti* and *P. hypophthalmus* respectively. For *P. bocourti*, higher feed intake induces high lipid retention that represents more than fifty percent of dry body mass increase. For fish receiving the treatment R5, body composition did not change so much for both species.

Values for common indices of growth performance and food utilisation are summarised in Table 2. Food conversion ratio (FCR) increased with higher food intake when ration was above R15 for both species. Yet, FCR is at its highest level with treatment R5, 1.14 for *P. bocourti* and 0.96 for *P. hypophthalmus*. In both species, efficiency indicators of protein intake like protein efficiency ratio (PER) or net protein utilisation (NPU) are at their highest level for treatment R15 to R25. Whereas, increase of SGR are still observed with higher diet intake, treatment R45 and R35, for *P. bocourti* and *P. hypophthalmus*, respectively. It suggests that fish accumulate a high proportion of other nutrient instead of body protein for treatments over R15 and R25. It is quite noticeable to find the high lipid retention, above 100%, with *P. bocourti* (Table 2). That refers the fish can deposit a large amount of fat. On the other hand, lower lipid deposition is



For each component, same letter indicates value not significantly different (α=0.05).

Figure 2: Modification of body composition in each species for an average fish according to the amount of diet supplied.

observed in *P. hypophthalmus*. The highest value was about 40% for treatment R25 in comparison to 150% for the same treatment with *P. bocourti*.

Based on each index, optimal condition may be determined for each species. Considering growth performance, optimal condition was encountered for group of treatments having high growth performance with the lower food intake. This is obtained with treatment R45 for *P. bocourti* and R35 for *P. hypophthalmus*. Similarly, treatment R25 and R35 are optimal, for *P. hypophthalmus* and *P. bocourti* respectively, when one considered protein increase and NPU which are higher among the group of treatment with the highest SGR. Optimal condition was then consequently determined for each index such as SGR, Protein increase, FCR, PER, NPU and NFU (Table 3). When all indices were considered, treatment R35 was found generally optimal for *P. bocourti* and R25 for *P. hypophthalmus*.

The choice between R25 and R35 will refer not only to general growth performance as well as food utilisation. Some others considerations such as acceptance of high fat content in fish by the consumer or the commercialisation way of fish (live, fresh or frozen fillet), may influence the fish farmers and lead them to produce fat or lean fish. Therefore both treatments, R25 and R35, will be further considered for the two species.

Nutrient and energy utilisation in P. bocourti *and* P. hypophthalmus

Nutrient utilisation (Table 4) indicated that *P. bocourti* can synthesise 6.8 to 7.74g protein.kg^{-1}.day^{-1} in ration corresponding to 25 to 35g protein.kg^{-1}.day^{-1}. While *P. hypophthalmus* can fix only 5.78 to 6.52g protein.kg^{-1}.day^{-1}. Thus, at intake levels ranging from R25 to R35, *P. bocourti* can synthesise some more protein than *P. hypophthalmus*. However, *P. hypophthalmus* uses dietary protein more efficiently since the fish fix 23% to 31% dietary protein when compared to

Indices	Treatment					
	R0	R5	R15	R25	R35	R45
P. bocourti						
SGR	-2.68^{a}	0.67^{b}	3.41^{c}	4.89^{d}	5.64^{e}	6.01^{f}
FCR		1.14^{a}	0.59^{c}	0.67^{bc}	0.80^{abc}	1.03^{a}
PER		1.42^{a}	2.59^{c}	2.26^{bc}	1.84^{ab}	1.48^{a}
NPU		0.01^{a}	0.28^{b}	0.26^{b}	0.21^{b}	0.16^{b}
NFU		0.05^{a}	0.55^{a}	1.50^{b}	1.65^{b}	1.24^{b}
P. hypophthalmus						
SGR	-0.62^{a}	0.80^{b}	2.88^{c}	3.45^{cd}	4.03^{de}	4.13^{e}
FCR		0.96^{a}	0.71^{a}	0.99^{a}	1.16^{ab}	1.53^{b}
PER		1.79^{ab}	2.27^{a}	1.65^{ab}	1.39^{b}	1.05^{b}
NPU		0.34^{a}	0.31^{a}	0.23^{a}	0.19^{a}	0.14^{a}
NFU		-0.53^{a}	0.08^{a}	0.40^{a}	0.35^{a}	0.18^{a}

Table 2: Growth performance and feed utilisation indices obtained for *P. bocourti* and *P. hypophthalmus*. Values with different letters in the same line are significantly different.

21%-26% in *P. bocourti* for the same fed intake.

With regard to lipid utilisation, both species cannot synthesise any body lipid at R5 intake level. To maintain a minimal requirement, the fish have to mobilise all dietary lipid. Yet, *P. hypophthalmus* has still synthesised body protein but neither *P. bocourti* for the same ration. It implies that *P. bocourti* has still mobilised dietary protein for maintenance at dietary protein intake as low as R5. At higher intake, R25-R35, *P. bocourti* has fixed 6.48 to 10.02g lipids per kg of fish per day. Meanwhile, *P. hypophthalmus* has fixed only1.65 to 2.03g lipid.kg^{-1}.day^{-1}. It showed that *P. bocourti* has a high ability to accumulate lipid, 4-5 times greater than that of *P. hypophthalmus*. The deposit lipid in *P. bocourti* was higher than the daily lipid intake (Table 2). It means that the fish has to transfer a large amount of dietary protein to deposit lipids. With regard to energy utilisation, the protein and lipid loss in fasted fish indicated that the energy requirement for maintenance in *P. bocourti* and *P. hypophthalmus* were 128 and 92 kJ.kg^{-1}.day^{-1}, respectively (Table 5). Energy utilisation for growth in term of synthesised protein and lipid of the fish was calculated for R25 and R35 feed intake. *P. bocourti* can synthesise 151 and 172 kJ.kg^{-1}.day^{-1} as fixed protein and *P. hypophthalmus* can synthesise a little lower, 128 and 145 kJ. kg^{-1}.day^{-1} as fixed protein at the same feeding levels. Similarly, *P. bocourti* can synthesise 252 and 390 kJ.kg^{-1}.day^{-1} body lipid and the latter species can fix only 64 and 79 kJ. kg^{-1}.day^{-1}.

An estimate of protein requirement was denoted as the addition of protein requirement for maintenance, R5 treatment, and fixed protein, R25 or R35 treatment. That was 248 and 269 kJ. kg^{-1}.day^{-1} in *P. bocourti* and 189 and 206 kJ. kg^{-1}.day^{-1} in *P. hypophthalmus,* when one convert protein to energy value on digestible basis regarding maintenance and on gross basis regarding fixed protein. Finally an estimated protein requirement was 12-13 g.kg^{-1}.day^{-1} for *P. bocourti* and 11-12 g.kg^{-1}.day^{-1} for *P. hypophthalmus*.

DISCUSSION

The present study demonstrated that *P. bocourti* has a higher growth rate than

Species	**Indices**					
	SGR	Protein increase	FCR	PER	NPU	NFU
P. bocourti	R45	R35	R35	R25	R35	R15
P. hypophthalmus	R35	R25	R35	R25	R25	R35

Table 3: Treatment gave optimal results for each index.

Species		***P. bocourti***			***P. hypophthalmus***		
Treatment		R5	R25	R35	R5	R25	R35
Received feed	g.kg^{-1}.day^{-1}	7.97	39.68	55.56	7.94	39.68	55.56
Protein	g.kg^{-1}.day^{-1}						
- received	g.kg^{-1}.day^{-1}	5.21	26.07	36.50	4.94	24.68	34.56
- fixed	g.kg^{-1}.day^{-1}	0.06	6.80	7.74	1.70	5.78	6.52
	%	1%	26%	21%	34%	31%	23%
- lost	g.kg^{-1}.day^{-1}	5.16	19.27	28.76	3.24	18.91	28.03
	%	99%	74%	79%	66%	69%	77%
Lipids							
- received	g.kg^{-1}.day^{-1}	0.87	4.33	6.06	0.83	4.13	5.78
- fixed	g.kg^{-1}.day^{-1}	0.04	6.48	10.02	0.00	1.65	2.03
from feed	g.kg^{-1}.day^{-1}	0.04	4.33	6.06	0.00	1.65	2.03
from body	g.kg^{-1}.day^{-1}	0.00	2.16	3.96	0.00	0.00	0.00
- lost	g.kg^{-1}.day^{-1}	0.82	0.00	0.00	0.83	2.48	3.74
from feed	g.kg^{-1}.day^{-1}	0.82	0.00	0.00	0.83	2.48	3.74
from body	g.kg^{-1}.day^{-1}	0.00	0.00	0.00	0.00	0.00	0.00

Table 4: Nutrient utilisation according to diet intake in *P. bocourti* and *P. hypophthalmus*.

Species		P. bocourti		P. hypophthalmus	
		Energy utilisation at maintenance level			
Treatment		**R5**		**R5**	
Burned as protein	$kJ.kg^{-1}.day^{-1}$	97		61	
Burned as lipids	$kJ.kg^{-1}.day^{-1}$	31		31	
Total	$kJ.kg^{-1}.day^{-1}$	128		92	
		Energy utilisation at optimal growth level			
Treatment		**R25**	**R35**	**R25**	**R35**
Received	$kJ.kg^{-1}.day^{-1}$	653	914	620	867
Fixed as protein	$kJ.kg^{-1}.day^{-1}$	151	172	128	145
	%	23	19	21	17
Fixed as lipids	$kJ.kg^{-1}.day^{-1}$	252	390	64	79
	%	39	43	10	9
Lost	$kJ.kg^{-1}.day^{-1}$	250	353	427	644
	%	38	39	69	74
		Estimation of requirements			
Treatment basis		**R25**	**R35**	**R25**	**R35**
Protein	$kJ.kg^{-1}.day^{-1}$	248	269	189	206
	$g.kg^{-1}.day^{-1}$	12	13	11	12
Protein/energy ratio (DP/DE)	$mg.kJ^{-1}$	18	14	17	13

Table 5: Energy utilisation and estimation of protein requirement for *P. bocourti* and *P. hypophthalmus*. Energy equivalents are calculated according to Luquet & Moreau (1989): 18.8 $kJ.mg^{-1}$ digestible protein (DP); 37.7 $kJ.mg^{-1}$ digestible lipids, 22.2 $kJ.mg^{-1}$ crude protein (CP) and 38.9 $kJ.mg^{-1}$ crude lipids.

P. hypophthalmus. However, the higher growth observed for *P. bocourti* is obviously associated to higher fat accumulation in the body. The protein efficiency, the NPU and the PER, tends to be reduced at higher protein intake in both species. This trend was similar to those found in *Cyprinus carpio* (Ogino & Saito, 1970), *Ctenopharyngodon idella* (Dabrowski, 1977), *Leptobarbus hovenii* (Pathmasothy & Omar, 1982). The highest protein retention was found in the present study to be 28% and 31% in *P. bocourti* and *P. hypophthalmus*, respectively. The figure was lower than those in other fish species as protein retention of 60% were obtained with *Clarias gariepinus* (Machiels, 1987) and 54% with Nile tilapia, *Oreochromis niloticus* (Kaushik *et al.*, 1995). Yet, the protein retention observed in the present study may not be related to values obtained in other studies as protein are supplied to cover all energy metabolism needs and other energy sources were not provided. Regarding estimate, fixed protein represents 60, 70% of intake for *P. bocourti* and *P. hypophthalmus*, respectively. Data in the nutrient utilisation showed that *P. bocourti* can synthesise body lipid, as they store more lipid than what they fed in diet. In that case, some of dietary protein was, therefore, transferred to body lipid. Comparing results obtained with R15 treatment and over, a higher protein loss was observed in *P. bocourti*. That must be associated to the fact that the fish tends to deposit a large amount of body lipid. It is interesting to realise that *P. bocourti* fingerlings can synthesise a large amount of body lipid at young stage.

Energy and protein requirement for maintenance was calculated to be 128 and 92 $kJ.kg^{-1}.day^{-1}$, and 5.16 and 3.24 $g.kg^{-1}.day^{-1}$ in *P. bocourti* and *P. hypophthalmus*, respectively. Many authors have determined the protein and energy maintenance needs in other fish species. That was found to be in the range of 1-1.32 $g. kg^{-1}.day^{-1}$ in channel catfish (Gatlin *et al.*, 1986), 1-2 $g.kg^{-1}.day^{-1}$ in common carp (Kaushik, 1995) and about 2 $g.kg^{-1}.day^{-1}$ in Nile tilapia when cultured at 28°C. The energy and protein maintenance requirement in *P. hypophthalmus* was nearly comparable to channel catfish and tilapia. It is noticed that the culture temperature in the study was 28-32°C, higher than the cultured condition of channel catfish and tilapia. That may be the reason for such a higher energy and protein requirement in *P. hypophthalmus*, since Schwarz and Kirchgessner (1984) found that the energy need for maintenance in common carp was reduced at lower temperature. Moreover, when comparing the two species of Mekong catfish, *P. bocourti* and *P. hypophthalmus*, it is obvious that *P. bocourti* has nearly a double protein and energy requirement for maintenance. The event may be linked to the fact that *P. bocourti* has higher growth rate and the fish has a high ability to synthesise a large amount of body lipid. Anyway, treatment R5 was retained for the maintenance estimate even if a slight growth was observed. This will be necessary to have an estimate of maintenance requirement by having a slight growth since one could calculate the maintenance requirement by interpolation between R0 and R5 treatment. Such estimates are safer regarding the purpose of the present study.

An estimate of protein requirement was in range of 12-13 and 11-12 $g.kg^{-1}.day^{-1}$ in *P. bocourti* and *P. hypophthalmus*, respectively. Daily protein requirement for most tropical catfish species ranges from 15-25 $g.kg^{-1}.day^{-1}$ (Wilson & Moreau, 1996), but it can be as low as 12 $g.kg^{-1}.day^{-1}$ in *Clarias batrachus* (Mollah & Hussain, 1990) or 10 $g.kg^{-1}.day^{-1}$ in *Clarias gariepinus* (Henken *et al.*, 1986). The value of 8.75 $g.kg^{-1}.day^{-1}$ was also reported to obtain maximum growth of channel catfish (Gatlin *et al.*, 1986). Therefore, the daily protein requirement in *P. bocourti* and *P. hypophthalmus* was in the lower range when compared to most catfishes.

The optimal protein to energy ratios for catfishes ranged from 20 to 30 $mg.kJ^{-1}$ (DP/DE) (Wilson & Moreau, 1996). The DP/DE ratio was estimated to be 18 and 17 $mg.kJ^{-1}$ in *P. bocourti* and *P. hypophthalmus*, respectively. These values are closer to the value of Nile tilapia (Kaushik *et al.*, 1995). In the present study, the low DP/DE ratio may be related to the fact that the protein requirement was relatively low in the two species. Even if such study appears to be a good way to compare performance between species, more studies remain necessary to investigate the energy utilisation in both species, regarding mainly the starch utilisation as an energy substitute in diet and the regulation of lipid metabolism.

REFERENCE

Cacot P. (1994) *Présentation de la pisciculture en cages flottantes dans le Sud Vietnam.* CIRAD-EMVT. 107p.

Chupapoehuk W. & Pothisooing T. (1985) Protein requirements of catfish fry, *Pangasius sutchi* Fowler. In: *Finfish Nutrition in Asia: Methodological Approaches to research development,* C.Y. Cho, C.B. Cowey, T. Watanabe eds. International Development Research Center, Ottawa, Canada, 103-106.

Dabrowski K. (1977) Protein requirement of grass carp fry *Ctenopharyngodon idella* Val. *Aquaculture*, **12**, 63-67.

Degani G., Ben Zvi Y. & Levanon D. (1989) The effect of different protein levels and temperature on feed utilization, growth and body composition of *Clarias gariepinus* (Burchell,1822). *Aquaculture*, **76**, 293-301.

Gatlin D.M.III., Poe W.E. & Wilson R.P. (1986) Protein and energy requirement of fingerling channel catfish for maintenance and maximum growth. *J.Nutr.*, **116**, 2121-2131.

Henken A. M., Machiels M.A.M., Dekker W. & Hoggendoorn H. (1986) The effect of dietary protein and energy content on growth rate and feed utilization of the African catfish *Clarias gariepinus* (Burchell, 1822). *Aquaculture*, **58**, 55-74.

Kaushik S.J. (1995) Nutrient requirements, supply and utilization in the context of carp culture. *Aquaculture*, **129**, 225-241.

Kaushik S.J., Doudet T., Médale F., Aguirre P. & Blanc D. (1995) Protein and energy needs for maintenance and growth of Nile tilapia (*Oreochromis niloticus*). *J. Appl. Ichthyol.*, **11**, 290-296.

Luquet P. & Moreau Y. (1989) Energy-protein management by some warmwater finfishes. In: *Advances in tropical aquaculture*; 1989 Feb 20-1989 Mar 4; Tahiti. AQUACOP, IFREMER. ; Actes de Colloque. v. 9, pp. 751-755.

Machiels M.A.M. (1987) A dynamic simulation model for growth of the African catfish, *Clarias gariepinus* (Burchell, 1822). 4, The effect of feed formulation on growth and feed utilization. *Aquaculture*, **64**, 305-323.

Madu C.T. & Tsumba T.T. (1989) Dietary protein requirement of mudfish (*Clarias batrachus*) fingerlings: 2. The optimum crude protein level for the diet of mudfish fingerlings in an outdoor rearing system. *Ann. Rep. Natl. Inst. Freshw. Fish. Res.Nigeria*, 1988, 104-109.

Mollah M.R.A. & Hussain M.A. (1990) Effects of artificial diets containing different protein levels on growth and feed efficiency of catfish (*Clarias batrachus* L.). *Indian J. Fish.*, **37**, 251-259.

Moreau Y., Cisse A. & Luquet P. (1995) Absolute feeding design, a realistic way for fish nutrient requirement determination. *Journal of Applied Ichthyology Zeitschrift Fur Angewandte Ichthyologie*, **11**, 367-371.

Ogino C. & Saito K. (1970) Protein nutrition in fish: I. The utilization of dietary protein by young carp. *Bull. Jap. Soc. Sci. Fish.*, **36**, 250-254.

Pathmasothy S. & Omar R. (1982) The effect of four different diets on the growth of *Leptobarbus hovenii*. *Mardi. Rec. bull.*, **10**, 110-113.

Roberts T. R. & Vidthayanon C. (1991) Systematic revision of the Asian catfish family Pangasiidae, with biological observations and descriptions of three new species. *Proceeding of the Academy of National Sciences of Philadelphia*, **143**, 97-144.

Schwarz F.J. & Kirchgessner M. (1984) Untersuchungen zum energetischen Erhaltungsbedarf des Karpfens (Cyprinus carpio L.). *Z. Tierphysiol. Tiermahr. Futtermittelkde*, **52**, 46-55.

Vellas F. (1981) Metabolisme des composés azotés. II. L'excrétion azotée. In: Fontaine, M., ed. *Nutrition des poissons*. Paris: C. N. R. S., Paris; pp. 149-161.

Wilson R.P. & Moreau Y. (1996) Nutrient requirements of catfishes (Siluroidei). *Aquat. Living Resour.*, **9 Hors serie**, 103-111.

THE BIOLOGICAL DIVERSITY AND AQUACULTURE OF CLARIID AND PANGASIID CATFISHES IN SOUTH-EAST ASIA

Proceedings of the mid-term workshop of the "Catfish Asia Project"
Cantho, Vietnam, 11-15 May 1998

Edited by :
Marc LEGENDRE
Antoine PARISELLE

CONTENTS

LARVAL BIOLOGY AND REARING

NUTRITION, FEEDING AND GROWTH

HYBRIDS EVALUATION

PATHOLOGY