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Energy — Protein management by some warmwater finfishes

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Abstract — *If warmwater finfish protein requirements as level in diet is low, absolute intake per day is similar to those of coldwater species. But relation of this requirement with specific growth rate differs for strictly warmwater fishes as Tilapias. Analysis of partition between protein and non-protein energy retention shows that these species with* ***Clarias*** *make a better use of non-protein energy provided and consequently improve their protein retention. Better carbohydrate digestibility and metabolism are propunded as part of the explanation.*

INTRODUCTION

One may discuss the problem of nutrition on aquacultured fish under three broad categories : (a) physical and biological modes of feeding, (b) specific nutritional requirements, and (c) diets formulation.

In the first category, we have to consider not only the physical texture and stability of compounded pellets from which belongs the relative food consumed, but also the feeding practices for which too little attention has be done. Indeed, meal timing plays a major role in feed utilization by fish. It affects growth rate, feeding efficiency, and body composition. It is related to the existence of circadian variations of metabolism and its hormonal control (see vol. 113 of the Trans. Am. Fish. Soc., 1984).

Among nutrients, protein requirements and optimal dietary protein levels remain an apparent melting pot even if a sustained literature is available in these fields. Additionally, both problems - protein requirements and optimal dietary protein levels - are often confused by reason of interfering problems of protein to energy relations, calorigenic function of proteins, apparent protein sparing effects of fats and carbohydrates, and available energy (Cho and Kaushik, 1985).

Because of the relationship between protein and energy levels, the optimal dietary protein level varies widely between successive experiments if diet energy density or feeding rate has been changed. However, in most cases the authors cannot conclude in terms of optimal dietary protein level, but only as optimal dietary to energy ratio (Garling and Wilson, 1976; Wang et *al.*, 1985 a,b).

The origin of the energy by itself can also act, and very heavy factorial plans have to be mounted. Consequently these types of experiments are scarce, and when they exist, a doubt often subsists (Berger and Halver, 1987).

These introductory statements have a general value, whatever the fishes, but they constitute many aspects to be taken into account to review specific nutrient requirements of warm water fishes. As a matter of fact, energetic aspects will be more extensively considered than protein requirements by itself, even if the protein cover need remains the chief purpose.

Optimal dietary protein level

The range for reported optimal dietary protein levels is quite large, but some results should be considered with cristicism, either they are unique and not corroborated, or too distant of the general tendancies. Considering only the most reliable values for growing fish, e.g. when there exist various convergent results, obtained with adequate feeding rates and diet energy levels, we may establish that there exists a general pattern when protein sources of good value are fed.

Apparent protein level needs seem to disminish when normal life temperature increases. For rainbow trout the reported values range from 35 to 45 percent of the diet, and the optimal level is close to 36 % when high fat diets are used (Takeuchi et *al.*, 1978a). The same team, thus working in the same type of approach, found that optimal protein level in diets ranges from 31 to 38 % for common carp at 22-25°C, and estimates that the optimum content of dietary protein for maximum growth is around 31 % (Takeuchi et *al*, 1979b). Summing up literature data, Luquet (1989) concludes that Tilapia species have a protein requirement of 28-35 % of the diet and that 30 % constitute a safe level for a 23-28°C normal temperature range. Channel catfish, living at around 27°C, are considered to need 28 % protein in their diet (Garling and Wilson, 1976), even if recorded values range from 22 to 36.

Daily protein requirements

When expressed in terms of daily allowances (gram of protein by kilogram of body weight per day) for optimal growth or maximal protein deposition, protein requirements appear more homogeneous. The recorded values range from 6.2 to 10.2 for rainbow trout (Takeuchi et *al.*, 1978 a,b,c), from 7.0 to 12.1 for carp (Takeuchi et *al.*, 1978b, 1979a,b), and from 7.2 to 10.8 for channel catfish (Garling and Wilson, 1976). For tilapias the data vary mostly according to the feeding rate (Luquet, 1989). When fed at 3 % B.W. per day, the data are closed (9.6 to 10.7) to that above; they increase to 15-20 with a 5-6 % feeding rate, and reach 68 with a feeding rate as high as 20 % B.W. (Winfree and Stickney, 1981). Thus, protein daily requirements of omnivorous warmwater fishes are similar or higher that for carnivorous coldwater fishes when expressed against body weight.

Tacon and Cowey (1985) have widely discussed the best way to express protein requirements. After the statement that « it may be more meaningful to express protein requirements as digestible protein energy relative to the digestible energy content of the diet », they show that protein daily allowances must also be related to the specific growth rate of fishes. They conclude that « there exists an almost linear relationship between daily protein requirement (grams of protein per kilogram body weight per day) and specific growth rate (SGR, percentage per day) of the different species examinated ». The data quoted include the Tilapia *Oreochromis niloticus*, *O. aureus*, *O. mossambicus*, and *Tilapia zilli*.

When adding other results related to the Tilapias, it seems therefore that Tilapia displays some particular trends. Two reasons may explain this, one related to experimental conditions and the other to own species characteristic such as strict stenotherm status. Needs values over the general trend are associated to feed conversion ratio over the means, involving a possible surestimation of needs. On the other hand, lower values observed indicate that Tilapia are able to maintain a higher specific growth rate without exceeding protein daily allowance. This implies a better management of available proteins.

Protein utilization

Protein utilization, usualy expressed as retained protein/protein intake ratio, constitutes a common criterion to check the synergistic interactions between major nutrient classes (protein sparing) or energetic cost of nutrient utilization (specific dynamic action = SDA). A dietary formulation low in protein entails minimal SDA, and would permit more efficient energy utilization.

Table 1 presents results of protein and energy efficiency in terms of % retained for some species. It is based on literature data selected as the most efficient in order to make a comparison of relative potentiality of these species in protein and energy utilization. In addition the body store compartiments (protein and non protein stores) are presented, as well as the percentage of non protein dietary retention. By this way, Cho and Kaushik (1985) have discussed in detail the partition of the energy and protein retention or losses in trouts under different protein to lipids diets.

The comparison between species allows us to ascertain that :

— *O. niloticus* retains more efficiently protein intake than other species. More than 55 % of energy retained is fixed as a nitrogenous form, while other values are below 50 %,

— energy retention in Tilapias, carp and *Clarias* is lower than for rainbow trout and channel catfish,

— this is mainly due to the fact that non protein energy is less retained (< 35 %) in these species,

— in carcass, most of the energy (more than 60 %) is retained as protein energy in *Clarias* and Tilapia, and as non protein energy (lipids) in trout, carp and channel catfish,

— the eurythermal carp and channel catfish appear closer to coldwater trout than strict warmwater fishes such as Tilapia even living in warmwater.

Then Tilapia appears to be very efficient to utilize both protein and energy. For proteins this is evident insofar as the fixed/ingested ratio is high. For non protein energy, reverse reasoning must be done : less the retention is high, better is their utilization efficiency. Indeed, energy incorporation in diets is for fuel purpose for metabolism or for protein synthesis. Then, in fish cultivated for food, the fixed energy, except that bound in proteins, must be considered as misused because not burnt.

Tab. 1. — Protein and energy efficience in term of % retained for some species

	Diet Characteristics					
Species	Prot. %	Fat %	D.E.(MJ /100g(1)	N.retained % intake	E. retained % of DE intake	% of non prot E. retained
Rainbow trout	34	22	1.760	47	63	73
«	55	13	1.870	34	53	88
»	33.8	19.5	1.967	47.9	58.8	58
Carp	31.5	14.6	1.549	39.1	42.5	39
Catfish	36		1.703	35	55	65
«	24.1		1.151	49.8	62.2	83
Clarias gariepinus	50.4		2.021*	38	32*	24*
O. niloticus	31.2	5.5	1.507	62.3	51.5	35
	31.4	2.5	1.632	55	38.5	21
O. mossam	42	9.83	1.578	25.6	20.8	10

* Gross Energy basis

(1) Energy value are calculated, if not given, on proximate analysis basis.
Coefficient are 22.2 CP: 38.9 EE: 17.2 NFE for gross energy and 18.8 CP: 37.7 EE: 16.7 NFE for digestible energy.

Energy availability and fate

Non protein energy supply in diets is obtained by addition of high lipids or carbohydrate compounds. Their utilization involves a good acceptability of fishes either during digestive or metabolism process.

Lipids are reported to be highly available with an emphasized digestibility coefficient of fat as ambiant temperature increases (Andrews et *al.*, 1978). Carbohydrates do not display any general performances. As a monosaccharide requires no digestion to be assimilated, a polysaccharide must first be hydrolised. The polysaccharides mainly used are starch and dextrin. With salmonids, starch digestion is depressed with increasing intake and could be largely enhanced by a precooking treatment (Bergot and Brecque, 1984). The ability of Tilapias to digest starch is not dependent on such kind of constraint, apparent digestibility of crude starch being close to lipids values (over 15 %) even with an intake as great as 6 mg/g body weight/day (Wang et *al.*, 1985a).

Energy efficiency of different digested carbohydrates must be comparable. Their utilization by *O. niloticus* is relatively homogeneous except for glucose which efficient use could be handicapped by a too fast assimilation (Anderson et *al.*, 1984). Recalculated non-protein energy retention is about the same ranging from 17 to 23 % for starch, dextrin, sucrose and glucose incorporated to diet at a rather high level, 40 %. Taking pelleting process into account, lipids could be added in diet. Rates over 15 % are well used (Takeushi et *al.*, 1978a), but unsaturated fatty acids composition must be regarded with care. Excess amount of n-3 has adverse effect on growth and lipid metabolism (Takeushi et *al.*, 1983; Robinson and Wilson, 1985). Once essential fatty acid needs are content, saturated fatty acids containing sources prevail as they dont show unfavourable propensity (Takeuchi et *al.*, 1978a; Cho et *al.*, 1985).

CONCLUSION

Warmwater fishes may use better provided protein. This is not only due to a better protein retention capacity but also to a better utilization of furnished non-protein energy. Being less retained, the protein sparing objective of this energy is more fulfilled. Better polysaccharides digestibility should play one of the leading parts of non-protein energy utilization, but the metabolic fate of nutrients has to be considered as fishes have to manage an « unconventionally » large amount of energy metabolites compared to traditionnal coldwater species.

Anderson J., A.J. Jackson, A.J. Matty and B.S. Capper, 1984. Effects of dietary carbohydrate and fibre on the tilapia *Oreochromis niloticus* (Linn.). *Aquaculture*, **37** : 303 - 314.

Andrews J.W., M.W. Murray and J.M. Davis, 1978. The influence of dietary fat levels and environmental temperature on digestible energy and absorbability of animal fat in catfish diets. *J. Nutr.*, **108** : 749 - 752.

Berger A.and J.E. Halver, 1987. Effects of dietary protein, lipid and carbohydrate content on the growth, feed efficiency and carcass composition of striped bass, *Morone Saxatilis* (Walbaum), fingerlings. *Aquaculture and Fisheries Management*, **18** : 345 - 356.

Bergot F. and J. Brecque, 1983. Digestibility of starch by rainbow trout : effects of the physical state of starch and of the intake level. *Aquaculture*, **34** : 203 - 202.

Cho C.Y., C.B. Cowey and T. Watanabe, 1985. Finfish nutrition in Asia : methodological approaches to research and development. IDRC, Ottawa, 154 p..

Cho C.Y. and S.J. Kaushik, 1985. Effects of protein intake on metabolizable and net energy values of fish diets. *In* : Nutrition and feeding in fish, C.B. Cowey, A.M. Mackie, J.G. Bell Eds., Academic Press, London, 95-117.

Garling D.L. Jr. and R.P. Wilson, 1976. Optimum dietary protein to energy ratio for channel catfish fingerling, *Ictalurus punctatus. J. Nutr.*, **106** : 1368 - 1375.

Henken A.M., J.B. Boon, B.C. Cattel and H.W.J. Lobee, 1987. Differences in growth rate and feed utilization between male and female african catfish, *Clarias gariepinus* (Burchell 1822). *Aquaculture*, **63** : 221 - 232.

Jauncey K., 1982. The effects of varying dietary protein level on the growth, food conversion, protein utilization and body composition of juvenile tilapias (*Sarotherodon mossambicus*). *Aquaculture*, **27** : 43 - 54.

Luquet P., 1989. Practical considerations on the protein nutrition and feeding of tilapia. *Aquat. Living Resour.*, **2** (in press).

Robinson E.H. and R.P. Wilson, 1985. Nutrition and feeding. *In* : Channel catfish culture, C.S. Tucker (Ed.), Elsevier, Amsterdam, 323-404.

Tacon G.J. and C.B. Cowey, 1985. Protein and amino acid requirements. *In* : Fish energetics : new perspectives, P. Titler, P. Calow (Eds.), Croom Helm, London, 155-183.

Takeuchi T., T. Watanabe and C. Ogino, 1978a. Optimum ratio of protein to lipid in diets of rainbow trout. *Bull. Japan. Soc. Fish.*, **44 (6)** : 683 - 688.

Takeuchi T., T. Watanabe and C. Ogino, 1978b. Use of hydrogenated fish oil and beef tallow as a dietary energy source for carp and rainbow trout. *Bull. Japan. Soc. Fish.*, **44 (8)** : 875 - 881.

Takeuchi T., M. Yokoyama, T. Watanabe and C. Ogino, 1978c. Optimum ratio of dietary energy to protein for rainbow trout. *Bull. Japan. Soc. Fish.*, **44** : 729 - 732.

Takeuchi T., T. Watanabe and C. Ogino, 1979a. Availability of carbohydrates and lipid as dietary energy sources for carp. *Bull. Japan. Soc. Fish.*, **45 (8)** : 977 - 982.

Takeuchi T., T. Watanabe and C. Ogino, 1979b. Optimum ratio of energy to protein for carp. *Bull. Japan. Soc. Fish.*, **45 (8)** : 983 - 987.

Takeushi T., S. Satoh and T. Watanabe, 1983. Dietary lipids suitable for the practical feed of *Tilapia nilotica. Bull. Japan. Soc. Fish.*, **49 (9)** : 1361 - 1365.

Wang K.W., T. Takeuchi and T. Watanabe, 1985a. Effect of dietary protein levels on growth of *Tilapia nilotica. Bull. Japan. Soc. Fish.*, **51 (1)** : 133 - 140.

Wang K.W., T. Takeuchi and T. Watanabe, 1985b. Optimum protein and digestible energy levels in diets for *Tilapia nilotica. Bull. Japan. Soc. Fish.*, **51 (1)** : 141 - 146.

Winfree R.A. and R.R. Stickney, 1981. Effect of dietary protein and energy on growth, feed conversion and body composition of Tilapia aurea. *J. Nutr.*, **111** : 1001 - 1012.