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Absolute feeding design, a realistic way for fish nutrients requirements determination

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Abstract

Feeding experiment is designed on the basis of food allowance rather than feed formulation. Food allowances are fixed in attempt to provide the desired amount of nutrients per body mass of fish per day (in terms of $g.kg^{-1}.d^{-1}$ or $J.kg^{-1}.d^{-1}$). By this way, previous determination of optimum feeding ration is not required, and utilisation of neutral feed complement (e.g. cellulose) is unnecessary. Experiment interpretation of this design is presented for a sample of protein-energy requirement experiment for a tilapia species, ***Sarotherodon melanotheron.*** *Interrelationship of commonly used indices for growth and nutrition efficiency is discussed.*

Introduction

The choice of optimum nutrients requirements for the fish farmer, as for the reviewer is often painful with the discrepancy of results obtain by different authors, especially for optimum protein/energy requirements. This could mainly result of difference in experimental procedure and first of all, the choice of the feeding rate which could vary from a specific percentage of biomass to *ad libitum* feeding strategy. To avoid this disagreement, protein/energy needs are no more recommended as optimum protein and energy contents of food, but rather as optimum protein/energy ratio in food (Garling and Wilson, 1976 e.g.). Furthermore, multispecies comparison of nutrient requirements conducted reviewers to standardise the

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data. Results were then presented in term of feeding allowance (nutrient amount per fish biomass per day) which in fact do not take care of the nutrient concentration in food (Cowey and Luquet, 1975; Tacon and Cowey, 1985). This representation of nutrient requirements, which is equivalent to the 'specific feeding rate' uses in trophic relationship studies, brings to results much more homogeneous (Luquet and Moreau, 1989).

In attempt to elude the interaction between chosen feeding rate and nutrient concentration in feed, we like to purpose an experimental design based on feeding allowance.

MATERIALS AND METHODS

Composition of diets and rations calculation

As feeding experiment are designed on the basis of food allowances rather than food formulation, no care is needed on global composition of food. So far, experimental diets should be regarded as an addition of different feeding ingredients, rather than a mix of ingredients. Then, the more practical way to calculate the contribution of each ingredients to the different diets is to build them in term of parts, even if the sum of parts was not constant over all diets. Table 1 provides an example of 5 diets designed to give an increasing amounts of starch associated to a fixed allowance of protein. Fish meal was used as protein supply, and cassava meal as starch one. Parts were calculated to satisfy the desired pattern of daily allowances in grams per kg of fish. As protein allowance must be the same for all diets, parts of fish meal will remain constant, when cassava meal addition will change from one diet to an other. Daily allowance of others nutrients (oil, vitamin and minerals) were calculated to agree with conventional or recommended utilisation of them. Thus, even if their concentration in diet vary from one to an other one, the amount provided each day (i.e. product of concentration by feeding rate) will be the same, whatever the diet considered. This will agree with the concept of daily requirements used by human nutritionists. Nevertheless, special care was taken for incorporation of digestibility marker (Cr_2O_3, for subsequent determination of digestibility) and binder in attempt to obtain the same density and texture for all diets. Thus, contributions for marker and binder were calculated as percent of total parts in each diets.

Total parts for each diet give the daily amounts of food which must be distributed for the biomass of fish considered as basis of daily allowance calculation. So, a specific ration was obtained for each diet. This 'one diet - one feeding rate' rule is certainly one of the main characteristics of this kind of design.

Scheme of interpretation of expected results

Table 2 presents a brief summary of results which could be expected of this kind of design.

Growth should be impaired by restrained supply in both protein or energy, but excess of both can also induce growth restriction.

If protein allowance is above optimum level, growth will not be limited as fare as full ingestion or assimilation of food is not damaged by excessive level of energy. Assuming that voluntary consumption of food is monitored by energy content, allowance of a surplus of energy will induce a restriction of food intake involving a deficient net protein ingestion/assimilation even if protein allowance is in excess. Furthermore, as protein allowance is closer above the optimum level, as growth is more sensitive to total energy allowance.

If protein and/or energy allowances are under the optimum level, growth will be limited. With a restrained protein allowance, the best growth will be obtain when protein catabolism could be spared by non protein energy allowance and when excessive energy allowance do not restricted protein ingestion.

Food conversion ratio, FCR, will be worse with lower growth. In addition, results for FCR will decay drastically when food ingestion/assimilation falls when excess of energy is offered. Inversely, rather good FCR could be obtained when energy allowance is weak and protein high, as the expected poor growth will be associated to a small quantity of food but with a high growth potential value.

Besides, net protein utilisation index (NPU) will be very sensitive to the participation of protein to catabolism, and then worst score will be obtain with weak non protein energy allowance. On an other hand, high energy allowance must maintain good NPU as far as protein ingestion/assimilation will not be impaired.

Sample of absolute feeding design

A trial experiment was performed with a native tilapia of Côte d'Ivoire (West Africa), *Sarotherodon melanotheron*. This experiment was designed to provide increasing amount of starch (from 0 to 40 g per kg of fish per day) associated to a fix protein allowance (15 g per kg fish per day). The five previous calculated diets were used. Table 3 provides their proximate analysis, and corresponding protein, energy and lipids allowances.

Fish were produced in our laboratory rearing facility, a close freshwater system consisting of ten 110 l cylindro-conic fibreglass tanks. Five days before the experiment, fish were spread in ten batches. Before to experiment, individual weight were determined (4.05g ± *0.7*)[1], ten groups of 12 fishes were composed and ten fishes were frozen for ulterior body composition determinations. Two replicates of the five treatments were randomly assigned. Individual weights were followed each week and feeding rates adjusted at this time.

After four weeks, fish were killed, individually weighed, and body compositions were determined on each pool as a whole. During the experiment no mortality was recorded, water temperature lay between 28 and 30°C, and no adversely water condition were observed (oxygen or ammonia).

RESULTS

Figure 1 summarises the results obtained for growth (weight gain and protein gain), food conversion ration and net protein utilisation. All growth and indices results are severely affected when daily allowance of starch increases to 30 $g.kg^{-1}.day^{-1}$ and over. This suggests that energy allowance impairs food assimilation and is over optimal level.

Similar growth results are obtained for starch allowance of 10 and 20 $g.kg^{-1}.day^{-1}$. Total body weight gain of fish receiving no starch is similar to those receiving starch supplemented diet, simultaneously, fixation of protein is lower, and FCR and NPU are slightly worsen. Protein allowance seems to be sufficient to sustain growth close to the best of them, but significant lower protein fixation implies a greater participation of protein to catabolism which could be spared by addition of small amount of starch.

DISCUSSION AND CONCLUSION

From this only 'one way trial', with no modification of protein allowance, we could obtain conclusion on maximum sustainable energy allowance (890 $kJ.kg^{-1}.day^{-1}$, diet AM20) supported by the species and on minimum protein allowance required (15 $g.kg^{-1}.day^{-1}$).

One of the first advantage of absolute feeding design is that it do not required previous determination of optimal feeding rate. On an other hand, in this approach, the utilisation of

[1] Prior to handling, water level was lowered and fish were anaesthesied (2-phenoxyethanol, 1.5 ml / 10 l). A very good recovery was observed as restart of feed occurs in a few hour.

filling (e.g. cellulose), which could present controversial guarantees of neutrality, is not necessary. Furthermore, this will meet the suggestion made to optimise food composition for limitation of waste effluent in fish farm (Cho, 1993).

Referring to the way of calculation of diet, absolute feeding design seems to induce easier methods to obtain experimental food composition. But for feed manufacturer this could not agree with linear programming procedure used to compute formulation. In fact, food allowance concept will conduct to the disappearance of the constrain which required that sum of all components must be equal to cent per cent. And, this could induce a reduction of the cost of food per amount of protein given. Nevertheless, as a specific feeding rate is not definitively recommended by this way for all kinds of feed, this could induce some disagreement in the feeding practice for fish farmer.

Relating to the nature of results obtain for protein and energy daily allowance, these will fit with the protein/energy ratio commonly used. This one, independent of feeding rate, is strictly equivalent to the ratio of protein and energy allowances.

In summary, absolute feeding design appears to be suitable for protein/energy requirement determination. But, special attention should be taken for some nutrients whose their proportion in food is important. This can be the case of amino-acids, where catabolic or anabolic utilisation of essential amino-acid is related to their pattern and their availability in food (Robinson *et al,* 1980; 1984).

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Feed name	AM0	AM10	AM20	AM30	AM40
Ingredients (in parts)					
Fish meal	21.95	21.95	21.95	21.95	21.95
Cassava meal	0.00	10.53	21.05	31.58	42.11
Soybean Oil	0.90	0.90	0.90	0.90	0.90
Vitamin & Mineral Premix	0.15	0.15	0.15	0.15	0.15
Digestibility marker	0.48	0.71	0.93	1.15	1.37
Binder	0.73	1.06	1.39	1.72	2.06
Total	**24.21**	**35.29**	**46.37**	**57.45**	**68.53**
Feeding rate	***2.4%***	***3.5%***	***4.6%***	***5.7%***	***6.9%***

Table 1. Sample of absolute feeding design. Feed compositions (in parts) and feeding rates (% body weight) are calculated to provide 15 g protein per kg body weight per day (68%CP fish meal) associated to increasing amount of starch (cassava meal) from 0 to 40 $g.kg^{-1}. day^{-1}$.

Protein allowance		Energy allowance		
		Weak	Optimum	Excess
Weak	**Growth**	**0**	**2**	**0**
	FCR	1	2	0
	NPU	*0*	*2*	*1*
Optimum	**Growth**	**0**	**3**	**1**
	FCR	2	3	0
	NPU	*0*	*3*	*1*
Excess	**Growth**	**0**	**3**	**2**
	FCR	2	2	0
	NPU	*0*	*2*	*2*

Table 2. Expected qualitative comparison of commonly used indices for growth and nutrition efficiency. Grade (0 to 3) refer to the quality of expected results for Growth (1st row, bold), Food Conversion Ratio (2nd row, roman) and Net Protein Utilisation (3rd Row, italic).

Feed name	**AM0**	**AM10**	**AM20**	**AM30**	**AM40**
Components (% of DM)					
Crude proteins	61.2	43.5	33.0	26.1	22.7
Energy ($kJ.g^{-1}$)	21.1	19.9	19.2	18.7	18.5
Lipids	10.1	7.2	5.2	4.3	3.7
Daily allowances (g or $kJ.kg^{-1}.day^{-1}$)					
Crude proteins	14.8	15.3	15.3	15.0	15.6
Energy	512	702	890	1073	1265
Lipids	2.4	2.6	2.4	2.5	2.6

Table 3. Proximate analysis of diets, and corresponding daily allowances given to fishes for proteins, energy and lipids. Analytical methods are: Kjehldahl (N*6.25) for proteins, calorimetric bomb for energy, and Soxhlet (Hexan extract) for lipids.

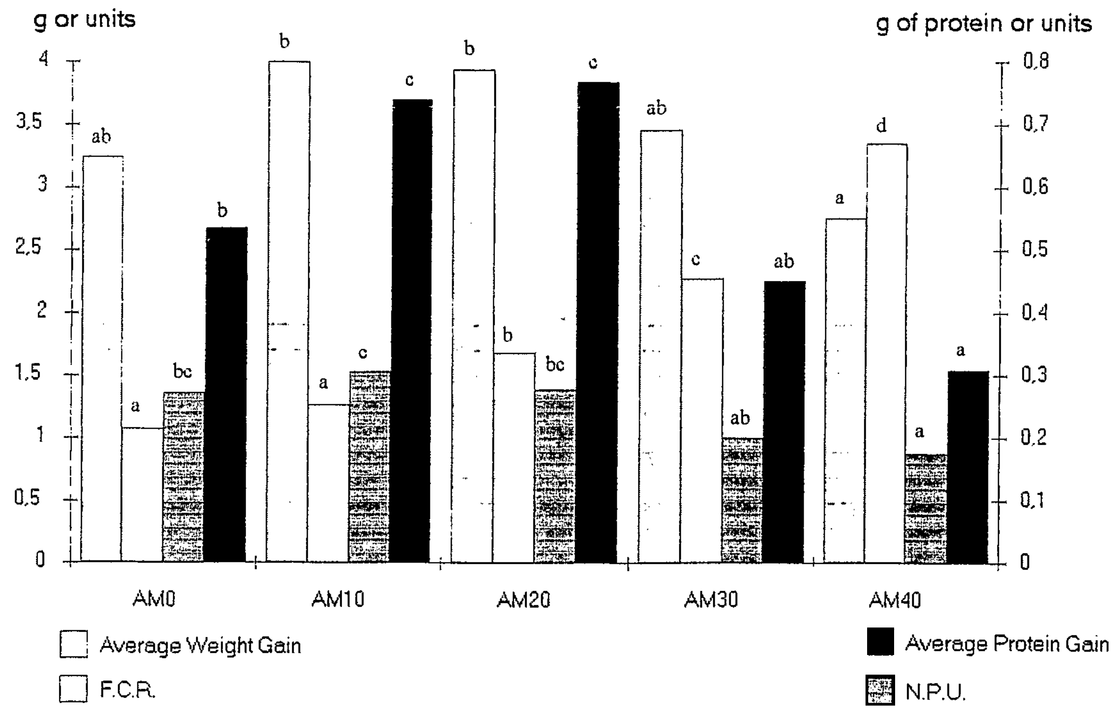

Figure 1. Average body weight increase and food conversion ration, FCR (left Y axis), body protein increase and net protein utilisation, NPU (right Y axis) obtained for fish (4.05g *± 0.7* initial body weight) fed with five different starch allowances (0, 10, 20, 30, 40 $g.kg^{-1}.day^{-1}$) associated to a fixed protein allowance (15 $g.kg^{-1}.day^{-1}$) during 4 weeks. Similar letters above bars indicate homogeneous groups (Duncan test, Statgraphics® v. 5.0 software package)