PLUS LA CROISSANCE EST RAPIDE, PLUS LE BESOIN EN PHOSPHORE EST IMPORTANT : LA CONSÉQUENCE DU CHANGEMENT DE STRATÉGIE ALIMENTAIRE SUR LES BESOINS EN PHOSPHORE CHEZ LES SALMONIDÉS

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RÉSUMÉ

En pisciculture, les régimes avec de hauts niveaux de lipides se sont substitués aux régimes riches en protéines, pour des raisons de moindre coût et de moindres rejets azotés et phosphorés. Chez les salmonidés, ces régimes à haute énergie ont amélioré l'efficacité alimentaire, la rétention protéique et le taux de croissance, mais ont conduit à une augmentation des dépôts de graisse et à des déformations vertébrales. L'hypothèse a été faite que les régimes riches en matières grasses (MG), donc pauvres en farine de poisson principale source de phosphore (P), affecteraient la minéralisation et entraineraient un abaissement de la concentration en P vertébral à l'origine des déformations observées. Pour tester cela, des lots (en triplicats) de truites arc-en-ciel (poids moyen: 49g), ont été nourris avec des aliments différant par leurs niveaux de MG (12 et 22%) et de P disponible, (0,4 et 0,8%). Tous les lots ont été nourris avec le même taux de rationnement, deux fois par jour. Après 12 semaines à 15°C, le gain de poids, l'indice de croissance quotidien, l'efficacité alimentaire et l'efficacité protéique étaient significativement plus élevés chez les poissons nourris avec des aliments riches en MG. Chez ces derniers, une tendance à la compression de la région caudale a été observée chez les poissons ayant reçu 0,4% P. L'incorporation de MG à forte concentration a augmenté de façon significative la disponibilité du P alimentaire. Par ailleurs une augmentation du P vertébral a été observée avec le taux de P le plus élevé dans la ration, quel que soit le niveau de MG.
En conclusion, pour l'alimentation de la truite arc-en-ciel élevée en eau douce, les régimes riches en matières grasses requièrent de veiller à un niveau suffisant de phosphore disponible pour assurer une bonne minéralisation, en particulier des vertèbres.

Mots clés: Truite arc-en-ciel; besoins en phosphore; régimes à haute énergie; minéralisation.

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FASTER THE GROWTH, GREATER THE NEED FOR PHOSPHORUS: THE CONSEQUENCE OF CHANGING DIETARY STRATEGIES ON PHOSPHORUS REQUIREMENT IN SALMONIDS

ABSTRACT:

Over the years, aquaculture feeds have witnessed dynamic changes in dietary composition. Nutrient dense, high fat diets are being used in commercial salmonid farming. Faster growth rates and increased feed efficiencies are achieved through such high fat diets. However, the effect of such high fat diets on dietary phosphorus needs has been overlooked. In this study, rainbow trout were fed diets with two levels of fat (low vs high) and two levels of P (adequate vs high). It was found that, the higher growth rate induced by high dietary fat affected growth allometry. Importantly, P supplied by adequate P in high fat diets was insufficient to maintain proper mineralisation. As a consequence, an attempt to maximise the dietary availability of P was observed, especially when P is limiting in the diet. Overall, fish fed high fat diets required higher P levels in the diet to maintain proper mineralization of body and vertebrae.

Key words*: Fish; phosphorus requirement; high energy diets; mineralization.*

1. BACKGROUND

Feed is a vital determinant of the productivity in aquaculture operations. The primary objective of feed formulation and management practices in aquaculture is to improve the feed efficiency and protein retention efficiency. These are largely determined by the nutritional profile of the feeds. Protein (amino acids) is the primary source of energy for fish, and the most expensive nutrient component of the feed. Therefore, improving the protein retention efficiency through increased inclusion of digestible non-protein energy sources (fat, carbohydrates) is an effective strategy to improve growth rates, reduce feed costs, and reduce waste output (Cho and Kaushik, 1990).

Phosphorus is one of the vital and most studied nutrients essential to fish. Strict environmental protection policies have made phosphorus the most stringently regulated nutrient in fish feeds. Over the years, high energy diets (mainly with high lipid levels) are commonly used in salmonid farming and are known to improve feed and protein efficiencies, with a consequent reduction in waste output in terms of suspended matter, nitrogen (N) and phosphorus (P).

Many physiological changes that occur due to the use of energy dense, high fat diets have been overlooked to a large extent. Mineralisation processes and the physiological need for phosphorus are a few to mention. The faster growth rates achieved with energy dense, high fat diets can affect the phosphorus balance in the body resulting in poor mineralisation especially under dietary phosphorus limitation. Given the improved feed efficiencies with such high energy diets, if the dietary P level is maintained at a fixed level, a situation is hypothesised where less dietary P will be available to the fish to support a higher (than normal) growth rate per unit quantity of feed consumed.

2. METHODOLOGY

Two levels of dietary fat, low fat (LF, 12%) and high fat (HF, 22%) and two levels of available P, namely adequate (AP, 0.4%) and high (HP, 0.8%), were tested in a 2x2 factorial design. Rainbow trout juveniles (IBW: 49±1g) were distributed into 12 experimental units and each unit was randomly assigned one of the four dietary treatments (in triplicates). All treatments were fed equal restricted rations (14 g kg-0.8 d-1), twice a day for 12 weeks at 15°C.

At the end of the 12-week experimental period, individual weight (W), standard length (SL) and caudal peduncle length (CL) were measured for analysis of allometric length-weight relations (LWR) expressed as $W=aL^b$ and tail ratio (TR = CL/SL).

Apparent availability coefficient (AAC) of phosphorus was determined using yttrium oxide as the inert marker. The chemical composition of experimental diets, whole fish and vertebral samples were analysed for moisture, crude protein, crude fat, ash and gross energy. The analysis of major minerals such as P and Ca in the diets, whole fish and faecal samples were also performed. Vertebrae samples were also analysed for P and Ca.

3. PRINCIPAL FINDINGS

3.1. High dietary lipids affect growth allometry in fast growing salmonids

Fish fed high fat diets showed higher rate of weight gain (WG) by 15% than the low fat diets at both levels of available P. Standard length (SL) was higher in fish fed high fat diets. Effect of dietary available phosphorus on tail ratio (TR) was observed only in high fat diets. Length-weight relation (LWR)* showed that the length exponent (b) was affected by dietary P level based on the dietary fat levels. Many investigations on the impact of dietary P levels on the incidence of vertebral deformities are reported in salmonids. Although vertebral deformities were not studied in the present study, morphological impression for compressed vertebrae in the caudal region was observed. According to the report of Malfotruite (2007), caudal peduncle and neck are the two most susceptible regions of the vertebrae to be affected by compressions. In the present study, data on the body condition indices suggest a compression in the tail region in AP-HF group. Moreover, the increase in the allometric coefficient (LWR-b) in the AP-HF group (b > 3) signifies that the length of the fish was not proportional to its weight i.e. the fish was too heavy for its length. *Note: LWR is an index of body condition, similar to BMR applied to humans for categorising the body condition as underweight < normal > obese.

3.2. Fish fed high fat diets require increased dietary phosphorus supply to ensure proper mineralisation

Based on the meta-analysis of Antony Jesu Prabhu *et al.* (2013), minimal dietary phosphorus inclusion required for maximal weight gain for rainbow trout was estimated to be 3.5 g available P kg^{-1}. Confirming this, the AP (4 g available P kg^{-1}) diets which were formulated based on the aforementioned finding resulted in similar growth in par with the HP (8-9 g kg^{-1}) diet fed groups. However, this may not be sufficient to maintain proper mineralization of hard tissues especially bones and vertebrae. The mineral content of the vertebra as indicated by ash, P and Ca were reduced by high fat diet fed with 4 g available P kg^{-1} available P. Inclusion of higher dietary P levels (8-9 g

available P kg^{-1}) increased the mineral content of the whole body and vertebrae even at high fat conditions. Higher weight gain and faster growth rates induced by high dietary fat requires increased available P supply to assure proper mineralization of whole body and vertebrae in rainbow trout. It is suggested that long term feeding of high energy can reduce vertebral mineralisation in rainbow trout.

3.3. Fish fed high fat diet attempt to increase absorption of phosphorus to meet the higher P demand for proper mineralisation

The inadequacy of dietary available P supply in high fat diets was explained in the earlier section. Under such circumstances, the fish would attempt to maximise the extraction of P from the diet, as a compensatory mechanism. As a consequence, the apparent availability coefficient of phosphorus was significantly higher in the high fat groups compared to the low fat groups. The magnitude of increase was more prominent (9%) under adequate dietary phosphorus rather than at high dietary phosphorus (4.5%). The results of the present study suggest that, fish fed high fat diets would attempt to maximise the dietary availability of P, especially when the later is limiting in the diet.

4. CONCLUSION

The aforesaid findings from the study lead us to conclude that, higher weight gain and a faster growth rate induced by high dietary fat alters the normal allometric growth of farmed fish. In addition, the fish requires increased available P supply to assure proper mineralisation of whole body and vertebrae. Consequently, absorption of phosphorus from the diet is increased in an attempt to meet the higher P demand for proper mineralisation, especially under conditions of dietary P limitation.

5. PRACTICAL IMPLICATION

Given the strict regulations on the level of P used in fish feeds, meeting the phosphorus requirement to ensure the welfare of farmed fish and to lessen the environmental impact of P outputs from aquaculture, a consorted effort is warranted.

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