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Lecture Notes

Part 2

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FISH NUTRITION AND CLIMATE CHANGE

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Introduction

Fish production, whether in the natural or captive aquatic ecosystems, largely depends on a reliable supply of nutritious food preferred by the different life-stages of a species and congenial environmental conditions that stimulate optimum intake, digestion and utilization of the food. Fish being ectotherms their survival, growth and reproduction are greatly influenced by changes in water temperature besides synergetic effect of several other physico-chemical factors prevailing in the aquatic environment. In this article, an attempt is made to highlight the basic nutritional needs of marine, and freshwater fish, and the likely impacts of climate change, especially the role of temperature on intake and utilization of food nutrients by fish.

Nutritional Needs Of Fish

Like all other animals the diet of fish should contain an adequate level of energy plus protein with a balanced profile of indispensable amino acids, lipids with adequate levels of essential fatty acids and phospholipids, essential minerals and trace elements, and vitamins. The need for about 40 nutrients has been established for fish, but the quantitative requirements are established for a few species. Energy needs of fish are met by metabolising the building blocks of carbohydrates, lipids and proteins in the diet. All the fish species studied todate require 10 essential amino acids (arginine, histidine, isoleucine, leucine, lysine, methionine, valine, threonine, tryptophan, phenylalanine) but there are considerable differences among species in their quantitative requirements. Thus the quality of dietary protein is largely dependent on the levels of these amino acids.

Lipids besides being a rich source of energy, provides the essential fatty acids required for synthesis of phospholipids, which are important structural components of biomembranes at the cellular and sub-cellular levels. The five most important fatty acids in the structure and functions of fish are linoleic acid (18 :n-6), linolenic acid (18 :n-3), arachidonic acid(20 :4n-6), eicosapentaenoic acid (20 :5n-3), and docosahexaenoic acid (22 :n-6). Most of the marine species are known to require 20 :5n-3 and 22 :6n-3 in ther diets as they lack the enzymes to biosynthesize these fattyacids from their metabolic precursors. Besides, temperate and polar marine species are known to contain greater levels of these fatty acids than those of tropical marine species, and that the demersal species relatively have higher levels of these fatty acids than pelagic ones. Some species, especially during the larval and juvenile stages require a supplement of phospholipids (phosphatidylcholine, phosphatidyl ethanolamine) for metamorphosis better survival and growth

All the 11 water-soluble vitamins (thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, folic acid, cyanocobalamine,ascorbic acid, choline, inositol) and four fat-soluble vitamins (A,D,E, and K) are found to be essential.

Fish are able to absorb most of the mineral and trace elements from the water, however, mineral and trace element supplements are essential in the diet to sustain faster growth rates. Dietary requirements for the nutrients varys with species, physiological state, stage in life cycle, and prevailing environmental conditions.

Impacts of Temperature on feed intake and metabolism

Temperature has many profound effects on many physiological processes and increases in temperature accelerate most of these processes. Oxygen consumption is an indicator of the metabolic state of a species. On an average a temperature rise of 10 degree C causes oxygen consumption to increase 2-3 fold. Oxygen is essentially required for the oxidation of absorbed food energy nutrients. Thus temperature increase causes increased metabolic rate resulting in increased demand for nutrients thereby enhancing food intake and growth upto the temperature optima. For instance, when channel catfish were exposed to five environmental temperatures (20,24, 26, 30, 35^{O}C) maximum growth was obtained at the optimum of 30^{O}C (Stickney and Andrews, 1971).

Effects of temperature on enzyme function

Somero (1978) provided an overview of the important structure-function relationships that characterize enzymatic adaptations to temperature and showed how the effects of temperature on enzyme structure and function may be instrumental in establishing the thermal optima and tolerance limits of metabolic functions, and thereby of the organism itself. Acclimation of fish to a particular set of environmental conditions basically is the acclimation of enzymes to the set of conditions, especially temperature since the ability of the fish to survive largely depends upon its ability to perform normal metabolic functions. Some enzymes associated with energy liberation (enzymes of glycolysis, pentose shunt, tricarboxylic acid cycle, electron transport and fatty acid oxidation) exhibit temperature compensation, whereas those enzymes dealing largely with the degradation of metabolic products show poor or reverse compensation (Prosser, 1973)

Enzymes exhibiting compensation : Phosphofructokinase, aldolase, lactic dehydrogenase, 6-phosphogluconate dehydrogenase, succinic dehydrogenase, malic dehydrogenase, cytochrome oxidase, succinate-cytochrome C reductase, NAD-cytochrome reductase, aminoacyl transferase, Na-K-ATPase and protease

Enzymes exhibiting reverse or no compensation : Catalase,peroxidase, acid phosphatase, D-amino-acid oxidase,Mg-ATPase, choline acetyl transferase, acetyl choline esterase, alkaline phosphotase, allantoinase, uricase, amylase, lipase, malic enzyme, glucose-6-phosphate dehydrogenase

Thus, two of the key enzymes involved in carbohydrate metabolism, amylase and glucose-6-phosphate dehydrogenase, together with an enzyme involved in fat digestion, lipase, show no temperature compensation. However, it is not certain if this is in any way connected with the cessation of feeding by fish at low temperature. The molecular mechanism of thermal acclimation are not well understood. Differences in kinetics, changes in the proportion of isoenzymes suitable for particular temperatures, and changes in co-factors such as lipids, co-enzymes, or other factors such as pH and ions may be important in animals adjustment to temperature changes.

Effect of temperature on lipid composition

There are a number of reports demonstrating the effect of environmental temperature on the lipid composition of fish. The fatty acids from a number of fish from temperate and arctic waters were found to contain higher levels of HUFAs than those from tropical regions . Th n-6/n-3ratio decreases with a decrease in water temperature. Thus increse in temperatures may result in lower levels of HUFAs especially EPA and DHA.

Mugil cephalus fry acclimated to 14^{O} C and 0.5 ppt salinity had 55% less total fatty acid those acclimated to the seawater at the same temperature (Kheriji *et al*., 2003). The trnsition of the acclimation temperature from 26 to 14 ^{o} C in seawater is followed by a 215% increase in the amount of total fatty acids. The authors conclude that the decrease of temperature and salinity results in an increase in the synthesis of PUFAs from the 18 carbon unsaturated precursors.

Kemp and Smith (1970) studied the fatty acid composition and individual phospholipids in gold fish adapted to different temperatures and found that temperature did not noticeably affect the fatty acid composition of the whole-fish lipids, but there were marked changes in the fatty acids of lipids extracted from homogenates of goldfish intestinal mucosa and that these changes were more pronounced in a membrane fraction prepared from these homogenates. They also found that raising the adaptation temperature by 20°C halved the percentage of $C_{20:1}$, $C_{20:4}$ and $C_{22:6}$ fatty acids and nearly doubled the percentage of $C_{18:0}$ and $C_{20:3}$ fatty acids recovered.Choline phosphoglycerides constituted about one-half and ethanolamine phosphoglycerides about one-quarter of the total membrane phospholipids. The fatty acids of choline and ethanolamine phosphoglycerides were more susceptible to temperature-dependent changes than were the phosphoglycerides of inositol or serine.

Carp undergo temperature acclimation of respiratory function by altering mitochondrial ATP synthase (F_oF_1-ATPase) both quantitatively and qualitatively (Itoi *et al*. 2003). The quantities of saturated fatty acids of mitochondria from carp acclimated to 10 °C were significantly lower than those of carp acclimated to 30 °C. While mono- and poly-unsaturated fatty acids tended to increase with cold acclimation of carp, the molar concentration of 16:0 aldehyde in mitochondria from the 10 °C-acclimated carp were less than those from the 30 °C-acclimated fish (Itoi *et al*., 2003)

Conclusions

Fish being aquatic ectotherms are likely to be affected greatly by global warming. There is convincing evidence that changes in environmental temperature affects oxygen availability to the fish, food consumption, digestion and utilization by the fish. Activity of many enzymes associated with digestion and metabolism of nutrients, and fatty acids synthesis are greatly influenced by environmental temperature.

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