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Nutritionally Induced Cataracts in Salmonids Fed Purified and Practical Diets

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As in other areas of animal industry, the cost of feed is a major contributing factor to the total cost of fish production. This is much more apparent for fish because they require 40-55 percent of their diet as protein, compared with 18-22 percent for poultry, for example. This problem is accentuated by the fluctuating availability and costs of animal protein which carnivorous fish generally require in large amounts.

In searching for acceptable alternate sources of plant protein for fish food at our laboratory, an 80-90 percent incidence of grossly discernible bilateral cataracts appeared in trout and salmon fed a commercial isolated soy protein (ISP), at 40 percent of the diet, for at least 8 weeks.

Reports from salmon and trout rearing facilities throughout the world indicate that fish cataracts, apparently of dietary origin, are widespread and cause marked economic loss in fish production.

We initiated studies at our laboratory to: 1) determine some of the nutritional factors responsible for cataracts and reduction of growth in salmonids fed diets containing ISP as the major source of protein, and 2) characterize the development of the dietary-induced cataracts.

Soybean products usually are deficient in the total sulfur amino acids, methionine, and cystine. Also, alkaline treatment during preparation of soy protein isolates possibly reduces the bioavailability of lysine, through conjugation of its bioactive sites such as the opsilon groups, to below the minimal level necessary to prevent cataracts in fish.

Preliminary experiments eliminated the dietary form of ISP (i.e., isoelectric ISP VS sodium proteinate ISP), the level of threonine, ascorbic acid, or chromium as possible causes for the lens opacity.

We conducted another experiment in which duplicate lots of 1-gm lake trout, *Salvelinus fontinalis,* were fed, for 16 weeks at 9°C, either a basal diet containing 38.7 percent ISP as the sole protein, or the basal diet plus a supplement of 0.9 percent DL-methionine and 1.15 percent lysine•HCl. A practical, production-type diet that contained no ISP was fed as a control diet.

We examined the intact eyes of live fish from each dietary group every month with a slit-lamp biomicroscope. Using the total amount of light transmitted through the normal lens as 100 percent, we assigned lenses the values of 100, 75, 50, 25, and 0 percent, according to the degree of opacity. After biomicroscopic examination, the eyes were enucleated and prepared for histological study of changes in lens structure.

Monthly biomicroscopic and histologic examination showed that, whereas fish fed supplemental methionine and lysine had normal lenses, those in fish fed the basal diet underwent a series of degenerative changes (including replication of anterior lens epithelium, and opacification, vacuolation, liquefaction, and hyalinization of fibers) progressing from the epithelium and outer cortex to the nucleus.

In another experiment, duplicate lots of 5-gm lake trout were fed a basal diet (40 percent ISP) or the basal diet plus singular supplements of 0.9 percent methionine, 1.15 percent lysine•HCl, 0.92 percent lysine (free base), or various combinations for 18 weeks at 12.4°C. Trout fed methionine, either singularly or with lysine, had normal lenses, but those fed the basal diet or lysine without methionine had lens cataracts which progessed inward from an initial cortical opacification and epithelial replication to a deeper nuclear involvement with the same degenerative changes observed in the first experiment. These results show that supplemental methionine, but no lysine, prevented cataract formation in lake trout fed an ISP as the sole protein.

In other feeding studies with diets containing casein and gelatin, but not ISP, a dietary riboflavin deficiency induced a lenticular-corneal abnormality in fingerling rainbow trout, *Salmo gairdneri;* a dietary vitamin A deficiency in swim-up brook trout, *Salvelinus fontinalis,* caused corneal and retinal, but not lenticular, abnormalities. Supplemental dietary β-carotene prevented corneal and retinal lesions in brook trout held in warm (12.4°C), but not in cold (9°C) water.

These results show the formation of a nutritionally induced cataract which can be prevented by feeding supplemental methionine, but not lysine. Although our results do not show specifically how the deficiency of methionine metabolically induced the cataractogenesis, evidence of work with other animals suggests that the sulfhydryl, rather than the methyl group of methionine, is most important in preventing methionine deficiency cataracts. One of the earliest detectable changes in most cataract formations is a rapid fall in concentration of sulfhydryl groups. The sulfhydryl groups possibly minimize conformational changes such as unfolded proteins and the subsequent formation of disulfide cross-link bonds and insoluble proteins of high molecular weights.

Soybeans and soy proteins often contain antinutritional factors such as trypsin inhibitors and hemagglutinins which interfere with normal intestinal absorption of nitrogen and metabolism of methionine. Such factors, as they possibly affect cataractogenesis, growth, and composition, warrant further study.

In summary, these studies show that at least three nutrient-related lesions occur in the eyes of salmonid fishes. A deficiency of an amino acid caused lens cataracts; a deficiency of riboflavin induced a lesion involving cornea and lens. A vitamin A deficiency caused lesions in the cornea and retina, but not in the lens.

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Environmental Parameters Affecting Fish Physiology in Water Reuse Systems

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The incorporation of water reuse, based on microbiological treatment, in large-scale salmonid production systems a few years ago was widely regarded as a major breakthrough in production technology. Since that time, those of us who have been involved in the development of water reuse technology have seen the value of our effort diminished by changing conditions and the appearance of physiological problems.

Innovative development work has enabled us to offset some of the effects of increased materials and energy costs, and meet the more stringent discharge criteria. On the other hand, high mortalities experienced in some facilities have been a severe setback, and clearly illustrate that when the environment is appreciably modified we can expect a physiological response. Unfortunately, physiological adaptation is not always adequate to insure survival.

Experience gained in culturing one species in water reuse systems is not always transferable to another species, and, similarly, problems encountered in one area are not necessarily experienced in another. Most problems encountered are related to water quality. Such factors as pH, mineral content, metabolite levels, temperature, and dissolved gases may be critical. Our more recent research, which is multidisciplinary in approach, has centered on the relationship between environmental factors and the well being of the cultured species as judged by biochemical, physiological, and pathological determinative procedures.

It is generally accepted that toxicity of ammonia is due to the undissociated fraction, with its concentration being temperature, salinity, and pH dependent. Thus, environmental pH manipulation can be employed to increase tolerance for ammonia. Since culturing in the range pH 6.0-7.0 is not always desirable, we have endeavored to develop a better understanding of the mechanism of ammonia toxicity. Data developed to date suggests that impaired respiration resulting from an altered acid base balance, with a corresponding blood pH shift, is the primary cause of mortality.

In water reuse systems employing microbial nitrification, nitrite, a microbial metabolite, may also be toxic to the fish being cultured. A wide range of LC_{50}'s of nitrite for various species has been reported. In our work, we have demonstrated that nitrite toxicity is related to temperature, oxygen concentration, and chloride ion concentration. In high salinity environments, nitrite has a low order of toxicity, and, in freshwater