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.

MFR Paper 1348. From Marine Fisheries Review, *Vol. 40, No. 10, October 1978. Copies of this paper, in limited numbers, are available from D822, User Services Branch, Environmental Science Information Center, NOAA, Rockville, MD 20852. Copies of* Marine Fisheries Review *are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 for $1.10 each.*

MFR PAPER 1349

Environmental Parameters Affecting Fish Physiology in Water Reuse Systems

THOMAS L. MEADE

Thomas L. Meade is with the Department of Animal Science, University of Rhode Island, Kingston, RI 02881.

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

with a chloride ion concentration of less than 1 mg/liter, nitrite is extremely toxic. The oxidation of ferrohemoglobin to ferrihemoglobin by nitrite or a derivative of nitrite is observed in nitrite toxicity. Under normal conditions, there is a change in the color of the gill tissue and the blood to a characteristic chocolate brown color. In our work, we have also experienced high mortality at moderate levels of ferrihemoglobin with an absence of blood color change. This suggests that a second mechanism may be operative. At this time, we are looking into two possible mechanisms: one involving interference in the final step involving electron transfer in the respiratory enzymes, and the other the effect of stress on the production of mineralocorticosteroids. In the case of the latter, elevated blood bicarbonate levels would result in alkalemia with its associated impairment of respiration.

Research is also underway on the problems involved during smoltification of steelhead trout in a water reuse system. Although work in this area is still in the exploratory stage, available data suggests that the problem is related to a lack of synchronization between increased hormonal activity associated with smoltification and activation of the Na+K ATPase system in the gill tissue.

In conclusion, it appears that environmental stress factors have a far greater influence on normal growth and development than previously recognized. High density culture in water reuse systems, although theoretically possible, is not without considerable risk, and the risk will not be minimized until we have a better understanding of the relationship between environmental factors and the physiology of the cultured species.

MFR Paper 1349. From Marine Fisheries Review, *Vol. 40, No. 10, October 1978. Copies of this paper, in limited numbers, are available from D822, User Services Branch, Environmental Science Information Center, NOAA, Rockville, MD 20852. Copies of* Marine Fisheries Review *are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 for $1.10 each.*

MFR PAPER 1350

PCB-Induced Alterations in Teleost Liver: A Model for Environmental Disease in Fish

DAVID E. HINTON, JAMES E. KLAUNIG, and MICHAEL M. LIPSKY

David E. Hinton is with the Department of Anatomy, West Virginia University School of Medicine, Morgantown, WV 26506. James E. Klaunig and Michael M. Lipsky are with the Comparative and Environmental Pathobiology Program, University of Maryland School of Medicine, College Park, MD 20740.

Man's population and continued economic and industrial development has led to increasing exposure of the aquatic environment to exogenous compounds. Alteration in structure/function of tissues arising from exposure to these pollutants comprises our working definition of environmental diseases of fish. The response of fish tissues to environmental pollutants may take either of two forms. In the first, there is acute lethal injury. This may be expected to occur after exposure to extremely toxic substances. The second form occurs following exposure to chronic sublethal concentrations of pollutants. This leads to an altered steady state, compatible with life, where changes in structure at the tissue, cellular, and organelle level can be correlated with alterations in function. Those pollutants which lead to the latter form of injury are noted by their persistence in the environment and their bioaccumulation.

The ability of fish to metabolize compounds can, to a large extent, mediate the form of injury which results. The primary locus of enzymes which metabolize foreign substances is the hepatic microsomal mixed-function oxidative system (MFOS). This system is capable of the detoxification of noxious substances and the activation of potential carcinogens (Dallner, 1963).

The polychlorinated biphenyls (PCBs) are important industrial compounds which have been used in paints, immersion oils, electrical capacitors, and heat exchange systems. Their presence and persistence in the aquatic environment have been documented