ADVANCES IN THE NUTRITION OF SALMONOIDS

P.A. MEGGISON*, R.G, REDMAN* AND C.K. FOSTER**

SUMMARY

Recent years have seen major growth in the aquaculture industry world wide. Particular emphasis has been placed on exotic fish such as trout, sea trout, atlantic salmon and prawns. Compared with agriculture, the aquaculture industry is still very juvenile and much research is needed to optimise husbandry, health, genetics and nutritional practices. This paper discusses the significance of salmonoid aquaculture in Australia, with particular reference to Tasmania and offers suggestions where much needed research may be concentrated in the future. Emphasis is given to sources and requirements of dietary nutrients. Also, feed quality, carcass quality and marketing are covered. Indications given for future research consider that the future of this industry will depend on very sensitive economics.

INTRODUCTION

Man has been rearing fish in captivity for thousands of years but only recently, during the past 20 years, has aquaculture become a significant industry for food production. Countries such as Norway, United Kingdom, Japan and U.S.A. are now quite advanced in salmonoid production. Norway is still the largest producer of salmon (28,600 MT Atlantic, 1985) whilst Japan, U.S.A. and Denmark were the leading producers of trout in 1985 (21,800, 22,200 and 24,300 MT., respectively). By the year 2000 world production of salmon is estimated to be between 0.4 and 0.5 million tonnes surpassing the target for trout by 150,000 tonnes (Hoffmann La Roche, 1989).

World wide production of salmon and trout in 1990 will have a revenue value of AUS $4860 millions and AUS $1666 millions respectively. In Australasia, projected production of 5,000 MT of salmon and 4,000 MT of trout (AUS $90 mio and AUS $28 mio, respectively) is small but nonetheless significant in the context of the local economy. So, what are the major limitations to the continued viability of this industry? As with most commodity sales in western societies the market is driven by production costs

* Colborn-Dawes Australia (Pty.) Limited, Wagga Wagga, N.S.W. 2650
** Salmon-Enterprise of Tasmania Pty. Ltd., Hobart, Tas. 7000

and market demand. By the year 2000 we will, on average, be eating five times as much salmon and almost twice as much trout as at present. As the market becomes mature normal economic forces will prevail and efficiency of production will be a key feature in the continued viability of the industry.

GROWTH AND PERFORMANCE

The major influences on the performance of livestock are environment, management, genotype, health and nutrition. Fish production is no different. Also in common with livestock production, nutrition contributes the greatest single cost.

Salmonoids, which are anadromous, have a potential to be one of the fastest growing and most efficient feed converters known to man. Atlantic salmon, approaching maturity, are able to grow at well in excess of 2% body weightper day during favourable growing conditions. Tasmania is particularly fortunate in that its disease and environmental status is very condusive to rapid and efficient growth and has some of the best performances in the world. Atlantic salmon are poikilothermic and are able to convert feed at feed conversion ratios (FCR) of as low as 1.2:1. Naturally, environmental conditions have a major influence on FCR. With current ratio costs atlantic salmon can be produced at a nutritional cost of about $2.00 - $3.00/kg.

NUTRITION

Providing fish feeds are balanced and fresh, feed intake depends largely upon water temperature and health status. Certain chemo-attractants have been used with some success. These are often based on mixtures of amino acids. (Rumsey, 1986). A common methyl donor, betaine, is one such product which has improved feed intake quite significantly.

Quality of fish feeds is vitally important in successful fish production. Quality encompasses many aspects including physical size and form, diet composition, raw material selection, and above all, balanced nutrient specifications.

The quality and handling of different ingredients strongly influences the nutritional and physical status of the diet. Polyunsaturated fish oils are very sensitive to oxidation even when stabilised and can confir destabilising characteristics onto the rest of the diet. Fats which have undergone oxidative rancidity are toxic to fish and can dramatically affect performance. Feed quality should be preserved by paying particular attention to antioxidants, moisture, packaging and storage. Antinutrient factors such as thiaminase and protease inhibitors, can be deleterious (Tacon and Jackosn, 1985).

PROTEIN

The most costly and arguable the most important component of diets for salmonoids is protein. Protein serves not only as a source of amino acids for maintenance and growth but is also a valuable source of energy. It is argued (Austrent, Grinsdale-Helland, Helland and Storebakken, 1988) that upto 50% of protein in salmon and trout is used, through gluconeogenic path-ways as a source of energy. Indeed, a challenge facing many researchers is how to shift expensive, high quality protein from a source of energy to supplying amino acids for growth. Protein sparing is now receiving research attention. A further negative effect of this deamination process is water pollution from unmetabolised ammonia entering the water through the fish's gills.

Much research on salmonoids has been focused on protein nutrition but there is still a general paucity of accurate data on protein/energy interrelationships, amino acid requirements, balances and digestibility and protein quality.

Over three million tonnes of the world's fish catch is now processed for use in intensive and semi-intensive aquaculture. In 1988 this amounted to 646,000 MT fish meal; some 10% of the total fish meal production. Since fish stocks for processing are rapidly declining globally, many countries are imposing restrictions on the types and quantities of fish caught. It is quite clear however, that the fish meal requirements for the projected production of salmonoids as mentioned earlier, together with growth in the production of other species will far out strip supply. Hence, it is vitally important that alternative sources of protein are found in the near future.

Preliminary examinations have been performed on many protein substances yet a true substitute for fish meal is yet to be found at economic costs. Common natural proteins such as meatmeals, bloodmeals, feathermeals and a large variety of vegetable proteins have been tested with variable results. Of the vegetable proteins soya bean meal, treated correctly, would still appear to have the greatest potential (Alexis, Papoutsoglou and Theochari, 1985). Much work is needed to perfect its use. Of the animal-derived products partial or total substitution of fish meal by poultry by-product meal has received much attention and with some refinements on product quality and amino acid balance/supplementation it could become a useful ingredient. Steffens (1985),(1987) has concluded that partial substitution of fish meal with good quality poultry by-product meal has no effect on growth and performance. Total substitution gives sub-optimal performance.

Other more novel protein sources have been investigated. Microbial proteins such as singe1 cell protein (pruteen), rotifers, artemic, algae and daphnia have been used. Worm meal and fly meal are also worthy of consideration. A comprehensive review of protein nutrition of salmonoids is given by Pfeffer (1982.)

An area which could merit further research is the use of refined proteins and modified by-products. Meat hydrolysates, soya and other vegetable protein isolates, refined potato protein, yeasts and totally hydrolysed feather meals all need to be assessed and supplemented against requirments.

AMINO ACIDS

Amino acids for growth and maintenance are required at tissue level, and hence in considering protein sources and amino acid requirements it is important to account for protein digestion, digestion of individual amino acids and the metabolizability of the absorbed amino acids. Given the difficulty in performing digestion and metabolism trials with fish, research on amino acid balances has been very much trial and error. Balance data are further confounded when one considers that some of the protein sources used (eg. fish meal) in fish feed production are very var -iable in relation to their conditions of processing; heat and moisture can dramatically affect protein quality and salmonoids are very sensitive to protein quality (Pfeffer, 1982). Many studies have been performed in an attempt to elucidate amino acid requirements for salmon and trout (Mearns, 1986; Poston, 1986; Holm and Walther, 1988; Longbein, 1988). Clearly, the potential is great for modelling for amino acid requirements and should be considered in future research.

Commercially, a number of companies have developed "specific" stabilised aquaculture proteins guaranteeing protein quality, fixed analysis and biogenic amino levels. The need for such products is evidence to the problem of consistent raw material quality and the difficulty in deriving dietary amino acid balances

ENERGY

Salmonoids are carnivorous, feeding on smaller fish, crustaceous insects and grubs. Over 50% of the energy requirement of salmon can be derived from protein by gluconeogenesis. As indicated earlier, protein of fish origin is a very expensive means of supplying energy. Energy-rich protein-sparing substitutes are therefore being sought with a view to producing more economic diets.

Fats of the correct nature are well digested and utilised by fish and can supply over half the fish's energy requirements. Dietary fats are required for a number of body functions. As well as rich sources of dietary energy, they are needed to supply an array of essential fatty acids (EFA). Diets for trout and salmon should contain at least 2.5% EFA. Phospholipids and glycolipids are also consumed by salmonoids.

Growth rates and feed conversion efficiencies have been improved in diets where the fat level in the diet has reached 25% (Austreng, 1976). It must be noted, however, that amino acid requirements are linked to dietary energy supply and that fat is a concentrated source of energy.

Fat type and quality is extremely important. Fish oil containing a high level omega 3 double bands was once seen to be the industry standard. In some countries fish oil is still very inexpensive but in Tasmania it is almost twice the price of feed fats. Fish oil is also very unstable due to its high degree of unsaturation and it readily undergoes oxidative racidity. In the same way that researchers are looking for less expensive alternatives to fish meal, in certain countries, more economic sources of fat are being sought. It has now been fairly well established that providing the essential fatty acid requirements are met, alternative sources of fat can be used as sources of energy in fish feeds (Bieber-Wlaschny and Pfeffer, 1987; Hardy, Scott and Harrell, 1987). It is worthy of note, however that, similar to non-ruminant animals, salmonoids lay down fat in their fat depots in a profile which is very similar to that of the dietary fat and therefore by feeding diets low in omega 3 fatty acids the consumer may be misled on his omega 3 consumption in his heart disease – control programme!

Another, but less significant source of energy for salmonoids is carbohydrates.

The utilization of carbohydrates can be limited both at the level of digestion and, subsequently, at the tissue level, and varies according to the type of carbohydrate and the processing technique used. Digestion consists of acidic and enzymatic degradation of the complex carbohydrates into monosaccharides. which are subsequently absorbed. The efficiency of digestion decreases with increased molecular complexity of the carbohydrate. Phillips and Brockway (1956) reported the digestibilities of the following carbohydrates by trout: glucose:99%; maltose: 93%; sucrose: 73%; cooked starch: 47%; raw starch: 38%.

There are no specific requirements for carbohydrates in salmonoid diets but a level of 12% digestible carbohydrates would appear to be the general upper limit.

OTHER DIETARY ADDITIONS

A variety of other dietary additions make up the complete diet for salmonoids. Unless feed is presented in the correct form sub-optimal consumption will result. Pellet size and pellet binding is extremely important in maintaining feed intake and FCR. Dust from feeds is readily lost at the cost to the producer. Pellet binders such as carboxy methyl cellulose (CMC), bentonite, clays, flow, wheat and dried dairy products have all been used with varying degrees of success.

It is quite clear that with upto 60% fish meal and 25% oil in a diet, agglomoration becomes a big problem. With this in mind many fish feed producers are moving away from steam pelleted feeds to extrusion. Extruded feeds have the added advantage of being able to float or at least sink slowly thereby allowing a higher utilisation of feed.

Bolder clay is very interesting material. Whereas wheat and wheat by-products tend to speed up the rate of feed passage in the fish's gut, bolder clay, added at levels of upto 10% has been shown to slow down feed passage, increase digestion and control pollution by elimination of organic fillers and binders in the diet. More work is needed in this field.

The natural colour of salmon and trout is pink. Without natural pigments found in algaes and crustaceans farmed salmon flesh would be almost white. Accordingly, to produce a marketable product, red or pink nature-identical fat soluble pigments are added to the diet, particularly during the finishing phase. Flesh pigmented in such a way is attractive to the eye. Some markets such as Japan pay a high premium for red coloured flesh produced from canthaxanthin or astaxanthin. The cost of pigmentation of farmed salmonoids may be as high as AUS $0.50/kg; 20% of the total feed costs.

Very significant amongst an array of essential vitamins and micronutrients is Vitamin C. Upto 2kg of Vitamin C is added per tonne of feed. This allowance is higher than the requirement since much is lost between feed manufacture and feeding. More stable sources of Vitamin C are being developed.

Finally but nonetheless significant, is the whole area of digestion modifiers and growth promoters. The common anti-bacterial Virginiamycin has been shown to improve growth rate, feed conversion efficiency and protein and energy retention by over 20% (Viola and Arieli, pers. comm.) Other anti-bacterials have had similar effects. This development has opened up a whole new horizon in both feeding and economics of fish culture which would need to be addressed in the near future.

CONCLUSION

As our expertise in the areas of growth, ration formulation, feeding and husbandry improve, we can expect better growth performance from fish. Genetic improvements will further affect performance and various aspects of metabolism. Consequently, the requirments for feed nutrients will change. Furthermore, the availability, quality, price and processing techniques of feedstuffs are likely to change in the future. This warrants a continuous re-evaluation of diet formulation, feeding practices and feed resources.

REFERENCES

ALEXIS, M.N., PAPOUTSOGLOU, E.P. AND THEOCHARI, V. (1985), Aquaculture, 50, 61-73.

AUSTRENG, B., GRINSDALE-HELLAND, B., HELLAND S.J. AND STOREBAKKEN, R. (1988), Livestock Production Science, 19, 369.

BIEBER-WLASCHNY, M. AND PFEFFER, E. (1987), J. Animal Physiol and Animal Nutrition, 57, 150.

HARDY, R.W., SCOTT, T.M. AND HARRELL, L.W. (1987), Aquaculture 65, 267.

HOFFMANN LA ROCHE (1989), Personnal Communication.

MEARNS, K.J. (1985), Aquaculture, 48, 253.

PFEFFER, E. (1982), Comp. Biochem. Physiol. 73B, (1), 51.

RUMSEY, G.L. (1986), Proc. Cornell Nutrition Conference for Feed Manufacturers, pp.100 - 110.

STEFFENS, W. (1985), Arch. Tierernahr., Berlin, 35, (5), 361.

STEFFENS, W. (1987), Arch. Animal Nutrition, Berlin, 37, (1), 98.

TACON, A.G.P., AND JACKSON, A.J. (1985), In "Nutrition and Feeding in Fish", (Academic Fress, London), pp.119 - 146.

VIOLA, S AND ARIOLI, Y. Personal Communication.