

dried in a dryer to reduce moisture levels to 8 to 10 percent so they can be stored without refrigeration.

There are limits to the amount of lipid that can be included in pellets because of frictional losses during processing. One of the advantages of the extrusion process over pelleting is that expanded pellets will absorb more lipid, which is applied with a fat coater. Fat is usually applied after drying and just before the feed is directed to storage bins. The fat coating adds energy to the diet and may improve palatability and reduce feed dust. The finished feed is taken from storage bins to be either bagged or loaded into trucks for bulk delivery.

Diet forms for small fish can be produced by various methods. Microbinding, microcoating and microencapsulation procedures will produce larval feeds ranging in size from 25 to 400 microns (Hardy and Barrows, 2002). Traditional meals and crumbles are produced by reducing the particle size of pellets and screening them into specific size ranges. The processing procedures and diet forms selected for feeding small fish of a given species may depend not only on the fish's nutritional needs but also on matching the diet's physical characteristics to those of the culture system for best distribution.



Figure 1: Different kinds of feed pellets/forms.

Feeding practices

Feeding practices affect production efficiency and the nutritional value of prepared feeds. When selecting a feeding practice, it is important to consider the life stage of the fish, the water temperature and its effect on fish metabolism, the physical characteristics of the culture system, and the availability of natural food items. There is no “standard” method for feeding fish. However, there are some general principles that should be followed whenever possible.

Natural foods

In certain culture systems (e.g., ponds), the food that is naturally available can make a valuable contribution to the nutrition of some life stages of fish. Producers should promote the growth of natural food when possible, using prepared feeds as a supplement. As fish grow older, they will need more nutrition than their environment can provide, especially under intensive production conditions, and should be given nutritionally complete prepared feeds. In culture systems such as raceways, cages/net pens and recirculating systems, where natural food is minimal, the use of nutritionally complete prepared feeds is critical.

Feeding schedules based on water temperature and/or fish size

For a number of fish species that have been cultured for several decades, such as rainbow trout and channel catfish, various feeding schedules have been empirically developed that take into account the effects of water temperature and fish size on the relative feed intake of the fish expressed as a percentage of body weight. Such schedules specify that prescribed amounts of feed be given at certain intervals. In general, the feeding frequency and feed quantity (expressed as a percent of body weight) are reduced as fish size increases and water temperature departs from optimum (Lovell, 2002). Feed manufacturers may provide such feeding schedules as general guides. They are also available in various publications (e.g., Lovell, 2002; assorted SRAC publications on the production of individual fish species).

Feeding to apparent satiation

In certain culture systems, such as large ponds, it may be difficult to maintain an accurate estimate of fish biomass, in which case fish can be fed to “apparent satiation.” This feeding method can be rather subjective because it depends on the feeding activity of the fish and the experience of the feeder. Ideally, feed should be provided in small amounts over the course of 20 to 30 minutes or until feeding activity slows. This approach gives all fish ample opportunity to obtain some feed, especially after the most aggressive fish have consumed all they want. However, this method does require considerable amounts of time when multiple culture systems are being managed. Generally, it is better to underfeed than to feed too much because the uneaten feed will not only be wasted but also might degrade water quality. And if water quality is not good (especially dissolved oxygen levels and total ammonia nitrogen concentrations) it might not be possible to feed fish all they will consume.

Demand feeders can be used under certain circumstances. These allow fish to consume feed whenever they



Figure 2: Raceway with demand feeder.

desire. A demand feeder has a feed storage container with a conical-shaped bottom and a disc located slightly below the conical bottom. A metal rod extends into the water. When fish touch the rod, feed is dropped into the water. The quantity dispensed can be adjusted. This type of feeder is commonly used in the produc-

tion of rainbow trout in raceways. Demand feeders should be checked regularly to make sure they are working properly and to refill with feed.

Feeding frequency and distribution

The frequency with which feed is distributed is primarily determined by fish size and the characteristics of the culture system. Young fish grow faster and have better feed efficiency when fed several times a day. Older fish do not exhibit the same benefits from frequent feeding.

Feeding can be done by hand or with automatic feeders. These feeders come in many different designs such as belt conveyers or vibrating dispensers, but generally can be adjusted to provide specific amounts of feed at set intervals.

In hatcheries and other small systems, fish are often fed several times a day. In larger culture systems such as ponds, this practice is more time consuming and the fish may not benefit as much because they have access to natural food.



Figure 3: Feed blower.

Adequate distribution of the feed is another important consideration. Feed is easy to distribute in relatively small culture systems such as raceways, cages, net pens or intensive flow-through or recirculating water systems. Distributing feed in large ponds is more difficult. Feed blowers mounted on or pulled behind trucks are commonly used to dispense feed in ponds. It is generally recommended that feed be distributed down one or more sides of the pond to make it accessible to as many fish as possible. If feeding must be limited to one levee, as on large facilities where numerous ponds must be fed daily, feed should be distributed from the upwind levee so it will disperse out into the pond.

Medicated feeds

One of the most effective ways of treating fish for bacterial infections, especially in large culture systems, is to use medicated feed. Three commercial antibiotic products—oxytetracycline, sulfadimethoxine/ormetoprim and florfenicol—have been approved by the U.S. Food and Drug Administration (FDA) for use in the farming of fish destined for human consumption (<http://www.fda.gov/AnimalVeterinary/DevelopmentApprovalProcess/Aquaculture/ucm132954.htm>). The quantity of antibiotic fed must be controlled. Proper feeding rates and withdrawal times must be followed to reduce the deposition of antibiotics into fish tissues or the release of antibiotics into the rearing water that may be discharged into the aquatic environment. Specific administration and withdrawal procedures for the various antibiotics and targeted fish species were established during the registration process. Antibiotics may be added to feeds in the U.S. only by a licensed manufacturer.

Conclusions

Reliable estimates of nutrient requirements have been established for major cultured fish species. These estimates are rather similar among species whose natural feeding habits and environmental requirements are comparable. There is also information about the nutritional value and suitability of common feedstuffs used in fish feeds. This knowledge has guided the development of diet formulations and feed management practices that promote efficient and cost-effective production while maintaining the health of the cultured species.

References

Gatlin, D.M., III. 2002. Nutrition and fish health. In: *Fish Nutrition*. J.E. Halver and R.W. Hardy (eds.), 3rd edition. London:Academic Press. pp. 671-702.