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Feeds and Feeding of Hybrid Striped Bass

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There are two main hybrids between white bass (*Morone chrysops*) and striped bass (*Morone saxatilis*) that are used in commercial aquaculture: 1) the original cross, or "palmetto bass," and 2) the reciprocal cross, or "sunshine bass." Both hybrids are carnivorous and have similar nutrient requirements that are met by a variety of commercial diets. Sunshine bass are produced by most hatcheries because white bass females are more available and are easy to spawn. Sunshine bass grow more quickly and convert feed more efficiently than palmetto bass during part of the production cycle. Most of the recent research on nutrition and feeds has focused on sunshine bass (Fig. 1).

Figure 1. Sunshine bass fingerling ready for a feeding trial.

Nutrient Requirements and Practical Feeds

Commercial feeds for bass must meet their nutrient requirements at a cost that maintains profitability for the producer. Most basic nutrient requirements of hybrid striped bass have been determined with small fish under controlled laboratory conditions using purified diets. Requirements for protein, energy, most of the essential amino acids, essential fatty acids (n-3), vitamins (A, E, C, riboflavin, pantothenic acid, choline) and minerals (phosphorus, selenium, and zinc) have been determined using growth as the primary criterion. The nutrient digestibility of purified ingredients is uniformly high, while the digestibility of practical ingredients (such as fish meal and soybean meal) can vary considerably.

Cost, supply, nutrient composition, and nutrient availability all play a role in choosing ingredients for feeds. Nutrient availability is usually determined with laboratory digestibility trials, which are tedious and time-consuming (Fig. 2). Nevertheless, this information is necessary for accurate least-cost feed formulations. Nutrient availability from a broad range of animal and plant ingredients has now been determined for hybrid striped bass. This is due

Figure 2. Fish feces are collected to determine the digestibility (availability) of nutrients in feeds.

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partly to the need to find alternatives for traditional feed ingredients such as fish meal. Fish meal is a superior protein source, but its high cost and limited supply have stimulated research to find alternatives. Additional factors such as taste can affect the use of certain ingredients. This has become a bigger challenge with the increasing use of plant ingredients in bass diets.

Protein and amino acids

Dietary proteins supply essential amino acids that are critical for growth, and protein feedstuffs are usually the most expensive diet ingredients. The amount and quality of protein must be adequate to support fish performance. Different protein sources vary not only in cost, but in their ability to supply the right balance of available amino acids to the fish. Historically, diets for hybrid striped bass included very high levels of fish meal, which is an excellent protein source for most fish. But because of the constraints mentioned earlier, intensive research is underway to identify nutritionally equivalent, cost-effective protein sources to replace marine fish meal.

By-products of the rendering process have good potential for use in bass diets. Aquarium studies have shown that fish meal can be replaced completely with combinations of meat and bone meal (32 percent of diet) and soybean meal (32 percent of diet), or poultry by-product meal (28 percent of diet) and soybean meal (32 percent of diet). Growth, survival, and body composition of fish fed these diets were similar to results produced with a 30 percent fish meal diet. In ponds, pet-grade poultry meal can replace fish meal completely without reducing bass performance. The key is to formulate diets on the basis of amino acid (not just protein) availability. In most cases, amino acids such as lysine, methionine, and threonine must be added to the diet to obtain equivalent results to a fish meal diet. Overall, protein digestibility of animal ingredients (e.g., poultry meals, blood meal, meat and bone meal, fish solubles, other fish by-products) is 47 to 70 percent. However, high protein digestibility of a feed ingredient does not necessarily mean that its amino acids are highly digestible. For instance, protein digestibility of fish solubles is high (70 percent), but some of the amino acids have low digestibility. Additional amino acids or complimentary protein sources might be needed to correct this type of imbalance.

Soybean meals and other plant protein sources have been evaluated as alternative protein sources for bass. Plant ingredients are considered more environmentally friendly to use than animal ingredients, and plant feedstuffs are often less expensive. However, plant feedstuffs have anti-nutritional factors (such as trypsin-inhibitor, phytate, tannins, etc.) that can reduce fish growth and cause other problems. They may also be unpalatable to bass. Plant products (e.g., meals from soybean, canola, peanut, sunflower, and Brewer's yeast) have a similar range of protein digestibility (43 to 80 percent) to animal products. Soy has one of the best amino acid profiles of plant products, and it is an abundant commodity. Therefore, many different soy products have been tested in hybrid striped bass: solvent-extracted meal, toasted meal, soy protein isolate, soy protein concentrate, and fermented soy products. Recently, improved soybeans produced by conventional breeding or genetic modification have become available for research. These products contain more protein and fewer anti-nutritional factors than traditional soybeans. As the nutrient composition of soy products improves, they can generally replace a higher level of fish meal in the diet. However, modification procedures, including chemical or genetic processes, will make these ingredients more costly. Again, the profitability of using these improved plant products needs to be further evaluated in hybrid striped bass.

Lipids (fats and oils)

Lipids in the diet provide energy and essential fatty acids. The replacement of marine fish meal, which contains about 10 percent fish oil, has led to another problem. Marine fish oil is rich in n-3 long-chain polyunsaturated fatty acids (LC-PUFAs, such as eicosapentaenoic acid [EPA] and docosahexaenoic acid [DHA]). These fatty acids are required by hybrid striped bass (0.50 to 0.75 percent of the diet), and cannot be eliminated entirely. Fortunately, as long as the dietary requirement for n-3 LC PUFAs is met, the rest of the lipid in the feed does not have to be fish oil. Other animal and plant lipids can be used to provide energy without reducing fish growth. However, bass fed diets without fish oil (or another source of n-3 LC-PUFAs) have fillets that are low in n-3 LC-PUFAs. These fatty acids have well-established benefits for human health. Bass low in n-3 LC-PUFAs might be less attractive to consumers who eat fish for health reasons. One solution is to use diets with fish oil (or algal oil, another source of n-3 LC-PUFAs) only as finishing diets for the last few weeks of production to increase the LC-PUFAs. Another approach is to use saturated fats in the diet to supply energy, which "spares" the n-3 fatty acids. This helps to retain more n-3 fatty acids in the fillet. The responses of hybrid striped bass to different types and amounts of lipids in the feed are well documented. However, there are currently no inexpensive sources of n-3 LC-PUFAs to use in fish diets. This is a major bottleneck to producing hybrid striped bass containing high quantities of healthy fatty acids without using marine fish oil.

Carbohydrates

Fish do not require carbohydrates in the diet. However, they are the least expensive energy source and should be included in the diet to reduce cost and ensure flotation of extruded pellets. Carnivorous fish cannot use as much carbohydrate as omnivorous fish. Research indicates that soluble carbohydrate may be included in the diet of hybrid striped bass at 20 to 25 percent without compromising fish growth or health.

Vitamins and minerals

Feed ingredients alone may not supply all of the micronutrients that fish need. Typically, premixes containing vitamins and minerals to meet the needs of carnivorous fish are added to practical feeds. As diet formulations for bass evolve to include new or alternative ingredients, the composition of vitamin and mineral premixes may have to be re-evaluated. With the increasing use of plant feedstuffs in bass diets, the availability of some minerals (phosphorus, zinc) will probably be reduced. It is important to provide vitamins and minerals to supplement those contributed by the feed ingredients. All commercial fish diets are over-fortified to account for variation among ingredient sources and losses during extrusion and storage. However, excessive over-supplementation should be avoided to reduce nutrient imbalances, diet cost, and water quality problems.

Feed supplements

Some products added to fish diets provide little or no nutrition but enhance fish performance. These supplements may improve fish growth, feed conversion, or immune response in a way that an un-supplemented feed does not. A number of supplements have been tested in hybrid striped bass (Table 1), and many of them have proven benefits.

Most of the products listed in Table 1 can be classified as prebiotics. These indigestible carbohydrates stimulate the growth of "good" bacteria in the gut (microbiota) and also can change the activities of the resident bacteria. The bacteria produce short-chain fatty acids, which reduce the pH of the gut. Minerals are absorbed better at an acidic (low) pH, and overall nutrient absorption from the feed may improve. Prebiotics also can cause bacteria to produce compounds that are absorbed by the fish and stimulate the immune system. They are a safe way to protect bass against bacterial diseases because there is no risk of producing resistance, as there is with antibiotics. Some supplements (such as nucleotides) are not classified as prebiotics even though they improve many of the same performance measures (weight gain, immune response) as prebiotics. In this case, the beneficial effects are not due to modification of the gut microbiota.

The challenge with prebiotics and other supplements is determining the correct dose and feeding period required to produce benefits in the fish. Some effects, such as changing the gut microbiota, may occur in a few weeks or less, whereas improved weight gain or protection against bacterial pathogens may take weeks to months. Some supplements seem to work temporarily, but then lose their effectiveness over time. They also may show benefits in some studies, but not in others done under similar conditions. Because supplements add cost to the feed, it would be best to determine the minimum time required to achieve target benefits under conditions that simulate commercial culture.

Table 1. Feed supplements tested in hybrid striped bass.

Additive name	Dietary inclusion level	Length of feeding	Effects
Grobiotic-®A*	1–2%	2–16 weeks	Improved growth and FCR; enhanced innate immune function; increased resistance to *Streptococcus iniae* and *Mycobacterium marinum* infection
Grobiotic-®A[a] Mannan-oligosaccharides Galacto-oligosaccharides Inulin	1% 1% 1% 1%	8 weeks	No effects on weight gain, FCR, or protein efficiency ratio; increased body protein
Brewer's yeast	1–2%	4–16 weeks	Improved growth and feed efficiency; enhanced innate immune function and resistance to *S. iniae*
Beta-glucans	0.1%	6 weeks	No effects on weight gain or immune function
Levamisole	0.01–0.1%	3 weeks	Improved growth, FCR and innate immune function (<0.05%); no effect on resistance to *S. iniae* or *Aeromonas hydrophila;* toxic at 0.1%
Nucleotides (Ascogen®)[b]	0.5%	7 weeks	Enhanced innate immune function and resistance to *S. iniae*

[a]Grobiotic-®A (International Ingredient Corp., St. Louis, Missouri)
[b]Ascogen® (Chemoforma, Ltd., Augst, Switzerland)

Figure 3. Feed supplements being tested in ponds at Texas A&M University. (Courtesy of Delbert M. Gatlin, III, College Station, Texas.)

More research is needed to address the inconsistencies of using supplements before they are likely to become standard additions to commercial diets (Fig. 3).

Other supplements are added to the diet strictly to enhance the taste and acceptability of the feed. Nucleotides, free amino acids, quaternary ammonium bases, and organic acids all have the potential to serve as feed attractants. Bass naturally consume very little plant material, so the need for supplements to enhance feed palatability will probably increase with greater use of plant feedstuffs.

Feeding Practices

Hybrid striped bass production can be divided into phases. In the 3-phase system, Phase I includes spawning and rearing of fry to small fingerlings; Phase II covers growth of the small fingerlings to larger fingerlings; Phase III consists of growing large fingerlings to market size. Some producers use a two-step method called direct stocking, where larger fingerlings are grown directly to market size. With either production method, the size and composition of the feeds used will depend on the size of the fish and their changing nutritional needs over time.

Fry require appropriate sizes of live food (zooplankton), which are stimulated by fertilizing ponds before stocking. This topic has been covered in detail in SRAC Publication No. 302, *Hybrid Striped Bass: Fingerling Production in Ponds,* and will not be addressed here. The first commercial feed may consist of a high-protein (50 percent) salmon starter feed, which is fed up to three times per day, 7 days a week, at 1 to 5 pounds per acre per day the first week. The feed rate may be increased to 10 to 15 pounds per acre per day (1.8 to 2.7 kg/ha/day) as the fish grow, but this feed is costly. Alternatively, the fry may be fed a #1 or #2 crumble with 42 to 50 percent protein at 2 to 10 pounds per acre (0.4 to 1.8 kg/ha) for the first few weeks. Feeds for larger size classes usually contain at least 45 percent protein and are top-dressed with fish oil to provide 14 to 18 percent dietary lipid. Regardless of the feed type and strategy used, the fry are susceptible to rapid starvation and must receive regular feedings of nutritionally complete feed. Therefore, fry may be fed four times or more per day, depending on available farm labor. The fry may not grow uniformly because of unequal feed distribution or differences in individual fish feeding behavior. Fry that do not consume much feed will be noticeably smaller, while the largest fish may become cannibalistic. More frequent feeding, and concentrating the fish in a small area during feeding, can reduce size variability at the fry stage.

In general, the amounts of protein and lipid in the feed decrease as fish size and feed particle size increase. During the fry-fingerling transition, fish may be fed a #3 crumble, and then a 3⁄16-inch (4.8 mm) feed with 40 to 45 percent protein and 10 to 12 percent lipid once or twice daily to satiation. As they continue to grow, fish are fed ⅛-inch to ⅜-inch pellets with 40 to 45 percent protein and 10 to 12 percent lipid. In the final months of growout, fish are fed a ¼-inch pellet with 38 to 40 percent protein and 8 to 10 percent lipid.

Like the fry, broodstock are typically fed nutrient-dense diets (50 or more percent protein, 12 percent or more lipid) to meet the high nutrient and energy requirements of egg production and spawning. Energy-dense diets also can be useful for other applications. Diets with 49 to 59 percent protein and 16 to 28 percent lipid stimulate very rapid growth and improve feed efficiency of juvenile hybrid striped bass. Similarly, energy-dense feeds may be fed to bass when feed intake is reduced because of low (< 59 °F [15 °C]) or high (>86 °F [30 °C]) water temperatures. The purpose of this strategy is to meet the nutrient and energy requirements of the fish

Figure 4. In warm weather, a diet with 40 percent protein and 18 percent lipid fed at 80 percent of satiation maintained bass performance. (Courtesy of Steven D. Rawles, HKD SNARC, Stuttgart, Arkansas.)

with less feed. Uneaten feed may reduce water quality and place additional stress on the fish. Nutrient-dense feeds are more costly than standard feeds, and the economics of using these diets will need to be evaluated for different scenarios. Some research indicates that other changes in diet composition may help fish tolerate temperature or ammonia stress. In studies, a feed with 40 percent protein and 18 percent lipid was helpful in maintaining bass performance at 87 °F (30.5 °C) when fed at 80 percent of satiation (Fig. 4). Withholding feed for short periods (2 weeks) can also enhance feed conversion temporarily through the process of compensatory growth. When feeding is resumed, feed efficiency and growth are accelerated as fish make up for the temporary lack of food. Compensatory growth has been demonstrated in hybrid striped bass but has not been exploited commercially.

Summary

Feeds for hybrid striped bass must meet the nutrient requirements of the fish and be palatable and cost-effective. The main nutrient requirements of hybrid bass are known. However, some requirements (essential amino acids, essential fatty acids) are being re-evaluated. In addition, the digestibility of individual nutrients is being determined. This new knowledge will increase the accuracy of least-cost feed formulation and support refinements to commercial feeds. The importance of determining nutrient availability from different feed ingredients will increase as alternatives to marine fish meal and oil are evaluated. The product quality of the fish must be considered as diet formulations change. In particular, strategies are needed to retain healthy n-3 long-chain fatty acids in the fillet. Feed supplements may supply missing nutrients or other compounds that enhance fish growth performance and stimulate the immune response without using antibiotics. Supplements may also increase the acceptance of plant-based feeds by hybrid striped bass. The potential of using nutrient-dense feeds or reduced feeding rates to enhance overall fish performance during stressful periods should be explored further. Evaluation of alternative diet formulations and feeding strategies should include economic analysis.

Suggested Readings

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