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What Are Nutrient-Dense Fish Feeds and Their Importance in Aquaculture?[1]

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Introduction

Dietary nutrient-density refers to the amount or proportion of a particular nutrient in relation to the total amount of nutrients contained in the diet. Commonly, a nutrient-dense diet refers to being rich in protein and energy, and the amount of the specific nutrient is represented in proportion to the total energy content of the diet. A simple, nutrient-dense diet can be rich in vitamins and minerals and have a low content of fat and relatively few calories (e.g., many fruits and vegetables are considered vitamin and mineral nutrient-dense foods). Seafoods in general are nutrient-dense foods and low in calories. Seafoods are high in protein, packed with vitamins and minerals, rich in polyunsaturates and omega-3 fatty acids, but low in sodium and total fats.

In animal nutrition there are six nutrients; water, carbohydrates, lipids, proteins, minerals, and vitamins. Animals derive energy from three of these nutrients: lipids, proteins, and carbohydrates (the chemical energy or heat density available for the animal to use in 1 gram of fat, protein, and carbohydrate is approximately 9, 4, and 4 kilocalories, respectively). The term *nutrient-density* refers to the amount and type of a particular nutrient, or combination of them, contained in a feed, usually a pellet of specific size or volume. For example, a high-performance grow-out pellet may contain a high concentration of protein to supply amino acids necessary to build muscles and support fast growth. The concept of nutrient-density encompasses the overall composition of the diet in relation to nutrients as well as caloric or energy density. The caloric or energy density of a feed is the number of calories that are contained, in relation to the total amount of nutrients, in a feed pellet of specific size or volume. Traditional livestock rations, pet foods, or human diets that are nutrient dense are typically formulated with specific or recommended amounts of nutrients in relation to the energy or caloric content of the diet.

In order to increase the nutrient and energy density of a feed, something has to be taken out to provide room for the selected nutrient. What is decreased in the diet is usually carbohydrate, particularly in fish feeds. Most species of fish derive energy from proteins and fats more efficiently than from carbohydrates, similar to some terrestrial carnivorous species, such as cats. The moisture content of a feed pellet also will influence its nutrient and energy densities because more water adds weight but no nutrients or calories. Therefore, dry, nutrient-dense feeds will have higher energy and nutrient densities.

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Fishmeal and the Cost of Fish Feed in Aquaculture

Fishmeal has traditionally been the principal source of protein incorporated into many types of feeds used in aquaculture. Fishmeal is also incorporated into feeds for poultry, swine, and other animal industries. Properly processed fishmeal is very digestible, carries large quantities of energy and high-quality protein per unit weight (protein-dense), and contains very little carbohydrate. Fishmeal is produced principally from small, wild-caught marine fish not usually harvested for direct human consumption. Although a renewable resource, fishmeal is expensive and the world-wide supply is limited, especially as the demand for aquaculture products expands and fishmeal is utilized in other animal industries.

The cost of feed often accounts for 30% to 50% or more of the operational expenses for an aquaculture facility. Feed is also a relatively large percentage of costs for land-based animal industries, such as poultry and swine. The price of the feed varies with the type of feed (e.g., live, wet, moist, and dry feeds), the type and quality of individual ingredients incorporated into the feed, the manufacturing process, and the method of delivery (i.e., bulk, bagged, or sacked).

The Role of Nutrient-Dense Feeds in Aquaculture

The use of nutrient-dense feeds continues to gain wide acceptance in the aquaculture industry. Amongst the greatest benefits is a substantial reduction in the overall variable cost of an operation through improved animal performance, better feed conversion ratio (FCR: the ratio of input to output or how many pounds/kilograms of feed are required to produce one pound/kilogram of whole animal), and improved water quality due to a reduction in the amount of nutrients and solids (i.e., feces and uneaten food) in the wastewater effluent. How do these benefits arise from the use of nutrient-dense feeds?

Improving Animal Performance

In most cases, nutritionists strive to provide to an animal at various stages of its life, a nutrient-dense feed that contains adequate quantities of nutrients for a desired type of performance. When formulating fish diets the nutrient-density can be increased or decreased simply by increasing or decreasing the percentage of one or more ingredients containing high concentrations of specific nutrient(s). Adjusting nutrient-density is a common practice as fish grow. For example, fingerlings and juveniles grow more rapidly than older fish. Since this growth is mostly addition of lean protein tissue, a higher percentage of protein is required in the diet to furnish the essential amino acids that make up the lean tissue. As fish get older and larger, their overall growth rate and deposition of lean tissue declines, and the percentage of protein in the diet is usually decreased. This concept of lowering the dietary protein content as the animal ages is the basis of *phase feeding programs*. Therefore, nutrient-dense feeds are formulated or *designed* to supply a specific nutrient concentration required for optimum performance at different life stages (life growth phases).

By selecting nutrient-dense feedstuffs, with high digestibility, farmers are able to provide fish with adequate intake of their recommended nutrients without exceeding the fish's energy requirement. Because more nutrients are available and easily assimilated in a nutrient-dense diet, fish growth is improved and FCRs are lowered. For example, in Idaho, trout raised on commercial, nutrient-dense feeds now exhibit a FCR of 1.2:1; a significant improvement from a traditional 1.8-2.0:1 FCR for most fishes. Raised on experimental nutrient-dense diets, trout and salmon have exhibited FCRs as low as 0.7-0.8:1. A FCR of 1.2:1 is quite significant, when considering the current FCR for land animals is approximately 8:1 for cattle, 4:1 pigs, and 1.8:1 for meat-type broiler chickens. (FCR, calculated on dry weight of feed to wet weight gain, hence values lower than 1.0).

Highly digestible, nutrient-dense diets are especially important for feeding larvae or small fish, such as ornamental species. Because of their small size, these animals require more nutrients per unit of body mass than older, larger animals. Use of nutrient-dense feeds also becomes essential for brood-stocks. For example, females may require specific amounts and kinds of nutrients prior to or during vitellogenesis (i.e., the process of yolk formation and its accumulation by the eggs). Also, the nutrient-density of a feed becomes important for fish with different feeding habits (i.e., carnivores, omnivores, herbivores, detritivores, etc.). For example, carnivorous fish such as salmonids typically have a large stomach with high capacity and a short intestine. Such fish do not utilize carbohydrates well and make almost no use of fiber, which is often common to diets having low nutrient density. Salmonid diets, therefore, are formulated to contain a higher nutrient-density, especially in relation to protein and energy.

Lipid (fats and oils), which is normally used in feed to increase energy density, also imparts palatability that enhances overall feed consumption and, as a result,

increases growth and improves FCR. A nutrient-dense feed also can be designed to enhance the quality of the final product. For example, increasing the concentration of omega-3 fatty acids can increase the health benefits of meat. Health benefits have been suggested for people who consume diets low in calories and high in omega-3 fatty acids. Aquaculture diets have always contained high levels of fish oils that are high in omega-3 fatty acids. The health benefits of marine oils are the main reasons fish oils are not replaced by plant oils in such diets. Enriching the feed with lipids rich in omega-3 fatty acids also promotes improved animal health in production facilities.

Nutrient-Dense Diets, Aquaculture Wastes, and the Environment

In any aquaculture rearing facility, feed is the major contributor to the unwanted nutrient enrichment of water leading to deterioration of water quality. This effect is brought about directly or indirectly through the contributions of excess nutrients, fecal solids, and uneaten feed.

When too much feed is the cause of water pollution, it may be the result of providing more food to compensate for low nutrient density. When feeds with low nutrient densities are used, the capacity of the gut may be exceeded before the fish consumes adequate amounts of nutrients. This situation leads to a need for more food, and more food may lead to problems with water quality. If the feed is of poor quality and it is not being digested efficiently, it contributes to higher quantities of fecal solids in the water. Even if the food is digested and absorbed, assimilation of the nitrogen (N), phosphorus (P), and other elements in a poor-quality feed may not be efficient, so these elements are excreted into the water. If too much protein is fed, the fish may use the carbon skeletons of the amino acids for energy instead of lean body tissue, and the excess N (in the form of ammonia) from the amino acids is released into the water. A low nutrient-dense feed also may not be palatable, which may increase the amount of uneaten feed in the effluent. A poor-quality pelleted feed also may be fragile and break easily into many fine particles (fines) that further increase waste, nutrient load, and turbidity.

Advanced feed extrusion and expansion technology permits the manufacture of nutrient-dense floating and sinking feeds, which both greatly facilitate their use in freshwater and saltwater environments and makes them appealing to more fish species resulting in less waste. A nutrient-dense feed permits formation of a compact feed pellet, thus reducing fines and feed load. As a result, the animal assimilates more nutrients, and fewer solids are released into the water thus maintaining water quality. New feed manufacturing technology, for cooking, extrusion, and expansion of ingredients, also allows nutrients, such as proteins and lipids from many different ingredients, to be incorporated at higher percentages. Use of ingredients from other animal and plant sources (e.g., soybean meal) reduces dependence on fishmeal, which helps ensure the sustainability of this valuable resource.

Summary

In aquaculture and terrestrial animal production facilities, feeds with low nutrient and/or energy densities often may not meet the specific nutrient and energy requirements of the animals. The use of nutrient-dense feeds is especially important in feeding fish and other aquatic animals to minimize nutrient losses since nutrients are quickly leached into the water. Improved feed manufacturing technology promotes more dense and stable pelleted feeds, which greatly reduces the quantity of fines and slows the leaching of nutrients. The ability to manufacture nutrient-dense feeds utilizing proteins and fats from different plant and animal sources drastically reduces the use of fishmeal (e.g., by some 30–35%) and lessens dependence on this limited and valuable resource.

The use of nutrient-dense diets in aquaculture operations can significantly increase profitability by reducing feed costs, improving animal performance, maintaining water quality, and minimizing nutrient loads to the environment. The manufacture and use of nutrient-dense feeds, based on high quality and digestible feedstuffs, is highly recommended for the aquaculture industry as long as the use of such feeds is profitable and compatible with the environment.