Preparing Your Own Fish Feeds[1]

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Introduction

Most fish farmers and ornamental fish hobbyists buy the bulk of their feed from commercial manufacturers. However, small quantities of specialized feeds are often needed for experimental purposes, feeding difficult-to-maintain aquarium fishes, larval or small juvenile fishes, brood fish conditioning, or administering medication to sick fish. In particular, small ornamental fish farms with an assortment of fish require small amounts of various diets with particular ingredients. It is not cost effective for commercial manufacturers to produce very small quantities of specialized feeds. Most feed mills will only produce custom formulations in quantities of more than one ton, and medicated feeds are usually sold in 50-pound bags. Small fish farmers, hobbyists, and laboratory technicians are, therefore, left with the option of buying large quantities of expensive feed, which often goes to waste. Small quantities of fish feed can be made quite easily in the laboratory, classroom, or at home, with common ingredients and simple kitchen or laboratory equipment. This paper presents examples of 1) Experimental and practical fish feed blends or formulas that are nutrient balanced and adaptable to particular conditions; 2) The formulation and preparation of a semi-purified ornamental African cichlid fish diet that can be used in the laboratory or when small quantities of feed are needed; 3) The preparation of a gelatin-based diet that is often used to administer medicines or other chemicals. Background information on nutrition, feedstuffs, and feed formulations are presented with emphasis primarily on the feeding of ornamental "aquarium" fishes.

Nutrition and Feedstuffs

Nutrients essential to fish are the same as those required by most other animals. These include water, proteins (amino acids), lipids (fats, oils, fatty acids), carbohydrates (sugars, starch), vitamins and minerals. In addition, pigments (carotenoids) are commonly added to the diet of salmonid and ornamental "aquarium" fishes to enhance their flesh and skin coloration, respectively. The general proportions of various nutrients included in a standard fish diet are given in Table 1. One of the best descriptions of the essential nutrients for fish and the nutrient content of various ingredients is *Nutrient Requirements of Fish*, a publication by the National Research Council available free on the Internet at http://www.nap.edu/.

In their natural environment fish have developed a wide variety of feeding specializations (behavioral, morphological, and physiological) to acquire essential nutrients and utilize varied food sources. Based on their primary diet fish are classified as carnivorous (consuming largely animal material), herbivorous (consuming primarily plant and algae), or omnivorous (having a diet based on both plant and animal materials). However, regardless of their feeding classification, in captivity fish can be taught to readily accept various prepared foods which contain the necessary nutrients.

1. This document is Cir 97, one of a series of the School of Forest Resources and Conservation, Program in Fisheries and Aquatic Sciences, UF/IFAS Extension. Original publication date February 2003. Reviewed December 2019. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication.

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Increased understanding of the nutritional requirements for various fish species and technological advances in feed manufacturing, have allowed the development and use of manufactured or artificial diets (formulated feeds) to supplement or to replace natural feeds in the aquaculture industry. An abundant supply of feedstuffs are available, and farmers and hobbyists are now able to prepare their own fish feeds from locally available ingredients.

Proteins and Amino Acids. Fish meal, soybean meal, fish hydrosylate, skim milk powder, legumes, and wheat gluten are excellent sources of protein. Additionally, the building blocks of proteins (free amino acids) such as lysine and methionine are commercially available to supplement the diet.

Utilizing raw fish as a main ingredient in fish feeds has long been recognized to be harmful to the health and growth of fish due primarily to the presence of the anti-nutrient, thiaminase. Thiaminase, an enzyme that destroys thiamine (vitamin B-1), one of the essential water-soluble vitamins, is mostly found in freshwater fish and is destroyed by heat (i.e., cooking). Other concerns related to using raw fish in diets include the spread of infectious diseases such as mycobacterium and botulism. In preparing diets, preferential use of marine fish is suggested to minimize thiaminase activity, and raw fish could be steamed or poached.

Lipids. Oils from marine fish, such as menhaden, and vegetable oils from canola, sunflower, and linseed, are common sources of lipids in fish feeds.

Carbohydrates. Cooked carbohydrates, from flours of corn, wheat or other "breakfast" cereals, are relatively inexpensive sources of energy that may spare protein (which is more expensive) from being used as an energy source.

Vitamins and Minerals. The variety and amount of vitamins and minerals are so complex that they are usually prepared synthetically and are available commercially as a balanced and pre-measured mixture known as a vitamin or mineral premix. This premix is added to the diet in generous amounts to ensure that adequate levels of vitamins and minerals are supplied to meet dietary requirements.

Pigments. A variety of natural and synthetic pigments or carotenoids are available to enhance coloration in the flesh of salmonid fish and the skin of freshwater and marine ornamental fish. The pigments most frequently used supply the colors red and yellow. The synthetically produced pigment, astaxanthin (obtained from companies such as Cyanotech and F. Hoffmann-La Roche Ltd.), is the most commonly used additive (100–400 mg/kg). Cyanobacteria (blue-green algae such as *Spirulina*), dried shrimp meal, shrimp and palm oils, and extracts from marigold, red peppers and Phaffia yeast are excellent natural sources of pigments.

Binding Agents. Another important ingredient in fish diets is a binding agent to provide stability to the pellet and reduce leaching of nutrients into the water. Beef heart has traditionally been used both as a source of protein and as an effective binder in farm-made feeds. Carbohydrates (starch, cellulose, pectin) and various other polysaccharides, such as extracts or derivatives from animals (gelatin), plants (gum arabic, locust bean), and seaweeds (agar, carageenin, and other alginates) are also popular binding agents.

Preservatives. Preservatives, such as antimicrobials and antioxidants, are often added to extend the shelf-life of fish diets and reduce the rancidity of the fats. Vitamin E is an effective, but expensive, antioxidant that can be used in laboratory prepared formulations. Commonly available commercial antioxidants are butylated hydroxyanisole (BHA), or butylated hydroxytoluene (BHT), and ethoxyquin. BHA and BHT are added at 0.005% of dry weight of the diet or no more than 0.02% of the fat content in the diet, while ethoxyquin is added at 150 mg/kg of the diet. Sodium and potassium salts of propionic, benzoic or sorbic acids, are commonly available antimicrobials added at less than 0.1% in the manufacture of fish feeds.

Attractants. Other common additives incorporated into fish feeds are chemoattractants and flavorings, such as fish hydrosylates and condensed fish solubles (typically added at 5% of the diet). The amino acids glycine and alanine, and the chemical betaine are also known to stimulate strong feeding behavior in fish. Basically, attractants enhance feed palatability and its intake.

Other Feedstuffs. Fiber and ash (minerals) are a group of mixed materials found in most feedstuffs. In experimental diets, fiber is used as a filler, and ash as a source of calcium and phosphorus. In practical diets, both should be no higher than 8–12% of the formulation. A high fiber and ash content reduces the digestibility of other ingredients in the diet resulting in poor growth of the fish.

Other common feedstuffs used in ornamental fish diets include live, frozen, or dried algae, brine shrimp, rotifers or other zooplankton. The addition of fish or squid meal will enhance the nutritional value of the diet and increase its acceptance by the fish. Fresh leafy or cooked green vegetables are often used. Although vegetables are composed mainly

of water, they contain some ash, carbohydrates, and certain vitamins. Kale, dandelion greens, parsley, and turnip greens are examples of relatively nutritious vegetables.

Feed Formulations

With few exceptions, feeding a single type of food is neither complete nor balanced and does not supply all the nutrients a fish might need in its diet. Hence, two or more ingredients should be mixed into homemade, laboratory and commercial feed formulations. A diet may be formulated to supplement natural foods already available in the production system or as a complete formulation when no other foods are provided. A complete diet must be nutritionally balanced, palatable, water stable, and have the proper size and texture. If natural foods are not incorporated in ornamental fish diets, the feed must be supplemented with natural or synthetic pigments.

The nutrient composition of numerous feedstuffs can be found in the literature and on the Internet. Two books that deal almost entirely with nutrient composition of feedstuffs are 1) *Handbook on Ingredients for Aquaculture Feeds* and 2) *Standard Methods for the Nutrition and Feeding of Farmed Fish and Shrimp*. Another book, which is available free on the Internet is *United States-Canadian Tables of Feed Composition*, found at http://nap.edu/. Also, available through the Internet is the information provided by the USDA Nutrient Data Laboratory at http://www.ars.usda.gov/main/site_main.htm?modecode=80-40-05-25.

Feeds are formulated to be dry, with a final moisture content of 6–10%, semi-moist with 35–40% water or wet with 50–70% water content. Most feeds used in intensive production systems or in home aquaria are commercially produced as dry feeds. Dry feeds may consist of simple loose mixtures of dry ingredients, such as "mash or meals," to more complex compressed pellets or granules. Pellets are often broken into smaller sizes known as crumbles. The pellets or granules can be made by cooking with steam or by extrusion. Depending on the feeding requirements of the fish, pellets can be made to sink or float.

Flakes are another form of dry food and a popular diet for aquarium fishes. Flakes consist of a complex mixture of ingredients, including pigments. These are made into a slurry which is cooked and rolled over drums heated by steam.

Semi-moist and wet feeds are made from single or mixed ingredients, such as trash fish or cooked legumes, and can be shaped into cakes or balls.

Feed Preparation

There is no single way for the preparation of formulated fish feeds; however, most methods begin with the formation of a dough-like mixture of ingredients. Ingredients can be obtained from feed stores, grocery stores, pharmacies, and specialty stores such as natural food stores, as well as from various companies that may be found through the internet.

The dough is started with blends of dry ingredients, which are finely ground and mixed. The dough is then kneaded and water is added to produce the desired consistency for whatever fish is going to be fed. The same dough may be used to feed several types of fish, such as eels and small aquarium fish.

Pelleting or rolling converts the dough into pellets or flakes, respectively. The amount of water, pressure, friction, and heat greatly affects pellet and flake quality. For example, excess water in the mixture results in a soft pellet. Too little moisture and the pellet will crumble.

Proteins and especially vitamins are seriously affected by high temperatures. Therefore, avoid storing diet ingredients at temperatures at or above 70°C (158°F) and do not prepare dry feeds with water at temperature higher than 92°C (198°F).

Tools and Storage Procedures

Making your own fish feed requires few specialized tools. The tools are used primarily for chopping, weighing, measuring ingredients, and for blending, forming and drying the feed.

Most of the utensils needed will already be in the laboratory or kitchen. Multipurpose kitchen shears, hand graters, a paring knife, a 5-inch serrated knife, a 6- to 8-inch narrow-blade utility knife, and a 10-inch chef knife for cutting, slicing, and peeling can be used. A couple of plastic cutting boards protect the counter and facilitate handling the raw ingredients. Heat resistant rubber spatulas, wooden and slotted spoons, long-handled forks, and tongs are very good for handling and mixing ingredients. A basic mortar and pestle, electric blender, food processor, or coffee grinder are very useful to chop or puree ingredients; use grinder sieves and mince die plates to produce the smallest particle size possible. A food mill and strainer such as a colander or flour sifter help discard coarse material and obtain fine food particles. For weighing and measuring ingredients, dry and liquid measuring cups and spoons, and a food or laboratory bench scale are required. Other utensils include plastic bowls (1½, 3, 5, and 8 quarts) for weighing and

mixing ingredients, a thermometer, and a timer. A 3-quart saucepan and 10-inch stockpot are good for heating gelatins and cooking raw foods such as vegetables and starches. The ingredients and blends may be cooked in a small electric or gas burner. A few trivets to put under hot pans will protect counters and table tops.

Ingredients may be mixed by hand using a rotary beater or wire whisk; however, an electric mixer or food processor is more efficient. After mixing, a dough is formed that can be fashioned into different shapes.

A pasta maker, food or meat grinder will extrude the dough into noodles or "spaghetti" of different diameters. As the noodles emerge from the outside surface of the die, they can be cut off with a knife to the desired length or crumbled by hand, thus making pellets. A potato ricer also serves to extrude the dough into noodles of the same size. For making flakes, a traditional hand-cranked or electric pasta maker will press out the dough into thin sheets.

The pellets or thin sheets can be placed on a cookie sheet and dried in a household oven on low heat or in a forced-air oven. A small food dehydrator also performs the task quite well. To add extra oil and/or pigments to pellets, a hand-held oil atomizer or sprayer can is useful. To separate pellets into different sizes, a set of sieves (e.g., 0.5, 0.8, 1.0, 2.0, and 3.0 mm) is required.

Freezer bags serve to store the prepared feeds, and using a bag vacuum sealer will greatly extend the shelf-life of both ingredients and the feed. The feed can be stored double bagged in the freezer but should be discarded after 6 months. Ideally, dried larval feeds are not frozen but stored in the refrigerator for no longer than 3 months.

A finished diet, especially used for experimental purposes, should be analyzed for nutrient content (proximate analysis: crude protein, energy, moisture, etc.). In addition, anyone intending to make his/her own fish feeds with unfamiliar ingredients should have them analyzed prior to their use.

Sample Formulations and Recipes

There are numerous recipes for making fish feeds, and it is beyond the scope of this publication to present them all. Presented here are examples of a purified, a semi-purified, and three practical diets that can easily be adapted to feed a wide variety of fishes (Table 2). Purified and semi-purified diets are used primarily in experimental formulations to study the effects a nutrient, such as the amount or type of protein, may have on the health and growth of fish.

One simple formulation, which is used traditionally to feed ornamental fish in ponds, consists of a mixture of 30% ground and processed oats or wheat and 50% of fish meal or pellets from a commercial manufacturer. By weight, approximately 2%–3% of fish oil, and a 0.3% vitamin and a 1% mineral premix are added to the mixture. This mixture is blended with water and can be formed into dough balls of different sizes.

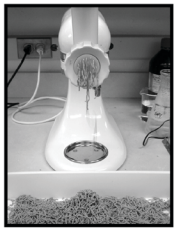
Following Table 2 are two sample fish feed recipes. These are:

1. A semi-purified diet, developed to determine the optimum protein level required by young ornamental African cichlid fish (Royes, unpublished Dissertation). This diet also can be used as a basis for feeding other types of ornamental fish in the laboratory. The cichlid feed recipe was derived principally from salmonid formulations and uses casein as the purified protein source. The ingredients in the recipe are listed under major nutrient categories such as proteins, carbohydrates, lipids, vitamins, and minerals. Pigments are added to enhance the coloration in these ornamental fish.

Semi-purified Feed Recipe for Juvenile Ornamental African Cichlid Fish

Ingredients
(for approximately 100 g of diet)

Proteins:
39.2 g Casein.
22.2 g Menhaden fish meal.
Carbohydrates:
11.7 g Wheat starch.
Non-nutritive binder:
3.0 g Carboxymethyl cellulose.
Non-nutritive bulk (or filler):
10.5 g Cellulose.
Vitamins:
0.4 g Stay-C.
0.8 g Choline chloride.
1.0 g Vitamin premix.
Minerals:
1.0 g Mineral premix.
Lipids:
2.5 g Menhaden fish oil.
2.5 g Soybean oil.
Pigments:
May add: *Spirulina* (0.5-1.0% of diet); or Astaxanthin (10-40 mg/100g of diet).



Extrusion of dough through meat grinder

Procedure
(mixing times will vary depending on the amount and type of ingredients)

1. Weigh all ingredients and set each aside in a separate container.
2. In a bowl, combine all protein, carbohydrate, non-nutritive binder and non-nutritive bulk ingredients. Mix together for 5 minutes.
3. Continue mixing, create a hole in the center of the mixture and add the Stay-C and vitamin premix separately.
4. Mix for a couple of minutes, then add the mineral premix in the same way.
5. In the least amount of distilled water, dissolve the choline chloride and add slowly to the mixture.
6. Total mixing time for all above dry ingredients should be about 10 minutes.
7. Add Lipids (oil) and mix for an additional 5 minutes.
8. Boil equal portions of water to ingredients. Add boiling water slowly to the mixture until a semi-moist (not wet) dough is formed. More water may be added until the correct consistency of the dough is achieved. Maintain water temperature around 70 to 90° C (158-194° F) to aid gelling while minimizing deterioration of proteins and vitamins (this will require some trial and error).
9. While hot, extrude dough through a pasta maker or meat grinder to form long spaghetti-like strands. Be sure to use the corresponding die size to make the appropriate pellet size for the fish that is to be fed.
10. Cut spaghetti into pellets of desired length and spread onto a cookie sheet.
11. Dry pellets in a kitchen oven at low heat (93° C or 200° F) for 30 minutes or air-dry in a forced air oven at 65° C (150° F) for 2-4 hours until approximately 10% moisture is achieved.
12. After the pellets have cooled, the feed can be double bagged using Zip-lock freezer bags, dated and stored in the refrigerator.

2. A gelatin-based diet, developed for difficult to feed fishes by the National Aquarium in Baltimore (from Francis-Floyd and Reed, 1994). In this diet, gelatin is the primary binder. This recipe can be modified and supplemented with a variety of ingredients. Supplemental or replacement ingredients are presented. Gelatin-based diets are popular in the aquarium fish industry and useful for preparing medicated feeds at home.

Gelatin-based Fish Feed Recipe

Ingredients (includes substitute ingredients)	*Procedure*
6 oz can of shrimp. May replace with canned sardines or clams, flakes or pellet feed, and beef heart.	1. Blend 5 oz of water with shrimp, spinach, carrots, baby cereal, brewer's yeast and vitamins.
2 oz frozen spinach. May use baby food, spinach or peas, or chopped kale.	2. Boil remaining 10 oz of water.
1 oz grated carrots. May replace with *spirulina*.	3. Add boiling water to gelatin in a bowl.
3 tbsp baby cereal (dry). May use rolled oats.	4. Cool gelatin mixture until warm (not cold).
2 tbsp Brewer's yeast. May use wheat gluten or wheat germ.	5. Add contents of blender to partially cooled gelatin mixture and mix thoroughly.
1 tsp liquid vitamins. May use ½ tablet multivitamin supplement.	6. If needed, add medication to cooled mixture.
5 mL cod liver oil. May supplement with Vitamin E (15 IU) as antioxidant.	7. Pour into flat pan or ice tray and refrigerate.
2 oz unflavored powdered gelatin.	8. Cut gelatinized mixture into cubes for feeding and store in a freezer.
15 oz water.	

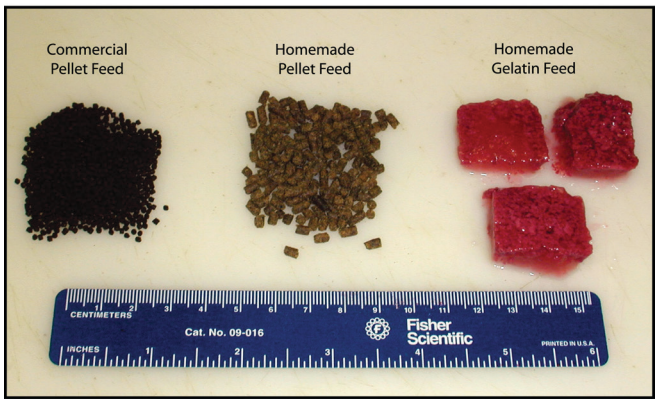


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Table 1. General amounts of nutrients incorporated into diets for growing fish.

Nutrients	Requirement (percent by dry diet)
Proteins (10 essential amino acids): lysine, phenylalanine, arginine, valine, leucine, isoleucine, methionine, threonine, tryptophan, and histidine	32–45%
Fat: Used as a source of energy and polyunsaturated fatty acids. In general, freshwater fish requite fatty acids of the linolenic (*w*-3) and linoleic (*w*-6) series. Saltwater and coldwater fish require EPA and DHA (*w*-3).	4–28% (should contain at least 1–2% of the *w*-6 or *w*-3 essential fatty acid series)
Carbohydrates: These are an inexpensive source of energy and is a binding agent. No essential requirements have been identified. These are poorly digested when fed raw. Highest digestibility is achieved when cooked. Major carbohydrates are starch, cellulose, and pectin.	10–30%
Minerals: Some 20 inorganic mineral elements, including calcium, phosphorous, magnesium, iron, copper, manganese, zinc, iodine, and selenium.	1.0–2.5% fed as a multi-mineral premix
Vitamins: These are inorganic substances required in trace amounts that can be divided into fat-soluble (vitamins A, D, E, and K) and water-soluble (vitamins C and the B-complex [thiamin, riboflavin, pyridoxine, pantothenic acid, cyanocobalamin, niacin, biotin, folic acid, choline, and myoinositol]).	1.0–2.5% fed primarily as a multi-vitamin premix. Vitamin C and choline are added separately from the premix because of their chemical instability.

Table 2. Ingredients[1] and their proportions (percent of dry weight) in five diet formulations. These formulations can be modified to feed fish in the laboratory or small farm. Modified from DeKoven et al.[2], 1992; Various sources[3, 4]; Meyers and Brand[5], 1975; Lovell[6], 1989.

Ingredients[1]	Purified[2]	Semi-purified[3]	Practical Diets		
			Basal[4]	Flake[5]	Dough[6]
Fish meal	–	25.0	23.0	34.0	65.0
Shrimp or krill meal	–	–	11.0	11.0	–
Soybean meal (48% protein)	–	–	25.0	5.0	5.0
Wheat middlings	–	–	10.0	–	–
Vitamin-free casein	31.0	40.0	–	–	–
Wheat gluten or starch gluten	15.0	12.8	–	20.0	–
Soybean lecithin	5.0	–	–	–	–
Dextrin	27.0	–	–	–	–
Egg white or albumen	4.0	–	–	–	–
Fish oil (cod or menhaden)	5.0	2.5	4.0	1.5	5.0–2.0 kg per 10 kg of mix
Corn or soybean oils	2.0	2.5	–	–	–
Pregelatinized potato starch	–	–	–	–	22.5
Corn	–	–	10.0	–	–
Beef heart meal	–	–	5.0	–	–
Liver meal	–	–	2.0	–	–
Rice bran	–	–	–	–	–
Yeast protein or extract	–	–	2.0	20.0	3.0
Vitamin premix	1.0	1.0	2.0	2.0	0.5
Stay-C (stabilized Vitamin C)	4.0	0.4	1.0	2.0	–
Mineral premix	3.0	1.0	1.0	–	2.0
Choline chloride	–	.08	–	–	–
Agar or Carrageen	–	–	3.0	3.5	–
Carboxymethyl cellulose	–	3.0	–	–	–
Non-nutritive bulk or cellulose	3.0	10.5	–	–	–
Spirulina or Astaxanthin	–	–	0.5–1.0	0.05	–
BHA	0.02	–	–	–	–
Water	–	–	–	–	8–10 kg per 10 kg of mix

[1] Ingredients can be obtained from a number of suppliers. The following list is not all inclusive and does not represent endorsement of a manufacturer or supplier.
- Fish meal and fish oils: Omega Protein, Inc.
- Fish hydrosylate: International Proteins Corp.
- Casein, soybean meal, wheat and corn starches, carboxymethyl cellulose, and choline chloride: ICN Biomedical, Inc.
- Soybean oil: Sigma-Aldrich Co.
- Mineral and Vitamin premixes: Ziegler Brothers, Inc.
- Astaxanthin, *Spirulina*: Cyanotech and F. Hoffmann-La Roche, Ltd.
- Stay C: Hoffman-La Roche, Ltd.