**Making homemade fish feed**

Fish feed is one of the most expensive inputs for a small-scale aquaponic unit. Feed is also one of the most important components of the whole aquaponic ecosystem because it sustains both the fish and vegetable growth. Therefore, it is necessary that farmers and practitioners understand its composition. Also, if commercial pelleted feed is not available, it is important to understand the methods to produce it on the farm. Moreover, homemade feed is useful when specific diets are needed to improve fish growth or aquaponic system performance.

**COMPOSITION OF FEED**

Fish feed consists of all the nutrients that are required for growth, energy and reproduction. Dietary requirements are identified for proteins, amino acids, carbohydrates, lipids, energy, minerals and vitamins (Table A5.1). A brief summary of major feed components, compositional tables and formulations is presented as a guide for the feed preparation process.

**Proteins**

Dietary proteins play a fundamental role for the growth and metabolism of animals. They are made of 20 different amino acids, reassembled in innumerable combinations to provide all the indispensable proteins for life and growth.

Only some amino acids can be synthesized by animals while others cannot; these must be supplied in the diet. For aquatic animals, there are 10 essential amino acids (EAAs): arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. Therefore, feed formulation must find an optimal balance of EAAs to meet the specific requirements of each fish species. Non-compliance with this requirement would prevent fish from synthesizing their own proteins, and also waste the amino acids that are present. The ideal feed formulation should thus take into account the EAA levels of each ingredient and match the quantities required by fish. Information on the level of EAAs (especially methionine, cysteine and lysine) is available in any feed ingredients datasheet (see Further Reading).

Recommended protein intake of fish depends on the species and age. While for tilapia and herbivorous fish the optimal ranges are 28–35 percent, carnivorous species require 38–45 percent. Juvenile fish require higher-protein diets than adults owing to their intense body growth.

Besides any optimal amino acid content in the feed, it is worth stating the importance of an optimal dietary balance between proteins and energy (supplied by carbohydrates and lipids) to obtain the best growth performance and reduce costs and wastes from using proteins for energy. Although proteins can be used as a source of energy, they are much more expensive than carbohydrates and lipids, which are preferred.

In aquaponics, any increase in dietary proteins directly affects the amount of nitrogen in the water. This should be balanced either by an increase in plants grown in the system or the selection of vegetables with higher nitrogen demands.

In general, the total amount of crude protein (CP) or a specific EAA from a formulated feed can be simply obtained by multiplying the CP (or the percentage of the specific EAA being investigated) of each ingredient by the percentage of its inclusion, and by finally summing all the subtotals obtained. For example, a diet with 60 percent

of soybean with 44 percent CP and 40 percent of wheat grain with 18.8 percent CP would be equal to **→** (0.6 × 44) + (0.4 × 18.8) = 26.4 + 7.52 = 33.9 percent CP. If the CP obtained by the calculation (or the amount of the specific EAA) meets the CP requirements of the fish (or the specific EAA percent) the diet is considered optimal.

The identification of the cheapest protein sources can be made by simply dividing the cost of each ingredient by the percentage of its crude protein. The results will give the cost of a unit of protein (1 percent) and can help find the most cost-effective feed formula.

**Carbohydrates**

Carbohydrates are the most important and cheapest energy source for animals. They are mainly composed of simple sugars and starch, while other complex structures such as cellulose and hemicellulose are not digestible by fish. In general, the maximum tolerated amount of carbohydrates should be included in the diet in order to lower the feed costs. Omnivorous and warm-water fish can easily digest quantities up to 40 percent, but the percentage falls to about 25 percent in carnivorous and cold-water fish. Carbohydrates are also used as a binding agent to ensure the feed pellet keeps its structure in water. In general, one of the most used products in extruded or pelleted feed is starch (from potato, corn, cassava or gluten wheat), which undergoes a gelatinization process at 60–85 °C that prevents pellets from easily dissolving in water.

**Lipids**

Lipids provide energy and essential fatty acids (EFAs) indispensable for the growth and other biological functions of fish. Fats also play the important role in absorbing fat-soluble vitamins and securing the production of hormones. Fish, as other animals, cannot synthesize EFAs, which have to be supplied with the diet according to the species’ needs. Deficiency in the supplement of fatty acids results in reduced growth and limited reproductive efficiency.

In general, freshwater fish require a combination of both omega-3 and omega-6 fatty acids, whereas marine fish need mainly omega-3. Tilapias mostly require omega-6 in order to secure optimal growth and high feed conversion efficiency. Most diets are comprised of 5–10 percent lipids, although this percentage can be higher for some marine species. Lipid inclusion in the feed needs to follow optimal protein/energy ratios to secure good growth, to avoid misuse of protein for energy purposes (lack of fat/carbohydrates for energy purposes) and to avoid fat accumulation in the body (diet too rich in lipids).

**Energy**

Energy is mainly obtained by the oxidation of carbohydrates, lipids and, to a certain extent, proteins. The energy requirements of fish are much lower than warm-blooded animals owing to the reduced needs to heat the body and to perform metabolic activities. However, each species requires an optimum amount of protein and energy to secure best growth conditions and to prevent animals from using expensive protein for energy. It is thus important that feed ingredients be carefully selected to meet the desired level of digestible energy (DE) required by each aquatic species. A brief reference on optimal protein and energy balance in most common fish for aquaponics is provided below (Table A5.1). Information on the level of DE is available in any feed ingredients datasheets (see the fish feed section in the Further Reading).

In general, the value of DE from a formulated feed can be simply obtained by multiplying the DE of each ingredient by the percentage of its inclusion and by summing all the subtotals obtained (e.g. a diet with 60 percent of soybean with DE 2 888 kcal/kg and 40 percent of wheat grain with DE 2 930 kcal/kg would be equal to

**→** [0.6 × 2 888] + [0.4 × 2 930] = 1 732 + 1 172 = 2 904 kcal/kg). If the energy obtained

by the calculation meets the energy (and protein) requirements of the fish cultured, the diet is optimal.

TABLE A5.1

**Optimal protein, energy, DP/DE ratio and essential amino acid requirements of selected fish species**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Species** | **Digestible protein (DP)** | **Digestible energy (DE)** | **DP/DE** | **Arginine** | **Histidine** | **Isoleucine** | **Leucine** | **Lysine** | **Methionine** | **Phenylalanine** | **Threonine** | **Tryptophan** | **Valine** |
|  | **(%)** | **(kcal/kg)** | **(mg/kcal)** | **(% of dry diet)** | | | | | | | | | |
| Nile tilapia | 30 | 2 900 | 103 | 1.2 | 0.5 | 0.9 | 0.9 | 1.4 | 0.7 | 1.0 | 1.0 | 0.3 | 0.8 |
| Common carp | 32 | 2 900 | 108 | 1.5 | 0.8 | 0.9 | 1.3 | 2.2 | 1.2 | 2.5 | 1.5 | 0.3 | 1.4 |
| Rainbow trout | 42 | 4 100 | 105 | 1.6 | – | – | – | 1.9 | 1.0 | – | – | 0.3 | – |
| Channel catfish | 27 | 3 100 | 86 | 1.0 | 0.4 | 0.6 | 0.8 | 1.2 | 0.6 | 1.2 | 0.5 | 0.1 | 0.7 |

*Source:* modified from NRC (1993).

**Vitamins and minerals**

Vitamins are organic compounds necessary to sustain growth and to perform all the physiological processes needed to support life. Vitamins must be supplied with the diet because animals do not produce them. Vitamin deficiencies are most likely to occur in intensively cultured cages and tank systems, where animals cannot rely on natural food. Degenerative syndromes are often ascribed to an insufficient supply of these vitamins and minerals.

Minerals are important elements in animal life. They support skeletal growth, and are also involved in osmotic balance, energy transport, neural and endocrinal system functioning. They are the core part of many enzymes as well as blood cells. Fish require seven main minerals (calcium, phosphorus, potassium, sodium, chlorine, magnesium and sulphur) and 15 other trace minerals. These can be supplied by diet, but can also be directly absorbed from the water through the skin and gills. Supplementing of vitamins and minerals can be done according to the requirements of each species (Table A5.2).

TABLE A5.2

**Common feed ingredient sources of the most important nutrient components**

|  |  |
| --- | --- |
| **Nutrient components** | **Feed ingredient sources** |
| Protein | Plant-based sources: algae, yeast, soybean meal, cottonseed meal, peanuts, sunflower, rapeseed/canola, other oil-seed cakes.  Animal-based sources: fishery by-products (fishmeal or offal), poultry by-products (poultry meal or offal), meat meal, meat and bone meal, blood meal. |
| Carbohydrates | Wheat flour, wheat bran, corn flour, corn bran, rice bran, potato starch, cassava root meal. |
| Lipids | Fish oil, vegetable oil (soybean, canola, sunflower), processed animal fat. |
| Vitamins | Vitamin premix, yeast, legumes, liver, milk, bran, wheat germ, fish and vegetable oil. |
| Minerals | Mineral premix, crushed bone. |

**ON-FARM FEED PRODUCTION**

The production of feed requires a fine balance of all of the nutrient components mentioned above (protein, lipids, carbohydrates, vitamins, minerals and total energy). An unbalanced feed will cause reduced growth, nutritional disorders, illness and, eventually, higher production costs.

Fishmeal is regarded as the best protein source for aquatic animals because of its very high protein content and it has balanced EAAs. However, it is an increasingly expensive ingredient, with concerns regarding sustainability. Moreover, fishmeal is not always available. Proteins of plant origin can adequately replace fishmeal; however, they should undergo physical (de-hulling, grinding) and thermal processes to improve their digestibility. Plant ingredients are, in fact, high in antinutritional factors that interfere with the digestion and the assimilation of nutrients by the animals, which eventually results in poor fish growth and performance.

The size of the pellets should be about 20–30 percent of the fish’s mouth in order to facilitate ingestion and avoid any loss. If the pellets are too small, fish exert more energy to consume them; if too large, the fish will be unable to eat. A recommended pellet size for fish below 50 g is 2 mm, while 4 mm is ideal for pre-adults of more than 50 g.

The use of any raw ingredient of animal origin (fish offal, blood meal, insects, etc.) should be preventively heat treated to prevent any microbial contamination of the aquaponic system.

**HOMEMADE FISH FEED FORMULATIONS FOR OMNIVOROUS/HERBIVOROUS FISH**

Two simple recipes for a balanced fish feed containing 30 percent of CP are provided below. The first formulation is made with proteins of vegetable origin, mainly soybean meal. The second formulation is mainly made with fishmeal. The lists of the ingredients for each diet are expressed in weight (kilograms), enough to make 10 kg of feed, in Tables A5.3 and A5.4. A simple step-by-step guide on preparation of the pelleted feed is then provided. Extensive information on feed, nutrition and formulation can be found on the FAO website listed in the section on Further Reading of the publication.

TABLE A5.3

**List and relative amounts of ingredients for 10 kg of fish feed using vegetable-based protein, including proximate analysis**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Feed ingredients** | **Weight (kg)** | **Percentage of total feed (%)** | **Proximate analysis** | **%** |
| Corn meal | 1.0 | 10 | Dry matter | 91.2 |
| Wheat flour | 1.0 | 10 | Crude protein | 30.0 |
| Soybean meal | 6.7 | 67.2 | Crude fat | 14.2 |
| Soybean oil | 0.2 | 2 | Crude fibre | 4.8 |
| Wheat bran | 0.7 | 7.8 | Ash | 4.6 |
| Vitamin and mineral premix | 0.3 | 3 | Nitrogen-free extract (NFE) | 28.3 |
| **Total amount** | **10.0** | **100** | **–** | **–** |

TABLE A5.4

**List and relative amounts of ingredients for 10 kg of fish feed using animal-based protein, including proximate analysis**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Feed ingredients** | **Weight (kg)** | **Percentage of total (%)** | **Proximate analysis** | **%** |
| Corn meal | 1.0 | 10 | Dry matter | 90.9 |
| Wheat flour | 4.0 | 40 | Crude protein | 30.0 |
| Soybean meal | 1.5 | 15 | Crude fat | 10.5 |
| Soybean oil | 0.2 | 2 | Crude fibre | 2.1 |
| Fishmeal | 3.0 | 30 | Ash | 8.3 |
| Vitamin and mineral premix | 0.3 | 3 | Nitrogen-free extract (NFE) | 34.5 |
| **Total amount** | **10.0** | **100** | **–** | **–** |

**Step-by-step preparation of homemade fish feed**

1. Gather the utensils as outlined in Table A5.5.
2. Gather the ingredients shown in Table A5.3 or Table A5.4. Purchase previously dried and defatted soybean meal, corn meal and wheat flour. If these meals are unavailable, obtain whole soybeans, corn kernels, and wheat berries. These would need to be dried, de-hulled and ground. Moreover, whole soybeans need to be toasted at 120 °C for 1–2 minutes.
3. Weigh each ingredient following the quantities shown in the recipes above.
4. Add the dry ingredients (flours and meals) and mix thoroughly for 5–10 minutes until the mix becomes homogeneous.
5. Add the vitamin and mineral premix to the dry ingredients and mix thoroughly for another 5 minutes. Make sure that the vitamins and minerals are evenly distributed throughout the whole mixture.
6. Add the soybean oil and continue to mix for 3–5 minutes.
7. Add water to the mixture to obtain a soft, but not sticky, dough.
8. Steam-cook the dough to cause gelatinization.
9. Extrude the dough. First divide the dough into manageable pieces, and pass them through the meat mincer/pasta maker to obtain spaghetti-like strips. The mincer disc should be chosen according to the desired pellet size.
10. Dry the extruded dough by spreading the strips out on aluminium trays. If available, dry the feed strips in an electric oven at a temperature of 60–85 °C for 10–30 minutes to gelatinize starch. Check the strips regularly to avoid any burn.
11. Crumble the dry strips. Break or cut the feed on the tray with the fingers into smaller pieces. Try to make the pellets the same size. Avoid excessive pellet manipulation to prevent crumbling. Pellets can be sieved and separated in batches of homogeneous size with proper mesh sizes.
12. Store the feed. Place the fully-dried feed pellets into airtight plastic containers soon after they have been broken into pieces to prevent them absorbing humidity.

TABLE A5.5

**List of tools and materials needed for feed formulation**

|  |  |  |
| --- | --- | --- |
| **Component** | **Quantity** | **Specifications** |
| Weighing scale | 1 | Capacity 1–3 kg, divisions of 1 g |
| Grinder | 1 | Electric coffee-type grinder |
| Metal sieve | 1 | 0.2–0.4 cm mesh |
| Mixing bowl | 1 | Capacity 10 litres |
| Plastic bowl | 3 | Capacity 2 litres |
| Meat mincer / pasta maker | 1 | Manual or electric |
| Mixing spoon | 1 | Large size |
| Aluminium baking tray | 10 | 40 × 40 cm or other available sizes |

**STORING HOMEMADE FEED**

Once prepared, the best way to store fish feed is to put pellets into an airtight container soon after being dried and broken apart. Containers must be kept in a cool, dry, dark and ventilated place, away from pests. Keeping pellets at low levels of moisture (< 10 percent) prevents them becoming mouldy and developing toxic mycotoxins. Depending on the temperature, the pellets can be stored for as long as two months.

Another way to keep pellets for long periods is to close them in a plastic container and store them in the fridge, though this would require electricity. Feed can be kept in this way for more than one year.

Feed must be used on a “first in, first out” basis. Avoid using any feed showing signs of decay or mould, as this could be fatal for fish.

**SUPPLEMENTARY FEEDING WITH LIVE FEEDS**

Fish can be advantageously supplied with supplementary feeds that are locally available. The use of fresh feed would in fact provide animals with supplementary proteins for their growth. It can also provide vitamins or minerals that might be deficient in the pellets.

A wide range of live feeds is available – the choice depends on the fish cultured and local availability. However, it is very important to remember that any feed coming from external sources might bring micro-organisms or parasites if collected from outside waters (contaminated or polluted) or if from animal origin (e.g. worms from non-pasteurized animal manure). Live feeds can be produced at home level under safer standards or can be heat-treated before being given to fish.

Examples of live fish feed include:

* + Duckweed and aquatic macrophytes. Duckweed is quite rich in proteins and can be supplied raw for up to 10 percent of the daily ration. However, macrophytes are less digestible than formulated feed owing to their higher fibre content, which would also increase the amount of solids/wastes in the system.
  + Crop residues from aquaponics or other sources can be supplied to herbivorous/

omnivorous fish in small amounts.

* + &arthworms are readily obtainable from green compost piles, especially in rural areas. A starve period of 1–2 days is recommended if worms come from outside sources in order to reduce the risk of introducing bacteria into the system.
  + \*nsect larvae are very rich in proteins, but care should be taken not to use them in excessive quantities owing to their higher lipid content. Larvae can be cultured on rotten organic matter (vegetables, fruits); however, a starve period of 1–2 days is recommended if the substrate contains material of animal origin.
  + \*nsects can be given to omnivorous or carnivorous fish species, but the presence

of the exoskeleton of chitin reduces their digestibility.

* + Small fish, crustaceans and molluscs are available from streams or ponds. However,

prudence may be needed owing to the risks of contamination and parasites.

* + Algae can easily be supplied to herbivorous/omnivorous fish. Algae can be

cultivated in separate tanks beside the aquaponic system and harvested.