

# Processing of Feedstuffs and Aquafeeds

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## Introduction

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Feed manufacturing and quality control of the finished feed are important to successful aquaculture. The technology of feed processing has undergone considerable improvements through the years. Processing of feedstuffs and aquafeeds has progressed from simple mixing of several ingredients by hand to mechanical mixing, to continuous mixing, and recently to computer-controlled processing. In spite of this, the basic concept of mixing the ingredients together to obtain a nutritionally-balanced feed remains unchanged. In feed processing, several factors have to be considered.

The production of good quality feeds requires the use of ingredients of high quality. There is also a need to avoid the conditions that could cause deterioration of the feedstuffs from harvesting to processing and storage. Many feedstuffs contain antinutritional factors that prevent utilization of nutrients (particularly proteins) by fish and other cultured animals. For example, the seeds of many legumes contain substances that inactivate trypsin and chymotrypsin, the enzymes for protein digestion in animals. The nutritional quality of feedstuffs depends in part on the processing they undergo to remove the antinutritional factors. Some of these factors are easily destroyed by heat while others are resistant to heat.

Growth and productivity of the aquatic animals greatly rely on the quality of feed given to them. Feeds represent a major portion of total costs in animal production. Thus, processing of feed ingredients, feed preparation, and storage are major considerations in making feeds. However, proper methods applied during processing and preparation will be useless if the end product is not carefully handled and properly stored.

In feed preparation, the main objective is not just to mix whatever ingredients are available but to prepare the feed using properly processed ingredients. Oftentimes, before these raw materials can be used, they have to be processed to remove substances that may prevent their proper utilization by the fish. The feed preparation process is more concerned with the physical conversion of a given formulation into compounded, nutritionally-effective diet. Feed storage must also be given equal importance as in feed preparation and processing because it affects the shelf-life of the finished product.

This chapter will help the reader understand and appreciate the basic principles of processing, preparation, storage, and quality control in the preparation of aquafeeds. The material in this section is presented in sequence beginning with the processing of basic ingredients to remove antinutritional factors, followed by steps in feed preparation, from the easiest to the more complex processes, and storage. This chapter presents methods and equipment that are useful not only for feed millers, but also for extension workers and fish farmers.

### Feedstuff Processing

Feedstuff processing refers to all operations necessary to obtain the highest nutritional value of a feedstuff and the best economic returns from their use. There are various ways of processing raw materials that can destroy some antinutritional factors present in feedstuffs. They are soaking, heating, chemical treatment such as extraction with organic solvent, and dehulling. The kind of treatment will depend on the substances present in the feed ingredient. Table 5.1 lists some antinutritional substances and their removal or inactivation.

Some are natural component of feedstuffs such as gossypol in cotton seed and thiaminase in raw fish. Others may originate from natural contamination of the raw materials such as aflatoxins produced by the mold *Aspergillus flavus*, or man-made contaminants such as polychlorinated biphenyls (PCBs), pesticides, herbicides, and hydrocarbons.

**Table 5.1 Various antinutritional substances in some feedstuffs and their removal or inactivation**

Substances	Adverse actions	Occurrence	Removal or remedy
<b>Heat Labile substances</b>			
Trypsin inhibitor	Binds trypsin to form an inactive compound	Soybean and other legumes	Dry heating at 175-195°C, or cooking for 10 min.
Lectins	Destroy the red blood cells	Soybean and other legumes	Boiling in water or autoclaving for 30 min.
Goitrogens	Inhibit the uptake of iodine by the thyroid gland	Soybean and other legumes	Steam and/or autoclave for 10 to 30 min
Anti-vitamin D	Binds Vit. D, making it unavailable	Soybean and other legumes	Autoclaving or boiling for 30 min.
Anti-vitamin E	Contributes to Vit. E deficiency	Soybean and other legumes	Autoclaving
Thiaminase	Promotes destruction of thiamin (Vit. B <sub>1</sub> )	Raw and spoiled fish, mussels, clams, and soybean	Autoclaving, heating, and cooking
<b>Heat resistant substances</b>			
Estrogens (isoflavones)	Interfere with reproductive performance	Plant glycosides	Solvent extraction
Gossypol	Binds phosphorus and some proteins	Cottonseed meal	Addition of iron salts or phytase
Tannin	Binds protein and inhibit trypsin digestion	Beans and other legumes	Dehulling
Cyanogens	Release poisonous hydrocyanic acid	Cassava leaves	Soaking in water for 12 h
Mimosine	Interferes with enzyme synthesis in the liver; destroys hepato-pancreatic cells of shrimps	Ipil-ipil leaves	Soaking leaves in water for 24 h
Peroxides	Bind proteins and vitamins	Poorly stored and unprotected oils	Proper storage
Phytates	Bind proteins and minerals and reduces their availability	Cottonseed meal, cereal hulls soybean, and other legumes	Dehulling

Feedstuffs are processed to:

- remove antinutritional factors and toxins
- increase palatability, digestibility, and nutrient availability
- adjust feed particle size to suit a given species and size
- reduce feed wastage
- maximize profit through optimum processing of feeds
- lower the moisture content of feedstuff to 10% or less

### Different methods of feedstuff processing

#### Soaking

Some feedstuffs have to be soaked in water for 6-24 h at room temperature. Soaking is sometimes done with heat to soften the grains that swell during the process and facilitate removal of some toxins (antinutritional factors) in some feed ingredients such as ipil-ipil *Leucaena leucocephala* leaf meal, cassava leaf meal, etc. Soaking *Leucaena* leaves which are rich in protein and some minerals releases mimosine, a non-protein amino acid that is stable to heat. Mimosine interferes with enzyme production and destroys the hepatopancreas of shrimps and liver of fish. Soaking the *Leucaena* leaves for 24 h reduces the mimosine content to an acceptable level. Incorporation of *Leucaena* leaf meal in shrimp feed should not be more than 5% to avoid toxicity. Untreated cassava leaf meal contains poisonous hydrocyanic acid. Cassava leaf meal when soaked for 6-12 h or blanched with boiling water releases its cyanogens and produces a safe cassava leaf meal.



Ipil-ipil leaf

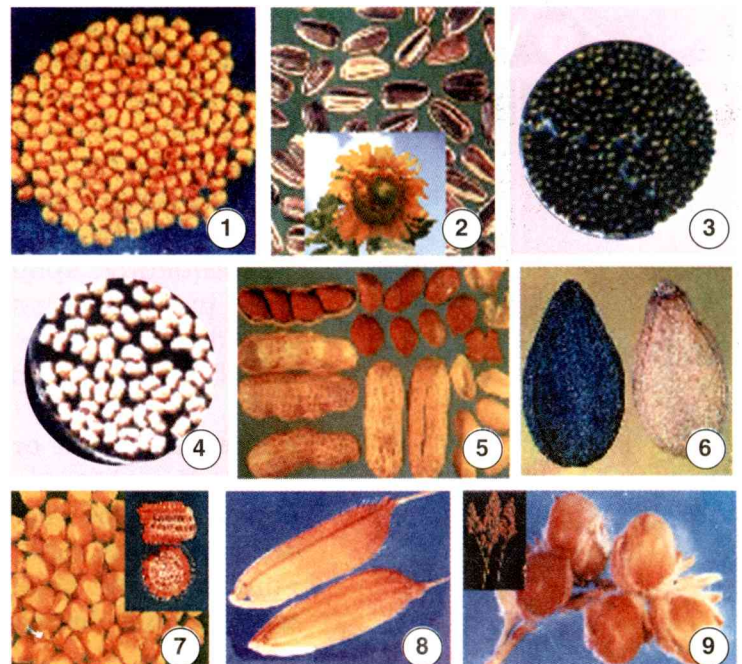


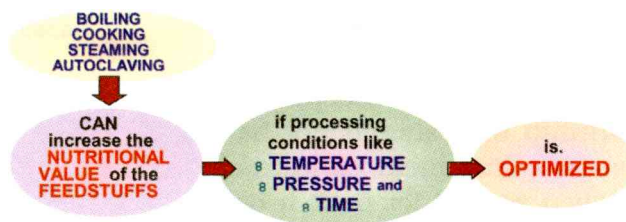
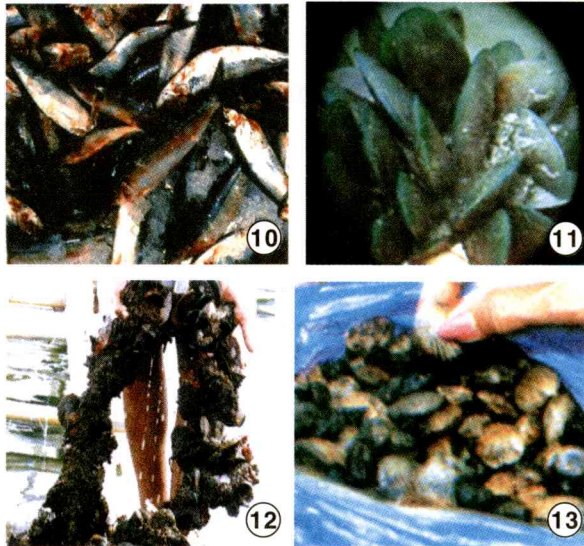
Cassava leaf

#### Heating and Cooking

Heat treatment is applied to dry feedstuffs to inactivate some antinutritional factors and increase utilization of nutrients. These antinutritional factors present in raw soybeans and other legumes can markedly affect the intestinal tract of the animals and prevent digestion and utilization of many nutrients particularly proteins and vitamins. The time and temperature of heating a feedstuff is of great importance in obtaining a good quality feed. In moist heat treatment, the sample is boiled for 30 min at 100°C, pressure cooked for 10 min at 120°C, or steamed for 30 min. In dry heat treatment, the sample is sun-dried for 6-12 h, oven-dried for 12 h at 60°C, or roasted for 2-5 min at 250°C

Soybean ① is a very good source of protein but it contains an antinutritive factor called trypsin inhibitor. Trypsin, an enzyme that digests protein is destroyed by the trypsin inhibitor in raw soybean meal. Sunflower meal ② is also a potential protein source but contains protease inhibitor that is destroyed by heat. Legumes, like mung beans ③, and cowpea ④, peanuts ⑤ and sesame seeds ⑥, and cereals such as corn kernel ⑦, rice grains ⑧, and sorghum ⑨ are potential ingredients but may contain non-



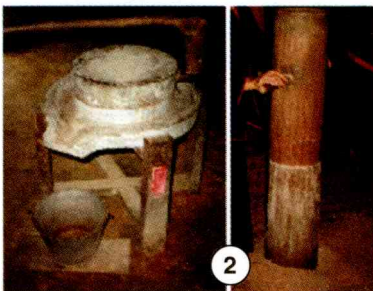


nutritive components if not properly processed.

Protease or trypsin inhibitors bind trypsin to form an inactive compound. Soaking and dry heating at 175-195°C for 15 min or pressure cooking for 10 min at 120°C inactivates these inhibitors. Lectins in raw soybean meals are destroyed or inactivated by boiling in water or autoclaving for 10 minutes at 120°C resulting in a digestible soybean meal. There are anti-vitamin D and E substances in raw soybeans that bind these vitamins. Autoclaving or boiling for 10 to 30 minutes destroys these factors making the vitamins available to fish.

Thiaminase, an enzyme in raw and spoiled fish ⑩, mussels ⑪, oysters ⑫, and clams ⑬ destroys the vitamin, thiamin and is inactivated by boiling in water or autoclaving for 30 minutes. This method makes raw and spoiled fish, mussels, and clams safe for use.

Moist heat is more effective than dry heat for legume seeds. Moist heat treatment also improves the digestibility and nutritional values of grains. It is also used to extract oil from oilseeds. Likewise, dry heat treatment increases the nutritional value of feedstuff but such treatment makes handling and pelleting easier than in the moist treatment



### Dehulling

Tannins are found mostly in seed coats or hulls of colored beans ①. Tannins and phytates bind proteins, minerals, and vitamins thus reducing the availability of these nutrients. Dehulling removes most of the tannins by splitting or peeling the soft seed coat using a dehuller to separate the hulls ②. This method is done by use of a splitting machine or by soaking 1 part of the seeds by volume in 3 parts of water for 4 to 6 h, followed by sundrying for 12 h or oven drying at 80°C for 12 h. Subsequently, splitting is done by using an ordinary corn mill or by hand pressing. Another way is by soaking the seeds in water or 12 to 48 h and allowing them to germinate. The germinated seeds are then dehulled and sundried.

### Extraction with organic solvent and chemical treatment

Organic solvents are also used to remove the antinutritional components of various feedstuffs. Extraction of lipid from leguminous seeds such as rape seed ①, and black beans ② with alcohol and water eliminates the beany flavor. Extraction of oil from cottonseed meal ③ with hexane decreases the toxin gossypol.



## Feed preparation techniques

To achieve good feed characteristics, feed must be prepared by the following procedures:

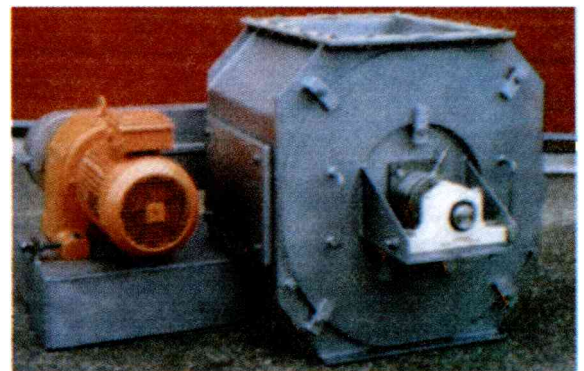
1. **Grinding** increases the surface area of ingredients. This improves mixing, digestibility, pelletability, and water stability of feedstuffs. The grinding equipment varies with the nature and texture of materials and the desired particle size. Feed components normally come in different particulate sizes and should be uniformly ground. Materials with a wide range of particle sizes do not mix well and produce structurally weak pellets.

There are a number of grinding equipment used for size reduction of feedstuffs. The hammer mill is a commonly used machine. Basically, hammer mills are impact disintegration machines composed of a high speed rotating shaft with free swinging hammers. The size of the ground material is controlled by the size of the screens or metal bars mounted on the exit opening usually found at the bottom of the machine. Other grinding machines that can be used for grinding and size reduction of feed components are:

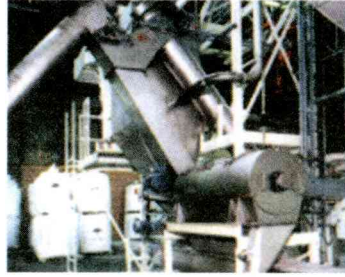
- a. **Swing type hammer mill** - an impact grinder with swinging or stationary steel bars forcing ingredients against a circular screen or solid serrated section designated as a striking plate. Materials are held in the grinding chamber until they are reduced to the size of the screen openings. This type of hammer mill efficiently grinds dry and low-fat ingredients.
- b. **Attrition mill** - grinding principle is through shattering by impact. However, it also imparts a shearing and cutting action. Grinding is accomplished between two discs equipped with replaceable wearing surfaces. This type of grinder is used for blending and smoothing out ingredients or a mixture (containing liquid) that have clumps.
- c. **Roller mill** - combine cutting, attrition, and crushing processes. It has smooth or corrugated rollers set at a pre-determined distance apart rotating at the same speed and with the material passing between the rollers. An additional tearing action may be provided by the bottom roll lateral corrugations or by operating the rolls at different speeds.



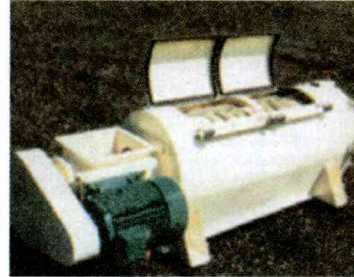
Hammer or grinder shattering



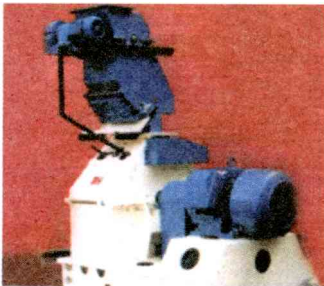
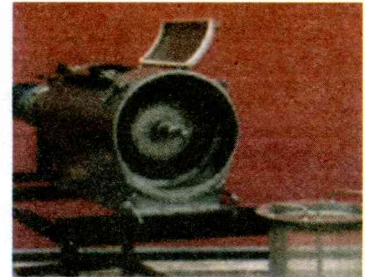
Swing type hammer mill



Attrition mill



Roller mill



Cutter mill



Sieving

**d. Cutters** - reduce dry particle solids mainly by shearing with knife edges against a striking plate. The mill consists of a rotating shaft with four parallel knives attached and a screen occupying one fourth of the 360° rotation. The mill is best suited for cracking whole grains with a minimum amount of fines. Cutters should not be used as a final process for reducing the size of ingredients used in aquafeeds.

**2. Size grading or sieving** screens ground materials to obtain a specific particle size of the feedstuffs. The size of the screen opening will determine the largest particle size that will pass through the screen which is usually expressed in mesh number. A No.40 mesh sieve (425 microns) is often used. Vibrating screens operate with high frequency and low amplitude. Some machines built with gas or airtight casings and suction fans are used for screening dusty materials like rice bran. Coarse materials (big particles) that do not pass thru the sieve are returned to the grinder and reground until all materials pass through the sieve.

**3. Weighing** of all ingredients. Weighing is a very important step in feed preparation. The feed components as prescribed in the feed formulation must be accurately weighed. An accurate balance with a taring device is best because it can be adjusted to zero and allows weighing with the container. The type of weighing machines depends on the amount and kind of feed ingredients to be weighed.

**4. Mixing** of weighed ingredients. Mixing is the process of scattering dissimilar parts into a blend. Feed ingredients are sequentially added and mixed for at least 5 min to produce a well blended mixture. Mixing of the feed components to form the meal are done in batches. There are

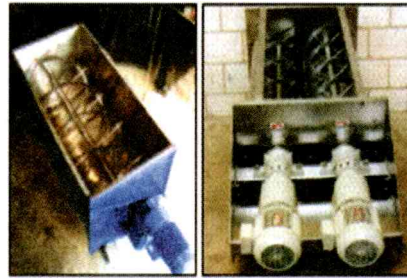
two mixing operations involved in the process: premixing of micronutrients, and blending of the bulk diet components. Feed components are sequentially added a little at a time or by batch. The three basic mechanisms in mixing are: transfer of adjacent particles from one location in the mass to another, distribution of particles over a freshly developed surface, and slipping of particles in the mass.



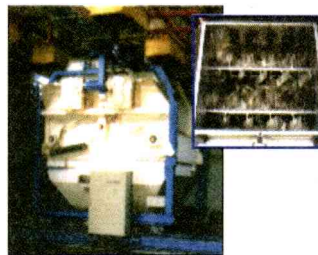
Weighing of feed ingredients

There are three general types of mixers used in the feed milling industry:

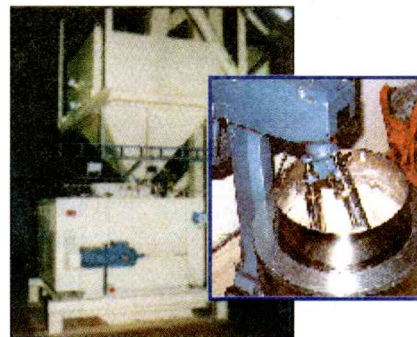
- ❑ **Horizontal ribbon type mixers** (batch and continuous). Normally, mixing is done through a horizontal ribbon type mixer when mixing ingredients of different particle size with some liquid. The design and configuration of the mixing ribbon in relation to the kind of material being mixed is essential.
- ❑ **Vertical boot loading mixer.** Mixers should be constructed for easy loading, meal discharge as well as cleaning of the mixer unit after every mixing operation. Residual meal can cause quality problems in the next batch or load.
- ❑ **Oscillating screw mixer.** Mixing, particularly when working with dry powders in the absence of dosing liquids, can cause fine feed particles to escape from the mixer unless proper covers are provided for in the mixing vessel. The power and speed of the mixer drives should be designed to meet the needs of the mixer when loaded at a maximum material density.



Horizontal mixer

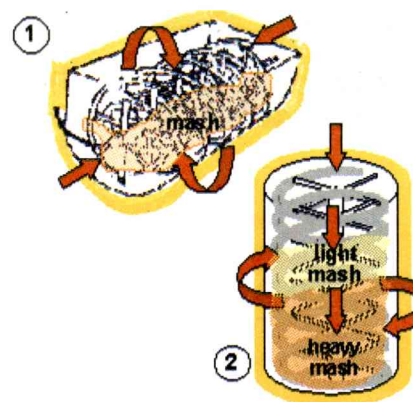


Vertical mixer

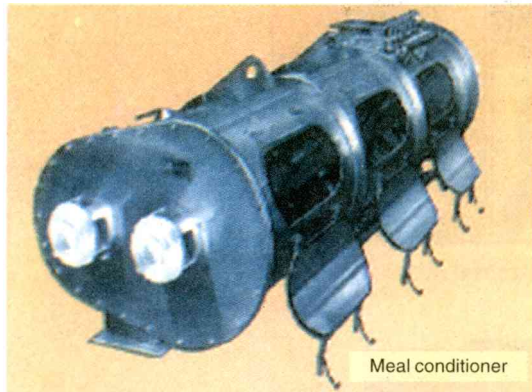


Oscillating screw mixer

Horizontal mixers ① are preferred in the industry because handling and mixing of bulk and high density materials are efficiently achieved. In vertical mixers ② high density ingredients tend to settle at the bottom leaving light weight (powdery) ingredients to escape during mixing. After the feed ingredients are mixed, the meal requires conditioning before pelletizing.



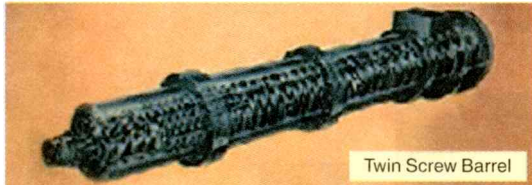
**5. Conditioning** is the process of adding liquids to the meal, kneading of the meal and steaming to allow some of the starch and other binders to gelatinize. The meal is usually steamed at a pressure of about 10 to 25 pounds/inch<sup>2</sup> (psi) with enough time (approximately 1-2 min) allowing a starchy material to form a gel. Control of steam temperature and pressure is very essential in order not to affect some of the heat-sensitive ingredients.



Meal conditioner



Single Screw Barrel



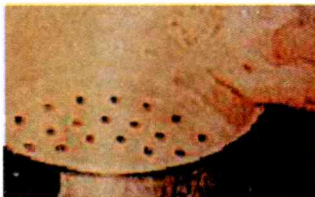
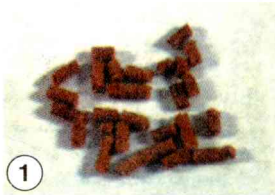
Twin Screw Barrel

Normally, pelleting machines are provided with the necessary source of steam, metering and dosing pump for the liquid additives, and a variable speed drive. The speed drive allows for the adjustment of the meal conditioning time to obtain optimum pellet quality. In conventional conditioning, about 30-35% of starch is gelatinized. However, the amount of starch and type of ingredients used may not be sufficient to produce a water stable pellet. Therefore, for pelleted shrimp feed it is recommended that at least 50% of the starch should be gelatinized. This is done by increasing the steam pressure to 28 psi.

Most pellet mills are equipped with one to three direct steam conditioner barrels where steam can be injected into the mash or into the conditioner jackets to partially gelatinize starch or diet binders (see Chapter 4). Increasing the retention time or using multiple conditioners and control of steam pressure can increase starch gelatinization. The feed mixture in the third conditioner reaches a temperature higher than 90°C before entering the pellet die. Steaming improves the water stability and digestibility of the feed and kills most harmful bacteria. In small-scale feed preparation, steaming is necessary for shrimp feeds but may not be necessary for fish diets. Steamed pellets are stable in water for 4-12 h depending on the effectiveness of the binder. Unsteamed pellets ① break up within 30 min ②.



①



②



**6. Pelleting and Extrusion.** Pelleting involves forcing the mixture through holes of a metal die plate to transform a soft feed into a hard pellet. The process is accomplished by compression, extrusion, and adhesion. The primary objective of pelleting is to compact the feed from the mixed powder form or meal. For shrimp feed, pelleting prevents the feed from immediate dispersion in the pond water which results in feed loss and water pollution. The loss of not more than 10% of the pellet weight after a 10 min immersion in water is considered acceptable.

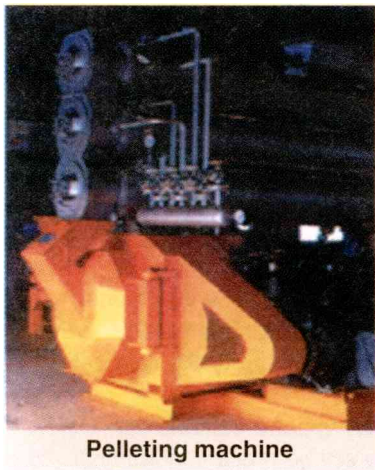


The more common types of pelleting machines are:

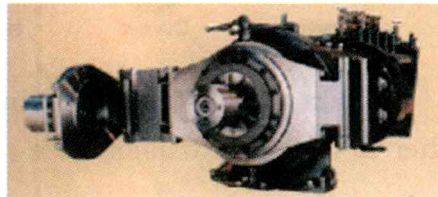
- ❑ Ring die pellet mill ①
- ❑ Dimpled rolls pelletizer
- ❑ Flat die pellet mill ②
- ❑ Screw type pellet extruder press
- ❑ Scheuler type pellet

The ring and flat die pellet mills are generally employed in aquaculture feed mills. Both are capable of producing fairly small pellets suitable for aquatic feeds.

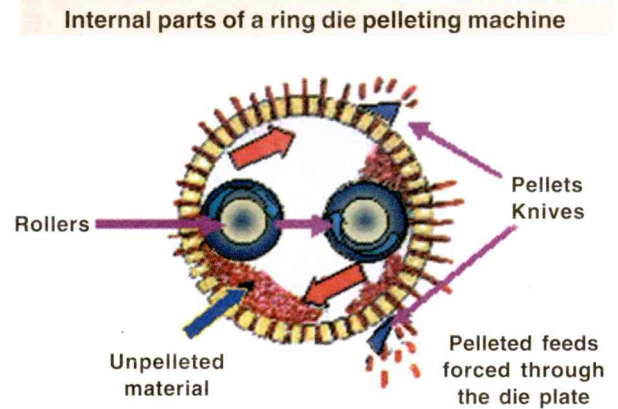
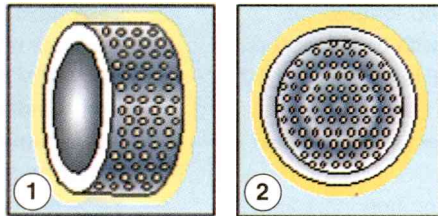
In the extrusion process the meal is heated, kneaded, and mixed. A pressure is increased to 20 to 70 bars depending on the product formulation. The sudden pressure drop at the outlet of the die results in material expansion. The length of the die channel plus the number of



Pelleting machine



Pelleting machine drum with built-in rollers

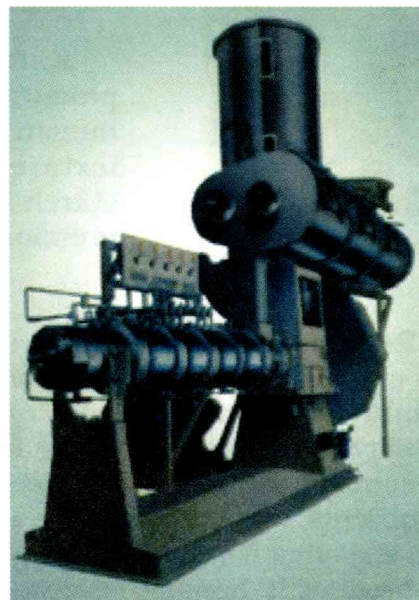


dies greatly influence the outcome of the final product. Unlike a pellet mill, the extruder can shape the material in almost any form.

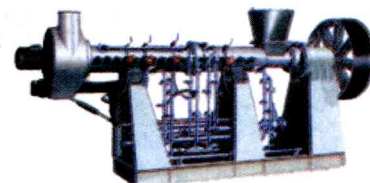
The two types of extrusion are:

**Dry extrusion** - the meal is extruded with water only. Usually the pellets are of burned taste and low bulk density. About 30-35% of the vitamins are damaged. The final product need not be dried but cooling is necessary.

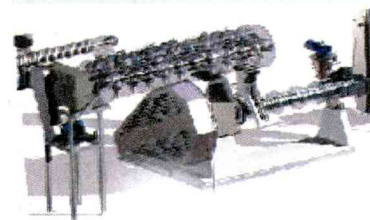
**Wet extrusion** - the meal is extruded with steam and cooked at lower temperature than in dry extrusion. Vitamin losses are only about 10%.



Extrusion machine

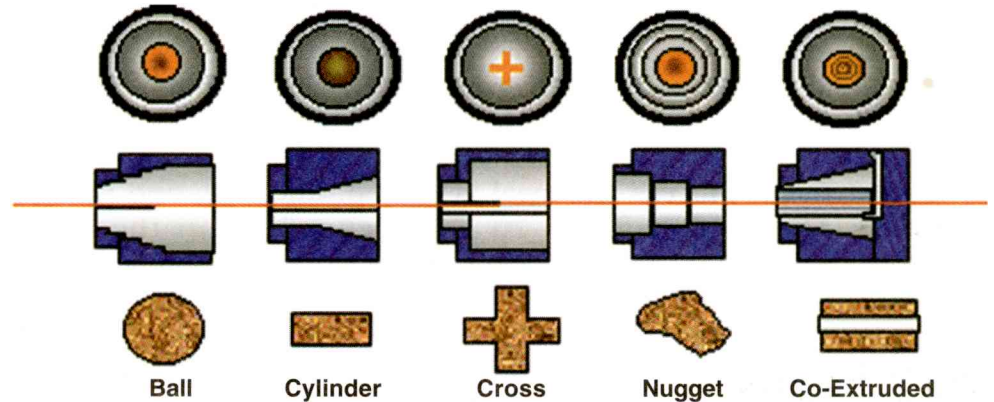


Expansion pellet mill



Internal parts of an extruder

The product is paste-like before it enters the die plate. Some of the possible shapes are:



### Extrusion vs Pelleting

The decision whether to use an extrusion or a pelleting machine depends on many factors.

Extrusion	Pelleting
1. Highly flexible in feed formulation.	1. Less flexible to feed formulation.
2. Can process meal with 55% moisture.	2. Moisture content up to 17% maximum.
3. Cooking of the meal is achieved at 90% or higher.	3. Cooking of the meal is achieved at 50% only.
4. Can handle fat levels up to 22% lipid in the formulation.	4. Can handle fat levels up to 8% lipid only in the formulation.
5. Can bind coarsely ground ingredients.	5. Requires finely ground ingredients.
6. Bacteria are eliminated in the process.	6. Bacteria may still be present in the final product.
7. High product durability and water stability.	7. Low product durability.
8. Higher acceptability of finished product.	8. Product are reworked through system to reduce fines.
9. Produces versatile (floating, sinking and slow sinking) feeds.	9. Produces only sinking feeds.
10. Higher capital and production costs.	10. Lower capital and production cost.



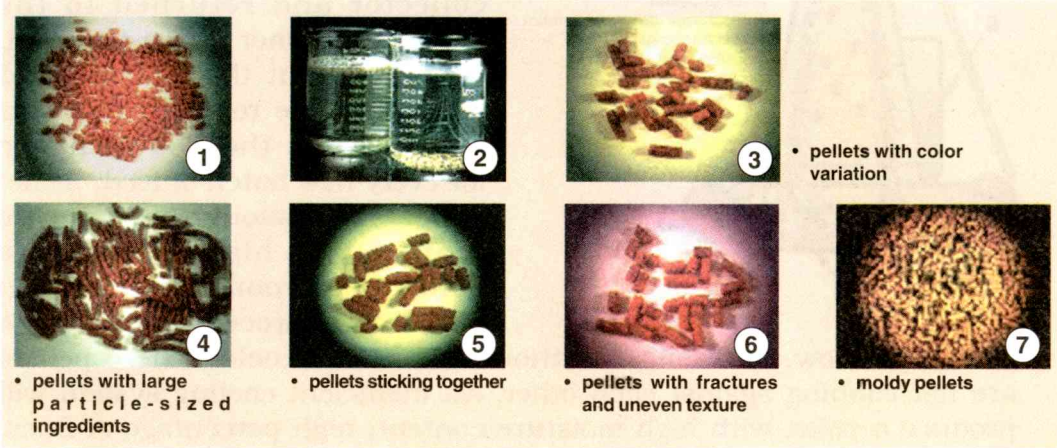
Extrusion is more efficient in producing varied forms of aquafeeds ①, human (breakfast cereals, snack foods, textured vegetable proteins (TVP) and starch-based industrial products) and premium pet foods ②.

### Benefits of Pelleted Feeds

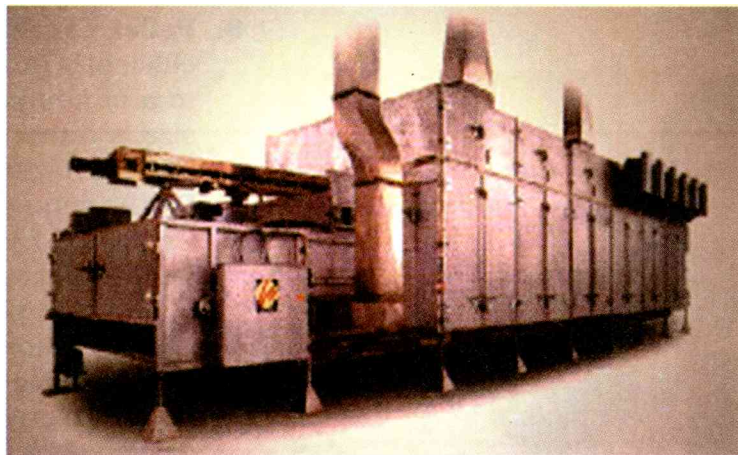
- Feeds are more stable and can be stored for at most three months with minimal nutrient degradation.
- Pellet stability is maintained during feeding.
- Feed consumption is increased thereby reducing the leaching of water-soluble nutrients.
- Salmonella* and other harmful and disease causing organisms are destroyed.
- Finished product is handled easily.

**Physical characteristics of a good pellet**

The ideal pellet is smooth, has uniform length and size ①, water stable ②, without color ③ and size variation ④ within a batch, does not clump ⑤, without fractures ⑥, and not wet and moldy ⑦.

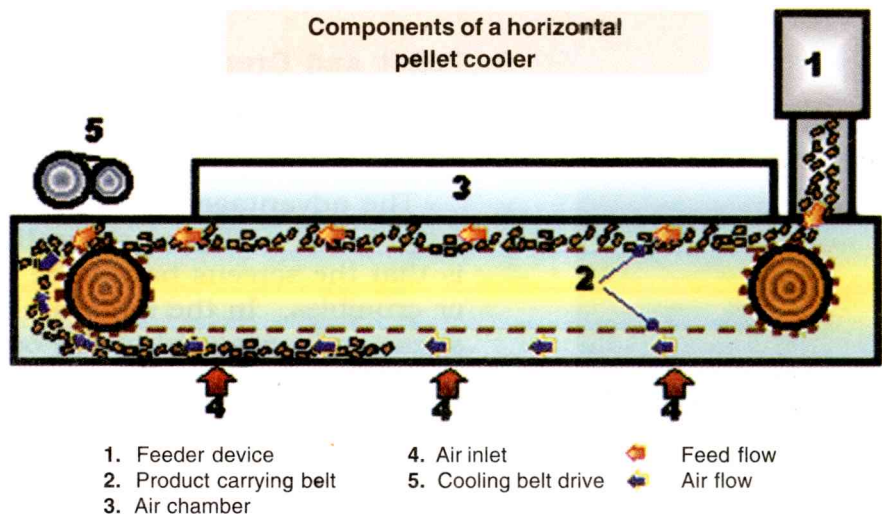


**7. Pellet Cooling and Drying.** The pellets leaving the die are still hot and must be cooled to allow the binders to set and harden. The cooling process is accomplished by blowing cool air in a counter current direction allowing the binder to set as the pellets are cooled. The vertical or horizontal type pellet coolers are commonly used.



Horizontal cooler

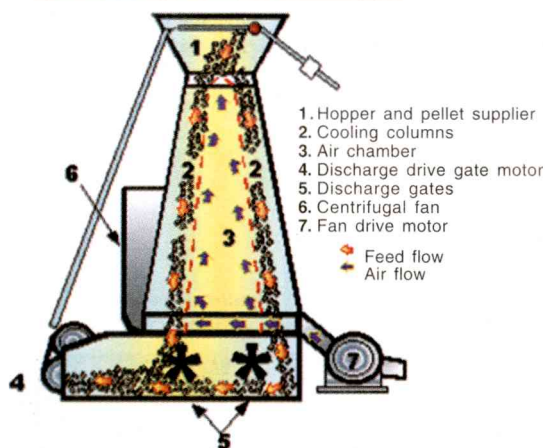
Horizontal cooler uses a number of horizontal moving perforated trays with the hot pellets moving countercurrent to the cooling air. One disadvantage of a horizontal pellet cooler is that it occupies a larger floor area than a vertical cooler of similar size. Of the two pellet coolers, the vertical type is commonly used for small capacity feed plants together with the pellet crumbler, installed at the lower exit end of the pellet cooler. A cyclone collector is also necessary to recover fine feed particles that may be carried



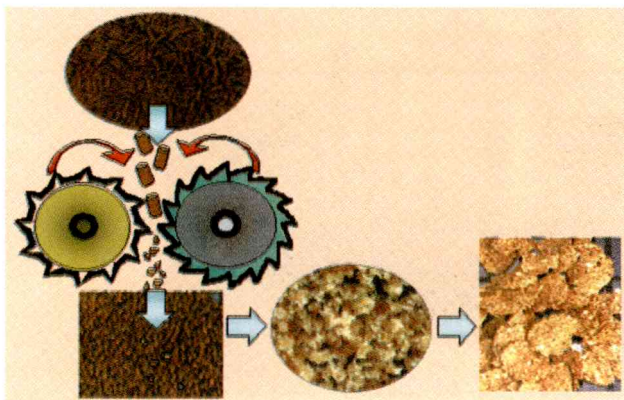


Vertical cooler

Components of a vertical pellet cooler



a high air flow, and long retention time in the cooler where pellets are not rubbing against each other. An inefficient cooling system will produce a pellet with high moisture content, high percentage of fines, and poor water stability.



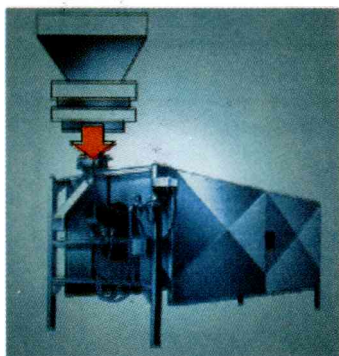
Breaking of cylinder pellets into crumbled feeds using rotating rollers

**8. Pellet Crumbler.** The size of the pellets that can be efficiently produced by a pelleting machine is limited to a minimum diameter of about 2.5 mm. This feed size is rather large for fry of up to 3 g size to handle. The most effective way to produce small size of feed for the young fry is to reduce the pellet by crumbling. Crumbled feeds are rhombic and irregular in shape because they are produced by breaking the cylindrical pellets.

The crumbler is composed of two closely spaced rotating steel rollers that crush the pellets as they pass through the rollers. Most crumblers are designed so that the surfaces of the two rollers run at slightly different speeds. This gives a shearing action on the pellets as they are crushed between the rollers to yield a 0.5 to 1.0 mm crumble size.

**9. Pellet and Crumbled Feed Cleaner.** Fines produced after pelleting must be removed by sifting or by using a fine separator in order to produce fine-free feeds. To separate fines from the pellets, multi-decked vibrating screens or rotary type sifters are used.

The advantages of the rotary sifter are its compact size, higher output, and effective separation of fines. However, the disadvantage is that the screens have to be changed for each desired size of pellets or crumbles. In the multi-decked vibrating screen a number of pellet sizes can be obtained in one operation due to the different sizes of the screens installed in the machine.



Sifter/ Fines separator

**10. Product Packaging and Storage.** Packaging and storage of a pelleted feed play very important roles in maintaining good feed quality. Feeds usually have a limited shelf life (3 - 4 months without antioxidants). Packaging materials such as porous sacks and loosely sewed openings can shorten shelf-life.

Freshness of the feed can be maintained when packed in bags made of laminated polypropylene (PLP) or paper bags with liners. The PLP is light, very strong, inexpensive, and provides good water proofing. Paper bags are prone to tearing during handling and are not recommended when transporting feeds to far places. Unlike feeds for livestock, aquafeeds are packed in smaller sizes of 5, 10, and 25 kilograms to avoid tearing of the bags.

Packing of pelleted feeds requires care and attention to prevent breaking of the pellets and production of fines. The very essential components of feeds such as vitamins, minerals, and lipids may be adversely affected by prolonged exposure to light, excessive moisture, poor ventilation or high temperature. In the farms, pellets are stored in tightly covered plastic buckets or jars after dispensing from feed bags.

The steps to be followed in large-scale, small-scale, and larval feed preparation and a guide to the type and kind of feed at various sizes and ages of aquatic animals are presented.

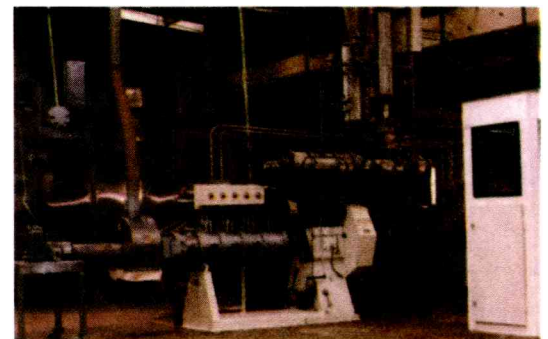
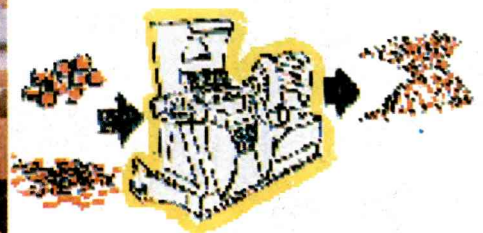
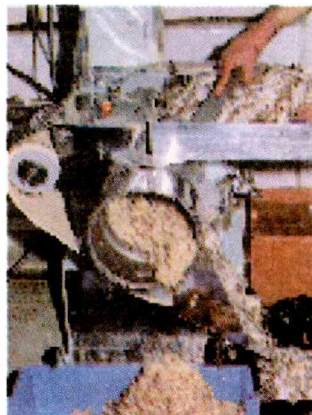
### A. Steps in Large-Scale Feed Preparation

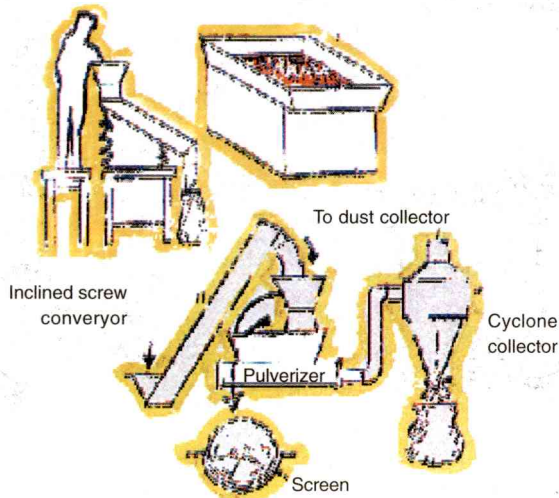
Sophisticated and large equipment are used in a feed mill. Pelleted feeds can be made much better and in larger amounts (as much as 1-20 tons of feed a day). The steps involved are:

#### Grinding

All dry ingredients are ground separately with a hammer mill or crusher

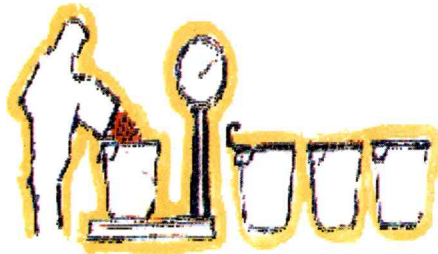
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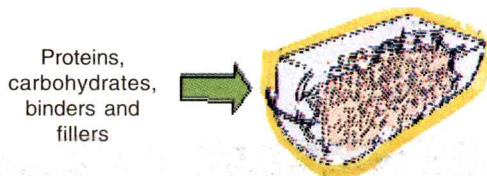
## 2 Sifting and sieving

Coarse materials are separated by sieving and returned to the grinder until all pass through the sieve. By means of a screw conveyor, sifted materials pass to the pulverizer and ground to uniform size. The sieved ingredients are blended for 5 to 10 min to obtain a homogenous product. The ground ingredient should be placed in tightly covered containers, and stored in an adequately ventilated room.



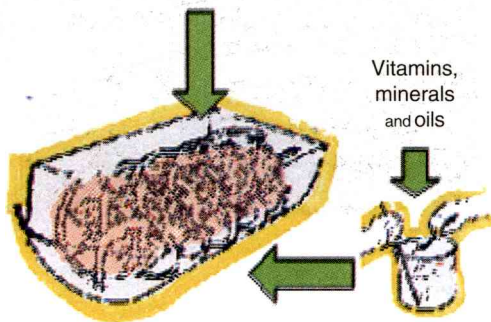
## 3 Weighing

All ingredients are individually weighed as accurately as possible by using a top loading weighing balance with a taring device.



## 4 Mixing

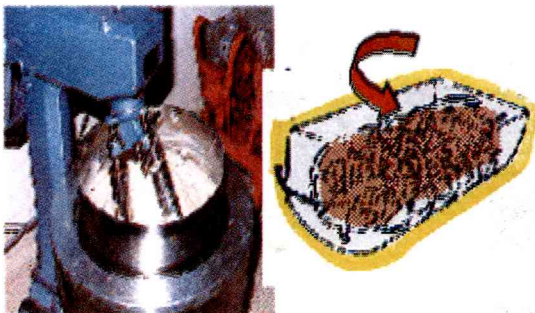
The formulation is then mixed by batch in a large mixer. The major ingredients (protein sources like fish meals, leaf meals, etc.) are poured into the mixer one at a time and mixed for 5 min. The other dry ingredients are added into the mixer one at a time and mixed for another 5 min.



## 5 Batch mixing

In a separate container, the micro-nutrients like vitamins and minerals are combined with a small amount of dry mixed ingredients and part of the lipid sources in the formula is added to the dry ingredients, thoroughly mixed, and poured into the mixer. This ensures good mixing of small feed components with the major ones.

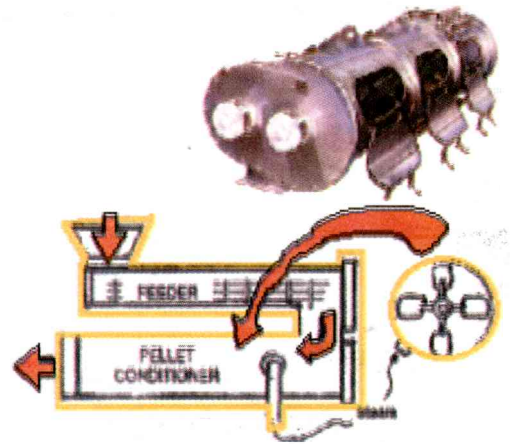
Note:  
Never place micronutrients  
in an empty mixer



When all dry ingredients including the micronutrients have been mixed, add the rest of the oil and mix for 15 min.

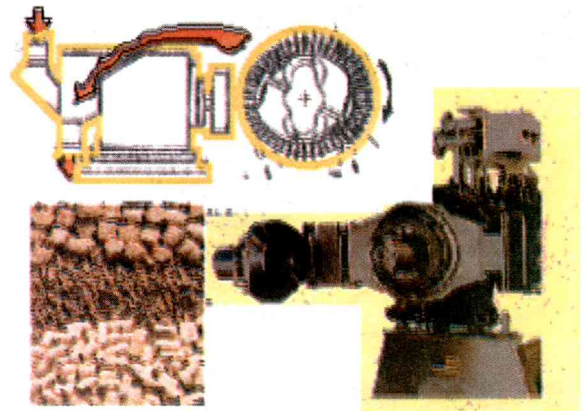
### Conditioning and gelatinization 6

The starch or binder is gelatinized by introducing steam into the pellet conditioner. The amount of water and heat required to cook the dried mixed ingredient is equivalent to the amount of steam injected. This is determined by water stability and palatability tests.



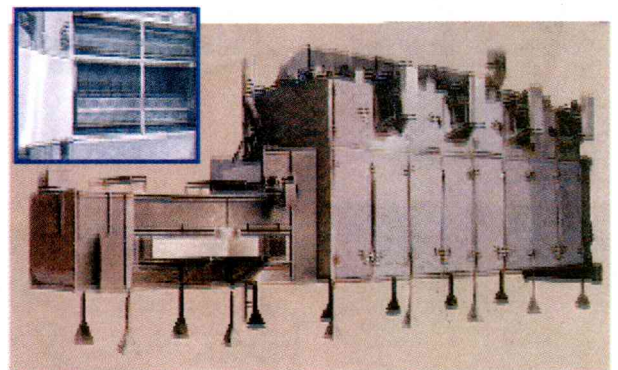
### Pelleting and extrusion 7

The conditioned feed mix is pelletized to the desired size. As the mixture passes through the die hole (2-22 mm in diameter), a rotating blade cuts it to the desired length (1.5 - 2.5 times the diameter).



### Drying and cooling 8

The pellets drop automatically into a cooling chamber with air at ambient temperature.



### Packaging and storage 9

Special feed finishing such as coating and glazing may be adopted to improve the quality and strength of the pellets.

The finished feeds are packed or bagged and labeled properly including the date of manufacture. Feeds are normally good only for three months. Bags should be piled (not more than 5 bags high) on a platform 12-15 cm from the floor in a well-ventilated room. The first bags that come in should be the first ones to go out.



### B. Steps in Small-Scale Feed Preparation

Mixing of locally available feed ingredients at home is a practical way of producing feeds for shrimps and fishes.



#### 1 Grinding

Dry ingredients are finely ground until fine particles of similar size are obtained.

#### 2 Screening

The ground ingredients are sieved or sifted using a No.40 sieve or a nylon net with mesh size of 425  $\mu$ m.

#### 3 Weighing

All ingredients are weighed or measured accurately in a bowl or basin.

#### 4 Mixing

All dry ingredients are mixed thoroughly. The vitamins and minerals are mixed separately with the lipid source (oil) and added to the dry mixture. The mixture is thoroughly mixed for another 5 min.

#### 5 Gelatinization or cooking

To cook corn starch, bread flour, and binders, 1 part starch is added into 4 parts of water (50 g in 200 ml water for 1 kg of feed) in a saucepan. The starch is cooked into a jelly-like consistency in a double boiler.



**Kneading**

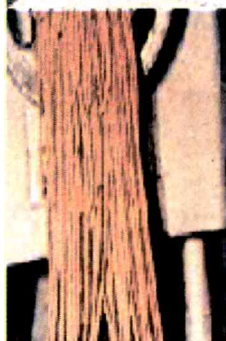
The gelatinized binder is removed from heat and allowed to cool. The cooled gelatinized starch or binder is added into the dry mixture and mixed for 5 minutes until a stiff dough is formed.

6

**Pelleting**

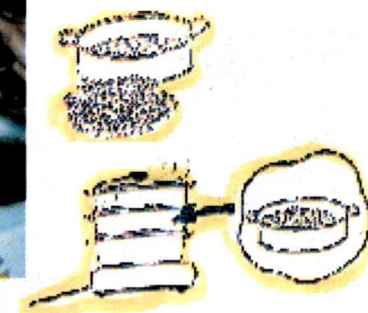
The dough is squeezed and passed through a meat grinder. The appropriate dye is used for the size of fish or shrimp to be fed (Table 5.2) for various sizes.

7

**Steaming**

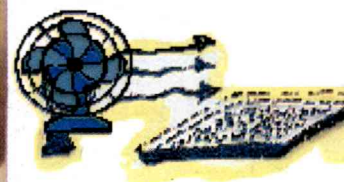
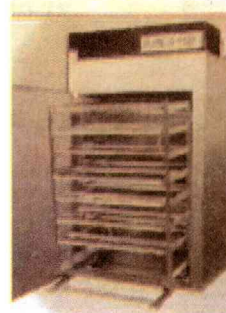
The pelleted feed is spread evenly on wire nets that fit inside the metal holders of the steamer. Water is boiled (5-8 cm deep) in a big pot and the pellets are steamed for 5 min. Overcooking or steaming can cause loss of nutrients and makes pellet stick to each other.

8

**Drying and cooling**

The steamed pellets are air dried for a few minutes with an electric fan, transferred to an oven and left overnight or for 8-12 h at 50-60°C. Pellets should not be dried under the sun to prevent destruction of some vitamins and other light-sensitive feed components.

9

**Cutting, packaging, and storage**

After the pellets are removed from the oven, they are cooled for 30-60 min. The dried extruded or pelleted feeds are cut to the desired lengths, placed in covered plastic jars, and stored in a cool dry place.

10



**C. Steps in Larval Feed Preparation****1 Weighing**

All ground ingredients are measured or weighed accurately.

**2 Mixing**

All dry ingredients are mixed thoroughly. If large batches are to be prepared, the dry ingredients can be mixed in a large cake or cement mixer.

**3 Blending of oil and lecithin**

The oil and lecithin are blended separately and added to the dry ingredients gradually with continuous mixing. When all the oil and lecithin have been added, mixing is continued for another 5 min.

**4 Cooking of carrageenan**

The carrageenan is cooked to gelatin-like consistency in a water bath at 80° to 100°C then slightly cooled.

**5 Microbouding**

The cooked carrageenan is added to the dry mixture and blended well until a completely homogenized mixture is obtained.

**Flaking**

6

The soft mass is passed through a drum dryer or flaking machine and the brittle flakes are collected.

**Grading/Sieving**

7

The flakes are ground gently using a mortar and pestle or meat grinder and sieved to uniform particulate size using varied mesh size sieves.



Different particle sizes for larval feeds are 25, 50-60, 125, and 250  $\mu\text{m}$ .

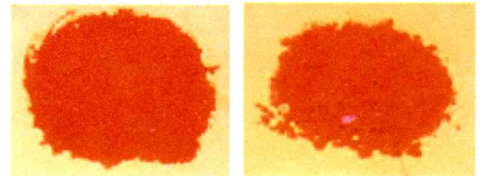


Table 5.2 Guide to types and kinds of feed for aquatic animals at various sizes and ages

Fish size approx wt (g)	Type of feed	Feed size, dia (mm)	Length (mm)
0.35 g and less	Starter	1.0	-
2 - 5	Grower	2.0	-
5 - 12	Grower	3.0	2-3
12 - 20	Finisher	5.0	3-5
20 - 30	Finisher	7.0	5-7

Shrimp age (days)	Shrimp size (g)	Feed type	Feed form	Feed size (mm)	Feed length (mm)
PL <sub>15</sub> - PL <sub>35</sub>	< 1.0	Starter	Fine crumble	0.6 - 1.0	-
PL <sub>36</sub> - PL <sub>55</sub>	2 - 3	Starter	Coarse crumble	1.0 - 2.0	-
PL <sub>56</sub> - PL <sub>75</sub>	4 - 7	Grower	Pellet	2.0 - 2.2	1.2 - 3.0
PL <sub>76</sub> - PL <sub>95</sub>	8 - 14	Finisher	Pellet	2.0 - 2.5	2.2 - 5.0
PL <sub>96</sub> - PL <sub>115</sub>	14 - 22	Finisher	Pellet	2.2 - 2.5	2.2 - 5.0
PL <sub>116</sub> - PL <sub>135</sub>	23 - >30	Finisher	Pellet	2.5 - 3.0	4.0 - 8.0



Stocking of 10 bags per pallet is practiced when feeds are stored for short periods (usually 3 to 5 days).



Indiscriminate storage of feed can trigger rapid deterioration of nutrients.

## Quality Control

Feed quality control is one of the major keys to a successful culture by selecting, evaluating, and monitoring feed ingredients during processing, manufacture, and until storage of aquafeeds. Storage conditions should be optimal so that the nutrients in feed ingredients and feeds do not deteriorate and economic losses of feed millers and fish culturists are avoided. The following pointers should be followed to avoid rapid deterioration of feeds.

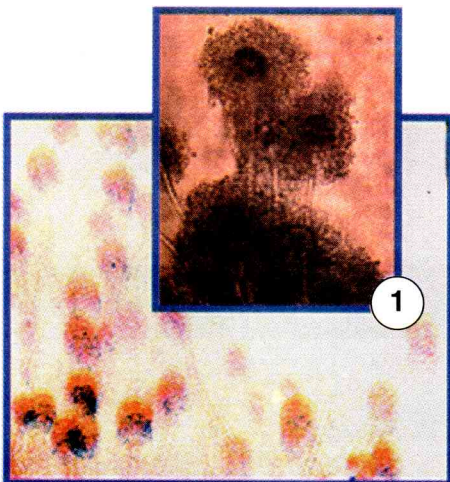
- ❑ moisture content should not be more than 10% and relative humidity not greater than 65% to prevent fungal growth and insect infestation that grows best at 26°-37°C.
- ❑ temperature should not be too high to prevent destruction and reduction of nutrient.
- ❑ exposure to oxygen should be limited to prevent oxidative rancidity particularly in feeds of high lipid content. The peroxides formed from lipid peroxidation may bind with proteins or vitamins and reduce their availability.

Feed should be:

- ❑ free from insects and rodents and spoiled feeds should not be used or recycled.
- ❑ stored in dry, cool, and well ventilated area and not under direct sunlight. Spoilage will occur immediately if feeds become wet.
- ❑ placed on wooden pallets and not directly on floors with not more than 5 bags per pallet if intended for long storage. Feeds should be stored away from walls to avoid moisture accumulation due to heat transfer from the wall to the feed during sudden temperature changes.
- ❑ used within three months from the time of processing and production. The first one that is stored should be the first to be used. The first-in first-out policy of storage should be strictly observed.

## Feed mill sanitation and maintenance

Effective management and proper maintenance of the storehouses and feed mill help ensure good quality feeds. Sanitation prevents infestation of insects, fungi, and bacteria. Infested materials should be removed and the infested areas should be disinfected. Only after disinfection can a new batch of feedstuff and feeds be stored. To prevent and control insect infestation and fungal and bacterial contamination particularly *Aspergillus flavus* ① and *Salmonella* in feed mills, several measures should be strictly followed.



*Aspergillus* sp. on contaminated feed particles.

- ❑ feeds and feedstuffs should be dried to a moisture content of 10% or less.
- ❑ feedstuffs should be processed to ensure complete destruction of bacteria, fungi, and viruses, or reduction to acceptable levels.
- ❑ whenever possible, varieties of feedstuffs that are resistant to fungi and toxins should be used. Feedstuffs such as maize, copra, and peanuts are easily contaminated with aflatoxin.

- ❑ environment-friendly chemicals such as vinegar, ammonia, and lysol should be used to disinfect the mill.
- ❑ moving parts such as gears, roller chains, etc. should be lubricated at least once every 4 h for every continuously mixed batch.
- ❑ at the end of each milling period, the feeder, conditioner, and the main drive of the pelleting machine should be always cleaned with a bag of rice bran (ordinary grade) or sawdust with cooking oil (100 ml of oil for every 2 kg of rice bran).

## Summary

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In processing feeds, the ingredients to be used should be free from molds and/or other harmful substances. Thus, the preparation of feedstuffs will depend on the presence or absence of harmful substances in the ingredients to be used in making feeds. Quality pellets can be produced when proper manufacturing practices are followed. Among the basic points to consider to produce good and quality pellets with minimal fines are the use of: a) satisfactory mixing practices with the right kind of mixer for the type of meal to be produced, b) the correct kind and quality of dosing liquid or binders, for the size of pellets and feed ingredients used, c) use of correct die size and thickness, d) use of proper pelleting pressure and temperature, e) correct type of pellet cooling rate and cooling air flow rates, f) correct crumbling roll setting in relation to the desired crumbled feed size, and g) post-pelleting, crumbling, and finishing treatments to remove fines and fractures from the finished product. A technically trained and skilled feed mill operator should oversee the manufacturing process.

The steps to be followed in large scale, small-scale, and larval feed preparation will guide the reader as to the type and kind of aquafeeds for fish and crustaceans at various stages and ages.

## Guide questions

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1. What are the important things to consider in the preparation of aquafeeds?
2. Why do we need to process feed and feed ingredients?
3. Why is grinding of ingredients a necessary step in feed preparation?
4. Explain the importance of knowing the moisture content of feedstuff and feed especially prior to storage?
5. What are some typical examples of antinutritional factors in feed ingredients and their effects on aquatic animals? How are these factors eliminated or minimized?
6. What is the purpose of pelleting and how does one make floating and sinking feeds?
7. Explain briefly the basic steps in small-scale feed preparation and compare these to steps in commercial feed preparation (milling).
8. What are the deleterious effects of prolonged and improper storage of feeds?

### Suggested Readings

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- Akiyama DM, Dominy WG. 1989. Penaeid shrimp nutrition for the commercial feed industry. Texas Shrimp Farming Manual Volume 1. Corpus Christi, Texas. 500 p.
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- Tacon A. 1988. The nutrition and feeding of farmed fish and shrimp A training manual. 3. Feeding methods. FAO Field Document, Project GCP/RLA/075/TA. Field Document 7/E. FAO, Brasilia, Brazil, 208 p.