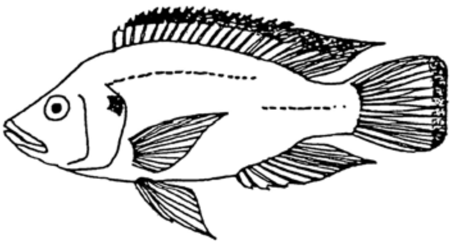
Australian Government
Australian Centre for International Agricultural Research

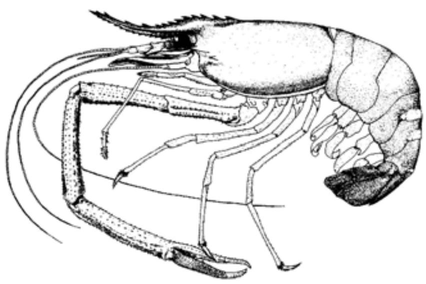
NSW DEPARTMENT OF PRIMARY INDUSTRIES

PREPARING FARM-MADE FISH FEED

by

Carmen Gonzalez and Geoff Allan





www.aciar.gov.au
www.dpi.nsw.gov.au

ISBN 978 0 7347 1802 0

Preparing Farm-made Fish Feed

March 2007

Authors: Carmen Gonzalez[1] and Geoff Allan[2]

[1] Visiting Fellow
Queensland University of Technology
2 George Street
Brisbane Qld 4001
[2] NSW Department of Primary Industries
Port Stephens Fisheries Centre
Private Bag 1,
Nelson Bay NSW 2315

Published by: NSW Department of Primary Industries

Postal Address: Private Bag 1, Nelson Bay NSW 2315

Internet: www.dpi.nsw.gov.au

ISBN 978 0 7347 1802 0

OTHER CONTRIBUTORS

FIJI MINISTRY OF AGRICULTURE FISHERIES AND FORESTRY

QUT Queensland University of Technology
Brisbane Australia

WorldFish CENTER

Papua New Guinea NATIONAL FISHERIES AUTHORITY

Aquaculture without Frontiers

Queensland Government
Department of Primary Industries

Table of Contents

Acknowledgements

We thank the Australian Centre for International Agricultural Research (ACIAR) for funding this publication and supporting feed development R&D in Asia and the Pacific. We would like to thank the following people for their assistance with the feed ingredient surveys, providing valuable comments on various drafts and for formatting and layout of the brochure: Mark Booth (NSW DPI, Australia); Cathy Hair (QDPIF, Australia); Helena Heasman (NSW DPI, Australia); Filamone Mate (MAFF, Fiji); Peter Minimulu (NDAL, PNG); Satya Nandlal (SPC, New Caledonia); Johnny Soranzie (NDAL, PNG); Jacob Wani (NFA, PNG); Kevin Williams (CSIRO, Australia); Barney Smith (ACIAR Fisheries Program Manager).

Tilapia cages in PNG. Production is increased when fish are fed.

1. Introduction

The culture of tilapia (fish species belonging to genera *Oreochromis* and *Tilapia*) and freshwater prawns (*Macrobrachium* species) has the potential to produce protein and income for small-scale fish-farmers in Fiji and PNG. However, lack of appropriate resources and capacity has contributed to low productivity of aquaculture in both countries. One of the key constraints identified is the poor quality and limited availability of supplementary feeds. Where commercial feeds are available, they are often prohibitively expensive. The alternative is for farmers to make their own feeds. However, the limited availability of ingredients, lack of information on fish nutrition and on how to make and deliver feeds often results in poor quality feed and reduced production and profitability.

In 2004 and 2005 as part of a mini-project funded by ACIAR, in partnership with SPC and fisheries departments in Fiji and PNG, potential feed ingredients for aquaculture in both countries were surveyed and a few simple feeds were formulated, some of which were later tested with tilapia in Fiji. This brochure briefly introduces the science (and art) of aquaculture feed formulation including sections on components of fish feeds, information on selecting ingredients, how to make simple feeds on a farm, feed storage and feeding rates. Several formulations (recipes) are given.

2. What do fish need in their feed?

Fish[1] (including prawns or shrimp) need energy and essential nutrients for maintenance, movement, normal metabolic functions and growth. Fish can obtain their energy and nutrients from natural food in ponds, from feed supplied by the farmer or from a combination of both sources.

The feed requirements of fish vary in quantity and quality according to their feeding habits and digestive anatomy as well as their size and reproductive state. Feed requirements are also affected by environmental variations such as temperature and the amount and type of natural food available.

Adult male Tilapia breeder from Naduruloulou Aquaculture Research Station in Fiji

[1] For this brochure, the term "fish" includes prawns or shrimp.

Adult male Macrobrachium rosenbergii *from Obo, Western Province, PNG*

Tilapia cages at Yonki Dam, Eastern Highlands in PNG

The major components of feeds are moisture (=water), protein, lipid (=fat), carbohydrate, minerals and vitamins. Fish obtain the energy they need by eating protein, lipid and carbohydrate (these nutrients are called the macronutrients). Small (or trace) amounts of minerals and vitamins are also essential. These are called micronutrients.

Rice by-products: husk rice, bran rice and brown broken rice from Evergreen Mills – Navua, Fiji

- Protein is composed of amino acids. There are 10 different amino acids that cannot be synthesised in fish at rates sufficient for maximum growth and development and have to be supplied in the diet. These are the "essential amino acids". There are many others that can be synthesised from the essential amino acids by fish. The exact requirements for essential amino acids vary between species and life stages.
- Lipids are composed of fatty acids and some of these are also essential for some species of fish.
- Carbohydrates include fibre, starches and sugars and while not usually considered essential, they can be an effective source of energy and improve food conversion efficiency when included at moderate amounts. Carbohydrates are usually the cheapest sources of energy although different species of fish differ in their ability to use carbohydrates. Carbohydrates can also help to bind a diet together (i.e. the pellet will not crumble easily).
- Minerals are important for normal skeletal development of fish but some also have a vital role in the functioning of enzymes and other metabolic functions. The ash content of an ingredient is the total amount of minerals (or inorganic matter) present within a food.
- Vitamins are complex organic compounds required in small amounts for normal growth, reproduction, health and general metabolism. Diets lacking adequate levels of vitamins and minerals can result in growth and development disorders and death in severe cases of deficiency. Many vitamins and especially Vitamin C (ascorbic acid) are easily damaged by heat, light and humidity and this reduces their usefulness to fish.
- Vitamins and minerals are contained in some feed ingredients but premixes are also often added to feeds, especially where fish or prawns are stocked at high densities or are obtaining most of their nutrients from the added feed rather than natural food.

Fish eat primarily to satisfy energy requirements. If there is too much energy compared with protein, animals will stop eating before they consume enough protein for maximum growth. Too much energy from dietary fat or carbohydrate can also lead to high body fat, low dress out yield and poor shelf life in market size animals. If there is too little energy compared with protein, part of the dietary protein will be used for energy. It is therefore important to determine the optimum ratio of energy to protein for different species of fish. This ratio can also be affected by the size of the animal. Generally the ratio of energy to protein increases as the animal gets bigger.

3. What ingredients should be used to make feeds?

There are 3 factors to consider in the choice of ingredients:

a) Quality - nutrient composition and presence of any anti-nutrients (substances that interfere directly with the absorption of nutrients or contaminants).

b) Quantity – how much is available locally & is the supply regular?

c) Price or cost

The raw materials are collected or delivered in jute or polythene or plastic sacks/bags or containers. Special care should be taken to inspect the materials for wetness, mould growth, insects and parasites. The inspection procedure starts with visual examination of a sample for the colour and texture and smelling for obvious contamination or rancidity.

Knowing the composition of the available ingredients and the basic nutritional requirements of the fish being cultured, it is usually possible to formulate a diet that will promote optimum survival and growth. Sometimes, expensive ingredients can be substituted by a single alternative ingredient or a combination of ingredients to provide cost savings. Formulating diets to meet given nutritional specifications by selecting the cheapest available ingredients is called "least-cost formulation" and can be achieved using spreadsheets or specifically designed computer programs.

To use a least-cost computer program to formulate feeds, the following information is needed:

- nutrient requirements of target fish
- cost and availability of feed ingredients
- nutrient and energy content of feed ingredients
- nutrient availability from feed ingredients
- nutritional and non-nutritional restrictions governing use of feed ingredients

Examples of grains that have potential for use in aquaculture feeds

Tables 1 & 2 are examples of ingredients available in Fiji and PNG (prices are estimates only in 2005/06). Composition is measured or estimated from published values for similar ingredients.

Table 1. Ingredient data base (Fiji)

	Cost[1]	Nutrient[2]				Energy (Gross)[2]
		Moisture	Crude Protein	Fat	Ash	
	$/Tonne	%	%	%	%	MJ/kg
Fish meal 52%CP	580	4.0	52.1	17.5	21.6	17.0
Fish meal 50%CP	580	4.7	50.3	16.5	21.2	18.9
Meat and bone meal	550	8.6	43.1	23.6	20.2	15.3
Pea skin meal	250	12.7	9.7	1.5	2.7	16.8
Split peas	310	15.2	19.9	1.9	2.7	17.5
Rice bran	310	10.0	12.2	11.8	13.1	16.6
Rice pollard	150	11.1	12.8	11.7	8.8	17.2
Husk rice	50	10.0	3.1	1.0	17.4	12.2
Brown broken rice	220	9.1	9.1	1.6	1.0	16.4
Mill mix	190	13.1	13.9	3.8	4.2	14.7
Wheat flour	250	12.0	11.7	1.2	0.5	16.1
Coconut meal	240	19.0	19.0	7.4	5.1	13.9
Vitamin & mineral premix	3000	19.0	10.0	8.2	39.2	9.7

[1] Cost is in AU$; they are approximate and will vary. Approximate exchange rate AU$1 = FJ$1.31
[2] Nutrients and energy values are as analysed or reported in the literature (e.g. Edwards & Allan 2004). Protein, fat and ash are "as is"

Table 2. Ingredient data base (PNG)

	Cost[1]	Nutrient[2]				Energy (Gross)[2]
		Moisture	Crude Protein	Fat	Ash	
	$/Tonne	%	%	%	%	MJ/kg
Fly river Herring fish meal (IFC, Lae)	716	6.2	52.7	8.4	21.9	17.6
Fish oil	1300			100.0		36.0
Rice bran	202	13.9	8.7	12.0	11.2	16.1
Mill mix	190	15.6	15.7	3.2	4.3	15.5
Copra meal	327	5.2	21.9	9.6	6.2	18.7
Cassava	200	68.8	0.9	0.2	1.0	5.3
Corn	400	12.2	9.6	3.9	1.5	16.3
Broken rice	101	11.3	8.1	0.6	0.7	14.5
Cocoa pod		11.5	5.8	0.7	7.6	14.4
Vitamin & mineral premix	3000	19.0	10.0	8.2	39.2	9.7

[1] Cost is in AU$; they are approximate and will vary. Approximate exchange rate AU$1 = PGK2.3
[2] Nutrients and energy values are as analysed or reported in the literature (e.g. Edwards & Allan 2004). Protein, fat and ash are "as is"

Tables 3 and 4 are examples of diet formulations.

Table 3. Example formulations - Fiji	**1**	**2**	**3**
	%	*%*	*%*
Ingredients			
Fish meal 52%CP	18.2	54.6	82.0
Fish meal 50%CP			
Meat and bone meal			
Pea skin meal			
Split peas			
Rice bran			
Rice pollard	20.0	11.3	16.5
Husk rice			
Brown broken rice			
Mill mix	30.0	12.6	
Wheat flour	11.8	20.0	
Coconut meal	20.0		
Vitamin and mineral premix		1.5	1.5
Total	**100.0**	**100.0**	**100.0**
Calculated composition			
Moisture (%)	12.1	7.6	5.1
Protein (%)	21.4	34.0	45.0
Fat (%)	8.2	11.6	15.0
Ash (%)	8.0	13.9	18.9
Gross energy (MJ/kg)	16.1	16.3	16.4

Descriptions (formulations are examples only, not necessarily optimum nor least cost because only the ingredients listed were available for diet formulation)

Diet 1 - low protein diet suitable for tilapia or carp in ponds stocked at low density with natural food

Diet 2 - high protein diet suitable for tilapia or carp in ponds or cages without natural food

Diet 3 - barramundi diet

Farm-made feeds will usually be made from a number of different ingredients.

Table 4. Example formulations - PNG

	1	2	3	4
	%	%	%	%
Ingredients				
Fly River herring meal				51.5
Fish meal	27.0	20.1	66.6	
Fish oil		1.1	11.1	5.4
Rice bran	30.0			
Mill mix	26.5		15.0	21.6
Copra meal	15.0		5.8	20.0
Wheat flour	1.0			
Broken rice				
Cocoa pod				
Chicken broiler feed		77.3		
Vitamin and mineral premix	0.5	1.5	1.5	1.5
Total	**100.0**	**100.0**	**100.0**	**100.0**
Calculated composition				
Moisture (%)	9.0	9.4	4.5	8.8
Protein (%)	25.6	28.0	40.0	45.0
Fat (%)	8.1	8.0	18.0	15.0
Ash (%)	10.8	12.7	16.5	11.3
Gross energy (MJ/kg)	17.5	18.7	21.2	20.9

Descriptions (formulations are examples only, not necessarily optimum nor least cost)
Diet 1 - diet suitable for tilapia or carp in ponds or cages
Diet 2 - diet for tilapia or carp based on broiler feed with additional protein
Diet 3 - trout diet; **Diet 4** - barramundi diet (assumes access to Fly River Herring)

Table 5. Recommended pellet sizes for tilapia

Fish Size (g)	Pellet Diameter (mm) *
0.5–1.0	0.5–1.5
1-30	1-2
30-120	2
120-250	3
> 250	4

* Pellet length same as diameter
Source: Adapted from *Goddard 1996*

Table 6. Recommended pellet sizes for prawns/shrimp

Size of prawn/shrimp (g)	Feed type	Pellet size diameter (mm) x length (mm)
0-3	starter	1.0 – 2.0 x 1.0 – 2.0
3-15	grower	2.0 – 2.5 x 4.0 – 5.0
>15	grower/finisher	2.0 – 2.5 x 6.0 – 8.0

Source: Adapted from *Goddard 1996*

Pellets come in different sizes, shapes and colours. These are commercially produced extruded or steam pressed pellets

4. How to prepare diets

Equipment needed

- ✓ Weighing scale or balance
- ✓ Mixer
- ✓ Grinder (e.g. hammer mill or flake mill to reduce particle size of ingredients to 0.4-0.6 mm)
- ✓ Sieve
- ✓ Pellet machine (mincer) with various size die plates (e.g. 1,2,3,5 mm diameter)
- ✓ Steamer
- ✓ Saucepan for cooking starch or starch rich ingredients
- ✓ Drier
- ✓ Moisture-proof container for pellets

STEP 1. Use finely ground ingredients of similar particle size. Dissimilar sizes results in an unstable pellet. Individual ingredients should be ground using a hammer mill, or other type of grinder or even a mortar and pestle. A sieve can also be used to remove large particles or foreign material like stones, pieces of metal etc that can damage machinery.

Rice bran milled in Goroka, PNG. The rice bran is ground to a fine powder during this process.

STEP 2. Weigh or measure ingredients. Take particular care when weighing micro-nutrients (vitamin and mineral premixes) as these are used in very small quantities and are very expensive.

A simple balance is used to weigh ingredients at DAL Highlands station in Goroka, PNG

STEP 3. Mix all ingredients thoroughly. If large batches are to be prepared, the dry ingredients can be mixed in a large cake mixer or even in a cement mixer. Poor mixing will result in variation of daily nutrient intake. Good mixing can also improve palatability.

Ingredient mixer- a simple cement mixer is suitable to mix small batches of feed

STEP 4. Mix vitamins and minerals with small amount (e.g. 10% of total batch) first then blend into larger mixture (to help ensure the vitamins and minerals are evenly distributed within the mixture).

STEP 5. Add the oil and then mix for at least another five minutes. To ensure oil is well mixed throughout the ingredients, it is useful to warm the oil or make an emulsion with warm water. Mix with dry ingredients slowly.

Mixing ingredients manually

STEP 6. Add water and mix well to form a mash with a cake-like consistency. Water should be added slowly and small test batches of the mixture extruded through the pellet machine (mincer) to see how easily the mixture passes through the die and how the pellets hold together. As a general rule, the total moisture content of the mash should be in the range of 45 to 55% to produce good pellets. If moist ingredients like trash fish, minced poultry etc are used, less moisture will be needed (e.g. 25-45%). Adjustments must also be made depending on the type of binders, if any, are used.

STEP 7. Pass the feed mash mixture though a pellet machine (mincer) with a 1, 2, or 3 mm die depending on the size of the fish that is being fed. It is usually best to use the largest diameter pellet that fish will readily eat. Tables 5 and 6 give a guide to the size of pellets required for different size fish and prawns.

Different size pellets are made by extruding the mash (mixture of ingredients) through dies with different size holes and then cutting the strands to the required length.

STEP 8. Cut the extrusion, (which look like noodles) into similar lengths to the closest pellet diameter (i.e. 2 mm long for 2 mm diameter pellets for fish). Pellets can be cut off with a knife during extrusion or broken into smaller lengths after they have been dried.

Pellet preparation using a pellet machine (mincer)

STEP 9. The moist pellets should be dried to a moisture content of 10% or less. Ideally, this should be at low temperature (less than 60 ºC) and with good airflow to dry the pellets as quickly as possible to ensure that heat-sensitive micronutrients such as vitamins are not destroyed. This can be achieved using:

- a fan-forced oven (e.g. set at <60 ºC) for several hours,
- a simple drying cabinet (with hot air supplied by a heater blower),
- a solar dryer or
- simply by spreading the pellets in the sun.

Open air sun drying of farm-made pellets

It is most important when drying pellets to prevent fungal contamination and to avoid an excessive loss of critical nutrients. Fungus can be toxic to fish and to the humans who handle the feed.

A simple solar dryer made from covering a timber frame with plastic. The air is drawn into the dryer through an open base, is heated by the sun in the dryer and exits through large gaps between the top of the walls and the roof.

Fan forced oven

Step 10. When pellets are dry and cool they should be stored in bags or containers that can be sealed against insects, rats or other pests and to keep out moisture. Avoid using plastic bags because feeds can sweat and this encourages growth of mould.

Final pellets produced

5. How to improve water stability of pellets

Water stability of pellets prepared for prawns is especially important because the pellet should remain intact in water until it is ingested. The water stability of the feed pellet depends primarily on how well the individual ingredients bind together. The addition of a specific feed binder to improve the water stability of the pellet in the water is often included for slow feeding animals such as prawns. For fish that are more instantaneous feeders, the water stability of the pellet is much less important although it is important that pellets do not break apart when pellets are shaken during transport.

Higher water stability of pellets can be achieved by:

- Using finely ground ingredients so that the small cavities on the surface of the pellets are filled up, thereby reducing the rate at which water is able to penetrate into the pellet.
- Increasing the compaction of the mixture by applying more force during pelleting.
- Cooking the mash or the moist pellets (e.g. by steaming) thus increasing the proportion of the gelatinised starch.
- Avoiding high concentrations of fat, water repellent or highly absorbing water ingredients in the diet mixture.
- Using binders.

Binders are substances which are used within aquaculture feeds to improve the efficiency of the feed manufacturing process, to reduce feed wastage, and/or to produce a water-stable diet. The dietary inclusion level of these binding agents generally varies between 1 and 2% of the dry diet. By contrast, for those aquaculture species which have a slow feeding habit and have to masticate their food externally prior to ingestion (e.g. prawns), it is essential that specific binders be used to delay the physical disintegration of the pellet or feed mash within the water until ingestion is complete. Under these circumstances additional dietary binding agents will be required such as starchy plant products (palm starch, cassava starch, potato starch, bread or wheat flour, rice and maize), which cause the feed particles to bind together when heat is applied to gelatinise the starch. Other aquaculture binders include alginates (seaweeds), carrageenan, plant gums (guar gum, locust bean gum, gum arabic), agar, high-gluten wheat flour, chitosan, propylene glycol alginate, gelatin, carboxymethylcellulose (CMC).

6. How to store your feeds

KEEP FEEDS AND INGREDIENTS DRY, COOL AND AWAY FROM PESTS. Poor storage of feeds and ingredients will waste money and can kill fish.

Any ingredient or feed requires special care during storage to prevent deterioration in quality. Stock control is also important to ensure you have enough but not too much of each ingredient available for manufacture when needed.

Environmental factors, such as moisture, temperature, light and oxygen influence deterioration and losses in feedstuffs. High levels of moisture favour growth of fungus or insect infestation. Fungal growth can be retarded by the use of mould inhibition agents (e.g. Myocurb). High temperatures also affect the rate of loss of heat liable vitamins and other nutrients.

Lipids can break down into free fatty acids, causing rancidity. Rancid fats reduce the palatability of the feed and contain toxic chemicals, which may reduce growth. Rancidity can be reduced through the use of antioxidants such as ethoxyquin (1,2-dihydro-6-ethoxy-2,2,4-trimethylquinoline), BHA (butylated hydroxyanisole) or BHT (butylated hydroxytoluene).

Thus, ingredients should be stored for as a short period of time as possible and compounded feeds used quickly, especially in tropical conditions. The method of storage depends on the type of ingredient.

Vitamin mixes are extremely expensive ingredients and should be given special care. They should be kept either in the manufacturer's containers or in airtight lightproof containers and preferably under air conditioning or refrigeration. Stocks should be turned over at least every six months.

Lipids (e.g. fish oil) must be kept in sealed, preferably plastic containers, in a cool dark place. Purchase only those that have antioxidants added at manufacture.

To store dry feed materials, provide a secure building, protected from rain, with ventilation points (windows are not recommended). The drier and cooler the store can be kept; the better will be the quality of the feed. Keep the store clean and free of vermin such as rodents. Remember DRY, COOL AND AWAY FROM PESTS.

7. Feeding rates

Correct delivery of food is important to reduce feed waste. Underfeeding can result in loss of production while overfeeding results in feed wastage and can lead to deterioration in water quality. A serious decline in water quality can result in loss of stock and the need for corrective measures.

Although the total quantity of feed needed will increase as fish grow, the amount of feed added as a percentage of total fish biomass needs to decrease over time.

For example as shown in Table 7, feeding rates for tilapia fingerlings of approximately 5 -10 g are 10 - 5% of biomass; for sub-adults of approximately 40 g the daily feed required is from 8 – 3.2 % biomass.

Feed twice a day preferably after sunrise (around 7-9 am) and before sunset (around 4-6 pm). Sample the animals every 2 weeks or once a month and recalculate the amount of feed to be given.

Table 7. Feeding Rate for Tilapia fed 25% protein feed at 24°C

Fish size (g)	Amount of feed	
	(g/fish/day)	(% biomass)
5–10	0.5	10.0–5.0
10–20	0.8	8.0–4.0
20–50	1.6	8.0–3.2
50–70	2.0	4.0–2.9
70–100	2.4	3.4–2.4
100–150	2.7	2.7–1.8
150-200	3.0	2.0–1.5

Source: Marek, 1975 (adapted).

For prawns, aim to feed about 8-10% of the total biomass when the post larvae are 1-10 g and 3.5% of the total weight when juveniles are more than 10 g. As a rule of thumb, allow for 90% survivors for the first month, 80% for the second month, 70% for the third month and 60% for the fourth month. The use of feeding trays to indicate feeding activity is a good idea as prawns reduce feeding activity in the couple of days prior to moulting and if the feed on the feed trays is not eaten, it is a good indication to reduce feed input.

8. References

Edwards, P. & Allan G.L., eds., 2004. Feeds and feeding for inland aquaculture in Mekong region countries. ACIAR Technical Reports No. 56, 136 pp.

Goddard, S. 1996. Feed Management in Intensive Aquaculture. Chapman & Hall, New York, N.Y. 194 pp.

Marek, M. 1975 Revision of supplementary feeding tables for pond fish. Bamidgeh, 27(3):57-64

New, M.B. 1987. Feed and Feeding of Fish and Shrimp. A manual on the preparation of compound feeds for shrimp and fish in aquaculture. FAO Rome, Italy. 275 pp.

Sim, S.Y., Rimmer, M.A., Toledo, J.D., Sugama, K., Rumengan, I., Williams, K.C. & Phillips, M.J. 2005. A practical Guide to Feeds and Feed Management for Cultured Groupers. NACA, Bangkok, Thailand. 18 pp.