To Cross Check

Feedstuff	%	Content CP (%)	Contributed CP (%)
RM	43.1	12	5.172
FM	56.9	70	39.830
Total	100		45.002

Note: The difference of 0.002% CP is due to approximate values in the calculation

Quadratic Equation

Let,
a stand for the proportion of RM required in the feed
b stand for the proportion of FM required in the feed

Contributed CP of RM in the feed $= CP_{RM} \times a$

Contributed CP of FM in the feed $= CP_{FM} \times b$

Therefore,

$CP_{RM}.a + CP_{FM}.b = CP_c$(concentrate) ----- eqn (i)

Likewise,

Contributed ME of RM in the feed $= ME_{RM} \times a$

Contributed ME of FM in the feed $= ME_{FM} \times b$

Therefore,

$ME_{RM}.a + ME_{FM}.b = ME_c$ ------ equation (ii)

Substitute the values of CP and ME in eqns (i) & (ii)

(For CP) $12a + 70b = 45$ ......(i)

(For ME) $3200a + 2800b = 2900$ ......(ii)

To solve for variation a in equations (i) & (ii), multiply (i) by 4 and (ii) by 0.1

$$
\begin{array}{lr}
(-) & 48a + 280b = 180 \\
 & \underline{320a + 280b = 290} \\
 & 272a = 110
\end{array}
$$

$$a = {}^{110}/_{272} = 0.4044118$$

$$\%RM \approx 0.404 \times 100\%$$

$$RM = 40.4\%$$

Substitute the value of a in equation (i) to solve for b

$$12a + 70b = 45 \ldots\ldots\ldots\ldots (i)$$

$$12(0.4044118) + 70b = 45$$

$$70b = 45 \quad 4.8529416$$

$$b = \frac{40.147058}{70}$$

$$0.5735294$$

$$\%FM \approx 0.574 \times 100\% = 57.4\%$$

So, 40.4kg of RM should be mixed with 57.4kg of FM to produce 100kg of concentrate of 45% CP and 2900kCalkg^{-1}

To Cross Check

Feedstuff	%	Content CP (%)	Content, ME (Kcal kg^{-1})	Contributed CP (%)	Contributed ME(kCal kg^{-1})
RM	40.4	12	3200	4.848	1292.8
FM	57.4	70	2800	40.180	1607.2
Total	97.8			45.028	2900.0

Question 2

A catfish farmer wants to formulate a 45% protein and 3000 kCal kg-^{1} concentrate for his adult fish, using biscuit waste, insect meal, hatchery egg meal and fish meal. Assuming the insect meal, hatchery egg waste and fish meal were to be included in the concentrate at a ratio of 1:1:2. Determine the percentage of each feedstuff in the concentrate.

Given data

Concentrate: CP = 45% and ME = 3000kCal kg^{-1}

Feed items: BW, IM, HEM & FM

IM:HEM:FM = 1:1:2(=4).

Thus, BW = 44.6%;

IM = 13.85%

HEM = 13.85%

FM = 27.7%

To Cross Check

Feedstuffs	%	Content CP (%)	Contributed CP (%)
BW	44.60	14	6.244
IM	13.85	70	9.695
HEM	13.85	70	9.695
FM	27.70	70	19.39
Total	100.00		45.024

Difference of 0.024% CP is due to approximations made in the calculation

Quadratic Equation

$\%CP_c$ of IM, HEM & FM = 70%CP (as shown above).

Collective ME (MEc) of IM, HEM & FM

IM = ¼ x 2900 = 725

HEM = ¼ x 3500 = 875

FM = $^2/_4$ x 2800 = 1400

ME_c = 3000kCal kg^{-1}

If, a represents the proportion of BW

b represent the proportion of C

$ME_{BW}.a + ME_C.b = ME_{(BW+C)}$ .... equation (i)

$CP_{BW}.a + CP_C.b = CP_{(BW+C)}$ .... equation (ii)

(Note BW + C = concentrate)

Since,

$ME_{BW} = 3400$ & $CP_{BW} = 14$

$ME_C = 3000$ & $CP_C = 70$

$ME_{(BW+C)} = 3000$ & $CP_{(BW+C)} = 45$

Substitute the above values in equations (i) and (ii).

$3400a + 3000b = 3000$ ......(i)

$14a + 70b = 45$ .....(ii)

If we choose to use elimination method, multiply equation (i) by 0.7 and equation (ii) by 170 to eliminate a

$$(-)\ 2380a + 2100b = 2170$$
$$\underline{2380a + 11900b = 7650}$$
$$9800b = 5480$$

$$b = \frac{5480}{9800}$$

$$b \approx 0.56 = \text{proportion of C}$$

Solve for a by substituting the value of b in eqn (ii)

$14a + 70b = 45$ ...... (i)

$14a + 70(0.56) = 45$

$14a = 45\ \ 39.2$

$14a = 5.8$

$a \approx 0.414$

$a \approx 41\% =$ proportion of BW

Therefore, % proportion of IM, HEM & FM will be

$IM = \frac{1}{4} \times 56\% = 14\%$

$HEM = \frac{1}{4} \times 56\% = 14\%$

$FM = \frac{2}{4} \times 56\% = 28\%$

So,

BW = 41%, IM = 14%, HEM = 14%, FM = 28%

To Cross Check

Feedstuff	%	Content CP (%)	Content, ME (Kcal kg^{-1})	Contributed CP (%)	Contributed ME(kCal kg^{-1})
BW	41	14	3400	5.74	1394
IM	14	70	2900	9.80	406
HEM	14	70	3500	9.80	490
FM	28	70	2800	19.60	784
Total	97			44.94	3074

Question 3

A catfish farmer with access to cheap broken rice waste from a rice mill and cultured duckweed, wishes to formulate a feed concentrate of 40% CP and 2900kCal kg^{-1} for his 4-month-old fish. If the feed materials to be used in the formulation are corn meal, fish meal, soybean meal (20%), rice (waste) meal and duckweed (10%), calculate the proportion of mixture of the feed ingredients, assuming corn meal and rice meal are to be included at ratio 1:1.

Given data

SM = 20% and DW = 10%

Others are CM: RM = 1:1, and FM

Concentrate (C) = 40% CP and 2900kCalkg^{-1}

Answers

Pearson's Square

20% SM will contribute 20/100 x 44% CP = 8.8% CP

10% DW will contribute 10/100 x 39%CP

= 3.9% CP

12.7% CP

So, CM, RM & FM will contribute (40 – 12.7) = 27.3% CP

%Content of CM, RM and FM in concentrate (C)

= 100 (SM + DW) = 100 (20 + 10) = 70%

I.e. CM, RM & FM = 70% feed content = 27.3% CP

Upgrade the % of CM, RM & FM (= 70%) to 100% to derive an equivalent %CP, for easy calculation

So,

$$100\% = \left(\tfrac{27.3}{70} \times 100\right)\% \text{ CP}$$

$$100\% = (0.39 \times 100)\% \text{ CP} = 39\% \text{ CP}$$

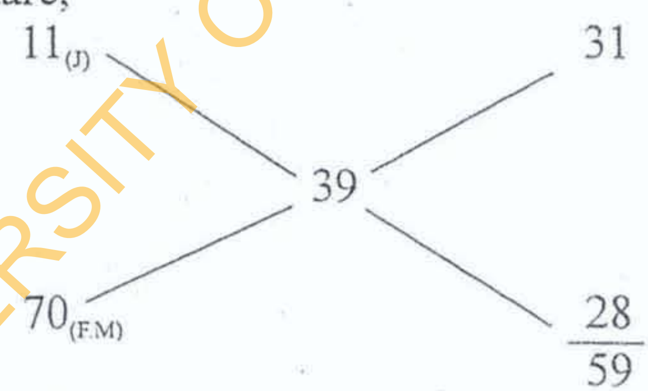
Note that CM: RM = 1:1 (=2)

So,

the joint (J) % CP contribution of each will be

CM = ½ x 10% = 5% CP
RM = ½ x 12% = 6% CP
CM: RM (J) = 11%CP

Apply the square,



$J = {}^{31}/_{59}$ of (CM, RM & FM)

$J = {}^{31}/_{59} \times 70\%$

J = 36.8% (CM + RM)

CM: RM = 1:1 = 2

CM = ½ x 36.8% = 18.4%

RM = ½ x 36.8% = 18.4%

FM = $^{28}/_{59}$ of (CM, RM & FM)

FM = $^{28}/_{59}$ x 70% = 33.2%

or

%FM = %(CM + RM + FM) - % (CM + RM)

= 70% – 36.8% = 33.2%

Thus, the concentrate formulation should contain

18.4%CM; 18.4% RM; 10% DW;

20% SM & 33.2% FM

To Cross Check

Feedstuffs	%	Content CP (%)	Contributed CP (%)
CM	18.4	10	1.840
RM	18.4	12	2.208
DW	10.0	39	3.900
SM	20.0	44	8.800
FM	33.2	70	23.240
Total	100.0		39.988

Quadratic Equation

20% SM will contribute 8.8% CP (as previously shown).

$ME_{SM} = {}^{20}/_{100} \times 2700 = 540 kCal\, kg^{-1}$

10% DW will contribute 3.9% CP (as previously shown)

$ME_{DW} = {}^{10}/_{100} \times 2450 = 245 kCal\, kg^{-1}$

CM, RM and FM will contribute,

$CP_{(CM, RM, FM)} = 40\ (8.8+3.9)$

$CP_{(CM, RM, FM)} = 27.3\%$ CP (as previously shown)

$ME_{(CM, RM, FM)} = 2900\ (540+245) = 2900\ 785$

$= 2115 kCal kg^{-1}$

% Content of CM, RM & FM = 100 (20+10)

CM, RM & FM = 70% content

To upgrade the variables to 100%,

$$CP_{(CM, RM, FM)} = \frac{27.3}{70\%} = \frac{27.3}{0.7}$$

$$= 39\%\ CP$$

$$ME_{(CM, RM, FM)} = \frac{2115}{70\%} = \frac{2115}{0.7}$$

$$\approx 3020 kCal\, kg^{-1}$$

Note that CM: RM = 1:1 (=2)

So, the joint (J) CP and ME contribution of CM and RM will be,

$$CP_J = CP_{CM} + CP_{RM} = (½ x 10\%) + (½ x 12\%)$$

$$CP_J = (5 + 6)\% = 11\% \, CP$$

$$ME_J = ME_{CM} + ME_{RM} = (½ x 3400) + (½ x 3200)$$

$$ME_J = 1700 + 1600 = 3300 kCal \, kg^{-1}$$

$ME_{FM} = 2800 k \, cal kg^{-1}$ and $CP_{FM} = 70\% \, CP$ (given)

If, a represents the proportion of J (i.e. CM + RM)

b represents the proportion of FM

$$CP_J.a + CP_{FM}.b = CP_{(J+FM)} (= CP_{(CM, RM, FM)}) \ldots eqn(i)$$

$$ME_J .a + ME_{FM} .b = ME_{(J+FM)} (= ME_{(CM, RM, FM)}) \ldots eqn(ii)$$

Substitute the values in both equations (i) and (ii)

$$11a + 70b = 39 \ldots.(i)$$

$$3300a + 2800b = 3020 \ldots\ldots(ii)$$

To eliminate a, multiply equation (i) by 300 and equation (ii) by 1

$$3300 a + 21000b = 11700 \ldots.. (i)$$

$$(-) \quad 3300a + 2800b = 3020 \ldots.(ii)$$

$$18200b = 8680$$

$$b = \frac{8680}{18200}$$

$$b \approx 0.477$$

Substitute the value of b in equation (i) to solve for a

$$11a + 70(0.477) = 39$$

$$11a = 39 - 33.39 = 5.61$$

$$a = {}^{5.61}/_{11} = 0.51$$

a is the proportion of J = 0.51

b is the proportion of FM = 0.477

Since J + FM = 70% of 100% concentrate formulation

J = 0.51 x 70%

J = 35.7%

J = CM + RM = 35.7%

(Remember, CM: RM = 1:1)

Therefore,

CM = ½ x 35.7% = 17.85%

RM = ½ x 35.7% = 17.85%

FM = 0.477 x 70% = 33.39%

FM 33.4%

SM = 20%

DW = 10%

To Cross Check

Feedstuff	%	Content CP (%)	Content, ME (Kcal kg^{-1})	Contributed CP (%)	Contributed ME(kCal kg^{-1})
CM	18.3	10	3400	1.830	622.2
RM	18.3	12	3200	2.196	585.6
FM	33.3	70	2800	23.310	932.4
GNC	20.0	44	2600	8.800	520.0
DW	10.0	39	2450	3.900	245.0
Total	99.9			40.036	2905.2

Harder Measuration

An easy example involving the use of harder measuration will be given for better understanding.

Question 4

A farmer wishes to formulate a concentrate for his 3 months old catfish, using corn meal, fish meal and an easy accessed, cheap blood meal. What proportion of each feed item will be required in making 100kg of concentrate of 50% CP, 3000kCal kg^{-1} and 4% ether extract (oil)?

Assumptions

Feedstuffs	Protein CP (%)	Energy, ME (kCal kg^{-1})	Ether extract E (%)
Corn Meal (CM)	10	3400	4.0
Fish Meal (FM)	70	2800	4.5
Blood Meal(BM)	70	3000	1.0

Given Data

$CP_{CM} = 10\%$; $ME_{CM} = 3400$ kCal kg^{-1}; $E_{CM} = 4\%$

$CP_{FM} = 70\%$; $ME_{FM} = 2800$ kCal kg^{-1}; $E_{FM} = 4.5\%$

$CP_{BM} = 70\%$; $ME_{BM} = 3000$ kCal kg^{-1}; $E_{BM} = 1\%$

$CP_C = 50\%$; $ME_C = 3000$ kCal kg^{-1}; $E_C = 4\%$

(Note: C = concentrate)

If,

a represents the proportion of CM in C

b represents the proportion of FM in C

d represents the proportion of BM in C

Then,

$CP_{CM}.a + CP_{FM}.b + CP_{BM}.d = CP_C$ ... equation (i)

$E_{CM}.a + E_{FM}.b + E_{BM}.d = E_C$ ... equation (ii)

$ME_{CM}.a + ME_{FM}.b + ME_{BM}.d = ME_C$ ...equation (iii)

Introduce given data into the equations.

$10a + 70b + 70d = 50$ ....(i)

$4a + 4.5b + 1d = 4$ .... (ii)

$3400a + 2800b + 3000d = 3000$ ..... (iii)

(Divide each equation by its highest common factor to limit the figures with which we will be working with)

Divide equations (i) by 10, (ii) by 0.5 & (iii) by 200

$a + 7b + 7d = 5$ .... (i)

$8a + 9b + 2d = 8$ .... (ii)

$17a + 14b + 15d = 15$ .... (iii)

Pair 2 sets of equations, and eliminate a

(i) & (iii); (i) & (iii)

(x8) $a + 7b + 7d = 5$ ......(i)

(1x) $8a + 9b + 2d = 8$ .....(ii)

$$
\begin{array}{rl}
 & 8a + 56b + 56d = 40 \\
(-) & \underline{8a + \ 9b + \ 2d = \ 8} \\
 & \therefore \ 47b + 54d = 32 \quad \text{.....(iv)}
\end{array}
$$

(x17) $a + 7b + 7d = 5$ ...... (i)

(x1) $17a + 14b + 15d = 15$ ...... iii)

$$
\begin{array}{rl}
 & 17a + 119b + 119d = 85 \\
(-) & \underline{17a + \ 14b + \ 15d = 15} \\
 & 105b + 104d = 70 \quad \text{...... v)}
\end{array}
$$

Pair equations (iv) and (v), and eliminate d

$$(x104) \qquad 47b + 54d = 32 \qquad \ldots. (iv)$$

$$(x54) \qquad 105b + 104d = 70 \qquad \ldots. (v)$$

$$\begin{array}{ll} (-) & 4888b + 5616d = 3328 \\ & \underline{5670b + 5616d = 3780} \\ & 782b \quad \ldots. \quad = 452 \end{array}$$

$$b = {}^{452}/_{782} = 0.578$$

Substitute the value of b in equation (v)

$$105b + 104d = 70$$

$$105\,(0.578) + 104d = 70$$

$$60.69 + 104d = 70$$

$$104d = 70\ \ 60.69 = 9.31$$

$$d = 9.31/104 = 0.0895$$

Substitute both b and d in equation (i) to solve for a

$$a + 7b + 7d = 5 \qquad \ldots\ldots (i)$$

$$a\ + 7\,(0.578) + 7\,(0.0895) = 5$$

$$a + 4.046 + 0.6265 = 5$$

$$a = 5\ \ (4.046 + 0.6265)$$

$$a = 5\ \ 4.6725 = 0.3275$$

So, the proportion of

CM = a x 100% = 0.3275 x 100%

CM = 32.75% ≈ 32.8%

FM = b x 100% = 0.578 x 100%

FM = 57.8%

BM = d x 100% = 0.895 x 100%

BM = 8.95% ≈ 9.0%

To Cross Check

Feedstuff	%	Content CP (%)	Content, ME (Kcal kg^{-1})	Content E (%)	Contributed CP (%)	Contributed ME(kCal kg^{-1})	Contributed E (%)
CM	32.8	10	3400	4.0	3.28	1115.2	1.312
FM	57.8	70	2800	4.5	40.46	1618.4	2.601
BM	9.0	70	300	1.0	6.30	270.0	0.090
Total	99.6				50.04	3003.6	3.003

5

Feed Processing and Production

Processing of Feedstuffs/Feeds

The drive to intensively produce large quantities of fish at an affordable rate and within a short period to meet both local and international animal protein demand has led to the use of various modified structures, hi-tech breeding and management, and the use of diverse feed materials. The continuous use of some cheap organic by-products/wastes such as poultry and hatchery wastes in fish management (without adequate processing) is often found to produce some deleterious effects on cultured fish and occasionally on the end consumer (man). The stress induced on farmed fish as a result of the high intensity of farming may further be worsened by the unmonitored, indiscriminate use of such unprocessed materials for pond fertilization or as fish feed. The final result is the horrible sight of various kinds of ailments that would have been prevented. Adequate processing of edible materials before use is thus considered a **must** to maintain minimal level of water pollution and 'potential' pathogens. This enhances fish health, minimizes loss of nutrient to immune building and promotes productivity.

Feedstuff/feed processing is recommended for the under listed reasons.

- To improve nutrient availability, palatability and presentation of the feed.
- To remove or minimize the risk of having pathogenic contaminants
- To minimize water pollution
- To make the incorporation of some unconventional feed materials into formulated fish diets feasible and healthy.
- To facilitate the preservation of feeds / feed materials.

Feed ingredients may be solitarily processed and stored for future / commercial use, or are collectively processed during production. The processing may be crudely performed, or the use of 'modern' machines employed. Feed processing may involve the use of heat-treatment ('dry' and 'wet' heat application), chemical application, seasoning and / or irradiation. These means of processing may be combined in various ways that ensures good quality product.

Heat-Treatment

Currently, this principle is mainly applied in aquafeed processing worldwide. It involves the use of heat to improve the quality of feed / feedstuffs. The treatment may be in the form of 'dry' or 'wet' heat application, or a combination. The effect of heat treatment is greatly improved under high-pressure. With high pressure application, the use of heat (i.e. steam / mechanical heat) will, in addition to destroying pathogens, increase the availability of some bound nutrients, enhance feed stability in water and denature anti-nutrients. This combination of high pressure and heat is effectively utilized in the operation of Universal Pellet Cookers, Steam Pelletizers and Extruders — see pressure pelleting and extrusion below.

Chemical Application

Some chemicals with food digestive properties may be applied to increase nutrient availability. An example is the use of potash, sulphide or pepsin in feather meal production.

Seasoning

Seasonings are often used to increase food palatability. Interestingly some seasonings have varied anti-microbial actions, thus are also useful as preservatives. Examples of common seasonings are salt, pepper, ginger, garlic and flavours.

The palatability and consumption of some poorly fed feeds may be enhanced if such feeds are carefully seasoned. This is sometimes observed when feeding rich fish concentrates that have low fishmeal content or are poorly scented. Such quality feeds are often rejected or poorly fed on when compared to the level of acceptance of less quality feeds (i.e. lower protein, energy and vitamins / minerals content) that contain relatively high fishmeal content or are better scented. The only way to increase the level of acceptance of such feed is to "season" it with the right additives, just before manual pelleting or after extrusion (except the scent is unaffected by heat). The use of fish flavour may be helpful in solving this puzzle.

Also, seasonings (as preservatives) are sometimes added to some processed feed ingredients such as fish and insect meals to increase the shelf-life.

Irradiation

One of the reliable ways of sterilizing feed materials is by irradiation. The technique, although very effective in feed sterilization and prolonging feed shelf-life, is yet to be explored in aquafeed processing.

Local Ways of Processing Some Unconventional Feed Items

Below are some suggested means by which the selected 'feedstuffs' may be processed by peasant fish farmers for local use.

Hatchery/Poultry By-products or Wastes

(Unhatched eggs/Dead-in-shell embryo/Dead chicks/ Poultry bird guts/Animal carcasses)

- Where necessary, chop sizeable 'meat' into bits e.g. dead birds / animals and intestine.
- Rinse in changes of clean water to reduce dirt.
- *Store in a refrigerator until enough quantity is obtained.
- Boil in salted water or steam the feedstuff for about 20 to 30 minutes.
- Drain off excess fluid.
- Properly dry up the stuff using a low heat feed drier — solar, electric or fuelled feed driers. Alternatively, sun-dry under hygienic condition, ensuring that the feed is properly dried in the sun for 2 to 3 days, depending on the weather.
- Mill into powdered form.
- Determine the nutrient content, package and store in cool dry place until it's needed for production.

Note: The calcium content of hatchery egg meal may be regulated by removing the shell or the calcium content considered when formulating the feed.

Bred Earthworms/Tadpoles/Insects

- Harvest and rinse the animal
- Immerse into hot, salted water for about 10 mins

- Drain off excess fluid
- Properly dry the feedstuff under low (uniform) heat in a feed drier or (alternatively) sun-dry under hygienic condition.
- Mill into powdered form
- Package and store for farm use.

*Note: * Flying insects, such as flying reproductive termites (before mating) and farm flies, may be harvested in substantial quantity with an '**insect-harvester'** overnight (pix 11).*

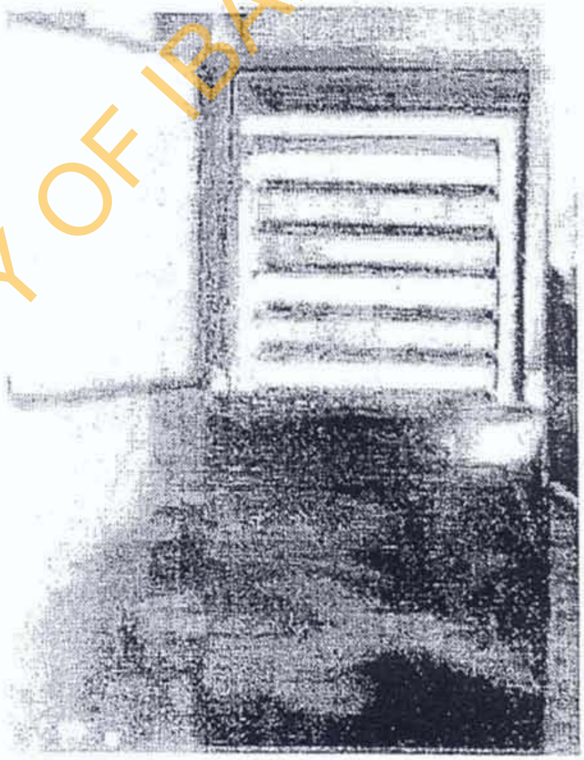
** Seasonings such as salt, ginger, garlic and pepper may be added to the final package to increase the shelf-life.*

Modern Fish Diet Production

Once the feed has been formulated to determine the proportion of mixture of the selected feed ingredients, the feed materials should be assembled for production.

In producing formulated fish diets, certain factors such as fish species, age group, size, feeding habit and environment must be put into consideration. Commercially produced fish concentrates are commonly sold as granulated, flaked or capsulated

Pix 11: Insect Harvester



Pix 12: Electric Feed Dryer

feeds, which may sink or float. The feeds come in various sizes, as cultured fish are best fed on feeds of about 20 to 30 % of their mouth size.

Commercial aquafeed production is basically by extrusion or pressure pelleting. The feedstuffs are pre-milled with a milling machine (mostly hammer mill / Bhurh mill) into fine powdered particles, and thoroughly mixed in a homogenizer (mixer). Homogenized fluid or semi-solid feedstuffs such as milk, blood, egg and tomato puree may be added to the mixture in the homogenizer to produce a mash. The thoroughly mixed feed ingredients/mash may be fed to a conditioner before being extruded/pelleted, or directly fed to an extruder / pelletizer.

Extrusion

Extruders are basically screw pumps within which feed ingredients are subjected to thorough 'cooking' under high temperature and pressure in an extruder barrel, to produce the sheared end product (finished feed) from the die. This method of feed processing, using an extruder, is termed feed extrusion. The process may or may not require that the mixed feed / mash be pre-conditioned in a conditioner before it enters the extruder barrel.

Basically, an extruder barrel consists of the barrel heads, screws, shearlocks (flow restrictors) and a die. The barrel heads may be jacketed for steam or cooling water to manage the cooking process in the barrel. Its wall is designed to maintain the generated pressure and resist the dough-like feed from sticking to the screws as they rotate.

The rotating screws generate the heat (mechanical energy) used in the cooking process, help in pressure building and distribution, and mixing of the mash into dough form. Shearlocks control the feed retention time, thus managing the pressure, the period of cooking within the barrel and the final product quality. The die aperture design dictates the shape and size of the final product.

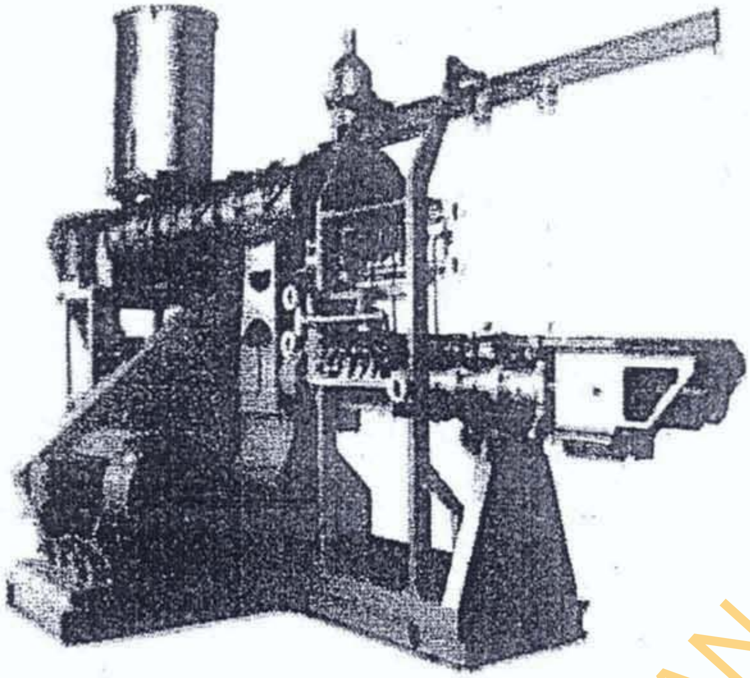
The extruder barrel may be sectioned into the feed zone, transition zone and metering (final cooking) zone. Each section is furnished with a set of screws, with or without shearlocks, for proper functioning. The feed zone serves as the entry point for feed mash into the extruder barrel. With the aid of the screws and shearlocks of the barrel transition and metering zones, the received mash is compressed, expanded, degassed and cooked (under high temperature and pressure) into amorphous, continuous dough. The cooking is facilitated by the pressured steam from the steam injector and the mechanical heat generated by the screws, with the continuous mixing of the mixture. The highest degree of cooking takes place in the final cooking zone. Moisture regulator may be installed in the barrel to control the moisture level.

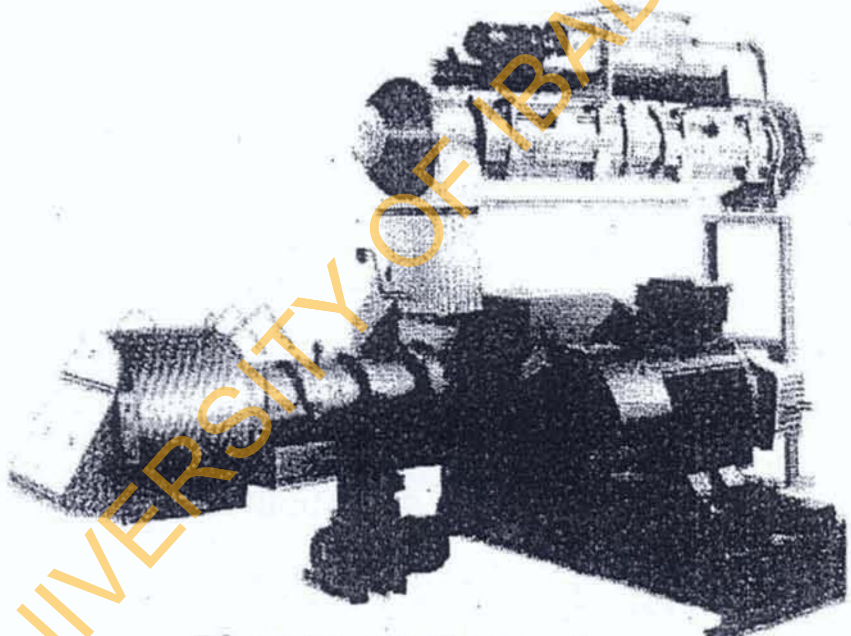
This cooking under great pressure and temperature is of enormous importance in improving feed gelatinization for proper binding (feed stability) and floating feed production. It also enhances nutrient digestibility, feed palatability, denatures anti-nutritional factors such as trypsin inhibitors and gossypol, and inactivates most microbial agents.

As the dough is forced out through the extruder die, it assumes the shape and size similar to the design of the die aperture. The length of the final product is regulated by the die shear rate. The feed is then heat dried and cooled with a cooling dryer or simply dried with a dry-low-heat blowing device to the desired moisture content (normally less than 10%) e.g. cabinet dryer and rotary dryer. Heat sensitive amino acids, vitamins, phytase, enzymes and drugs are often applied as feed coating after extrusion. The obtained dried feed strands may then be crumbled and sieved to produce the desired granule size for fish seedlings.

The resultant feed is well bound and floats on water surface. Floating feed is often preferred to other feed types (sinking and slow-sinking feeds) because it enables farmers observe the rigorosity at which their fish feeds ("feeding frenzy"), and so determines when their fish are satisfied, as well as their growth performance.

Pix 13: An Extruder





Pix 14: An Expander

Pressure Pelleting

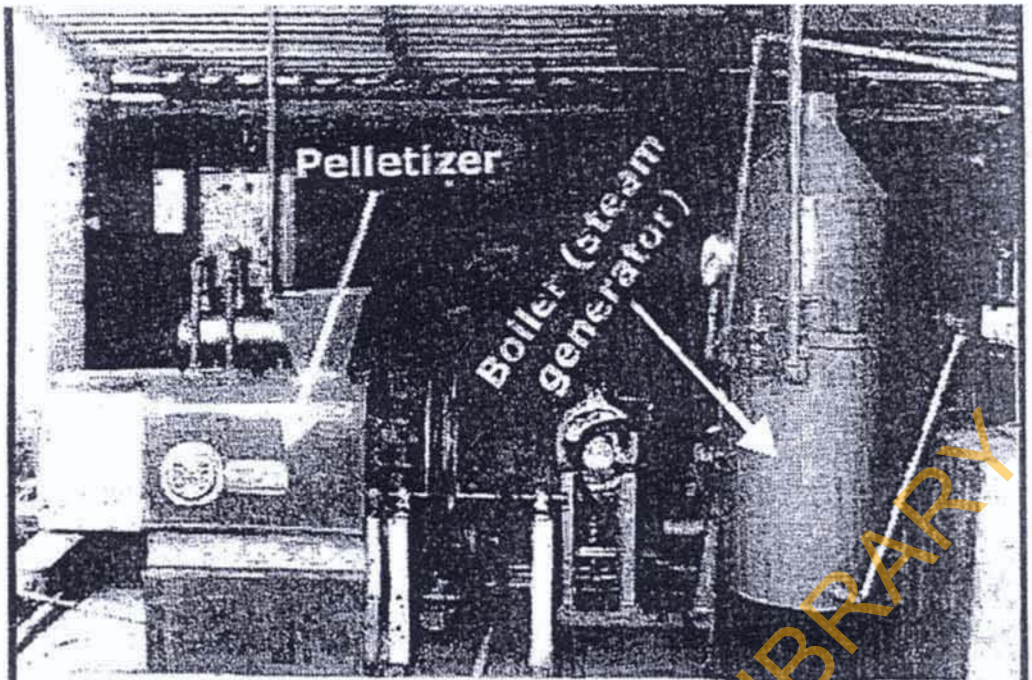
This was initially achieved by forcing moist feed mash through the barrel of a meat mincer or a manual / motor driven screw pump, and out through the apertures of its die. The screw of the barrel is either manually or mechanically driven to mix and move the mash towards the die. The pressure generated by the screw forces the mash through the die apertures to produce compressed feed strands that are sheared and dried to form feed pellets. There is no significant feed 'cooking'.

Later on, a series of steam pelletizers were manufactured to produce feed pellets under pressure and heat. The homogenized feed/mash fed into the barrel is cooked by mechanically generated heat and injected steam to a temperature of about 70 – 85°C. Pellets produced are more stable and of higher quality.

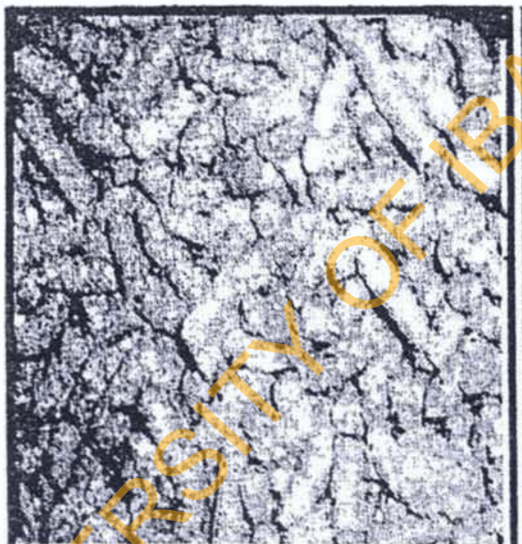
This method of feed processing has further been improved on lately. The mash is 'cooked' under slightly elevated steam pressure at a temperature of about 100°C (or more) in the barrel of the pelletizer.

The formed dough is forced through the apertures of a die to produce pellets from the sheared noodle-like output. The pellets are then dried, cooled and bagged for future use. This type of feed may float for a while and later slowly sinks in water, especially when the feed materials are carefully selected.

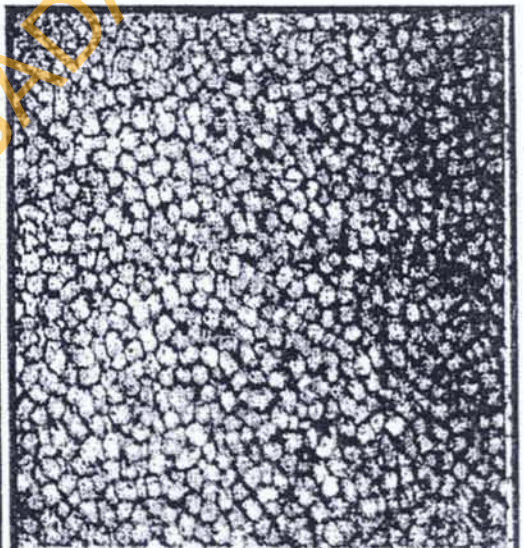
Today, virtually all the available feed processing machines employed in aquafeed industry function by means of heat treatment (wet and dry heating) under high pressure — extruders, pelletizers, universal pellet cookers, expanders, feed driers e.t.c. — to produce wholesome feed for fish consumption. However, the extrusion technique may be preferred in handling highly contaminated materials that are being considered as feed ingredients (e.g. hatchery wastes and animal intestine), because of the high processing temperature and pressure.



Pix 15: Locally fabricated Pressure Pelletizer with Steam Injector



Pelletized Feed



Extruded Feed

6

Determining the Quality of Fish Feed

Once the concentrate formulation has been determined, the next step is to find a good miller that will assemble all the necessary feed materials (including the required additives) to produce the expected quality feed bargained for.

Ideally, it is expected that aquafeed millers should ensure that quality feedstuffs are used in their industry to produce quality feeds, but the opposite is often encountered. This may be due to factors such as:

- miller's inability to distinguish between good and poor quality feed materials.
- desire to increase their net profit by buying

cheap products / poor graded feedstuffs.

- in an attempt to sell/produce fish feed at similar price to other competitors.

The quality of fish concentrate is affected by the underlisted factors that should be carefully considered in feed production.

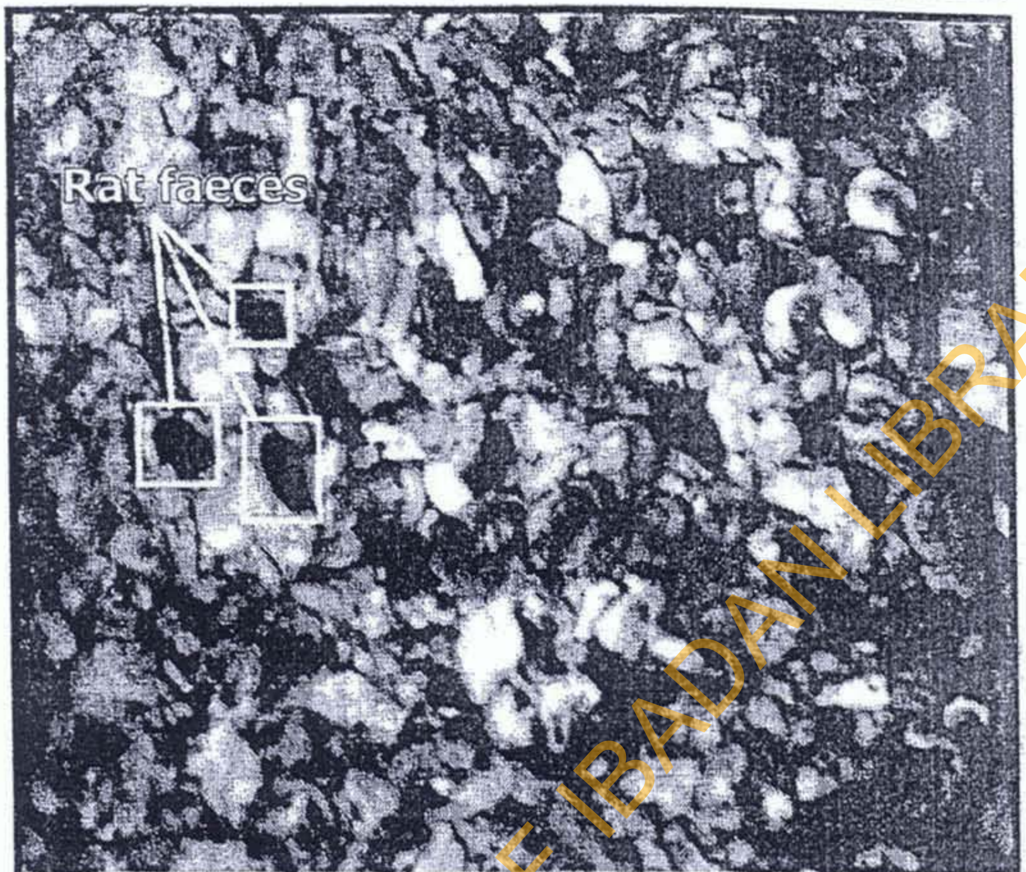
Quality of feed items

The grade or quality of feed materials used in feed production is a major determinant of the final feed quality. Incoming grains and other feedstuffs brought into a feed-mill by dealers are expected to be physically examined for purity, texture and density by the quality control manager or trained management personnel, in order to maintain good standard of operation. The supplied bagged ingredients should be randomly sampled using an appropriate probe (e.g. spear probe for grains). The obtained samples of each ingredient should be thoroughly mixed, the volume reduced, and the final lot examined for normal colouration, moisture, odour (for freshness), mouldy growth, weevils and impurities, with or without the aid of a hand lens. Where fine granules and powdered materials are involved (e.g. fish meal & lysine), feed microscope may be required to physically examine the quality of such items. Part of the mixed sample should also be ground and submitted for chemical quality control analysis, especially when in doubt of the examined feed quality. Parameters to be determined in the quality control laboratory include moisture content, crude protein, crude lipid, crude fibre, ash, nitrogen-free extract, calcium, phosphorus and lysine. Feed ingredients that are predisposed to high levels of certain anti-nutrients need to be tested prior to use.

Poor quality feedstuffs may, in addition to not providing the expected nutrients, serve as possible source of harmful microbes / chemicals e.g. salmonella and mycotoxin contaminants. The sight of broken grains, dull looking or mouldy feedstuffs, rat faeces and the likes in bagged feed materials, is an indicator to the poor quality of feed materials (pix 18) available in a feed mill. It is disheartening to note that some feedstuffs are purposefully adulterated by their suppliers just for the sake of getting more gains, without considering the possible effects of such acts on both the cultured fish and final consumer (man). As a result, farmers are encouraged to physically examine the available feedstuffs in a milling centre for quality assessment before producing their animal feeds.

Some Impurities often Found in Adulterated Feed Items

Feed Items	**Impurities**
Corn	Chopped cobs & chaff, stones
Soybean	Sand, stones & millet
Full-fat soy	Ground yellow corn
Groundnut cake	Cottonseed cake
Brewers dried grain	Sand & stones
Lysine	Yam flour
Methionine	Cassava flour
Bone meal	Charcoal
Milled oyster shell	Beach sand



Pix 18: Impurities Found in Sampled Corn

Feed processing

Aquafeeds are often processed into pellets, flakes or capsulated feeds for various reasons. The degree and method of 'cooking' in a feed processor goes a long way in determining the final feed quality — nutrient availability, feed stability, digestibility, palatability, pathogens destruction, anti-nutrients denaturing and so on. The heating effect of feed extrusion, for instance, is significant on some amino acids (e.g. lysine) and vitamins availability, although it favours feed stability in water and microbial denaturing.

Where the quality of the finished feed cannot be guaranteed due to lack of an appropriate processing equipment, it is safer and better to maintain cultured fish on an expensive, nutritive locally produced or imported feed of high quality than to produce a cheaper feed of poor (health) quality. The method of feed processing is important, especially when producing fish diets from animal protein or other easily contaminated materials. To prevent the ugly site of diseases, formulated feeds should be hygienically handed and processed.

Feed presentation (Finished Feed)

Feed millers are expected to produce well blended, thoroughly mixed, quality fish diets. The quality of finished feed produced from a feed-mill or those obtained from feed-sales outlets may be assessed by the manager / farmers by considering its physical appearance and odour, before sending the sample to a feed laboratory for further analysis.

Physical Appearance

Quality finished feeds may be ascertained by ensuring that the ingredients are well blended, thoroughly homogenized and hygienically pelleted. Feed samples should be crushed, examined and the following questions answered.

- Is the feed dull looking or fresh in appearance?
- Is the appearance identical to those (same formulation / product) previously bought from a reliable source?
- Are the feed crumbs similar, well blended and homogenized?
- Is the feed stable in water?
- For how long can the feeds (if expanded) float in water?

The obtained response to these questions may give a lead to the type of quality feed expected.