A SHORT HANDBOOK - CATFISH FEED FOR NIGERIA

MATERIALS STORAGE, HANDLING, STOCK AND QUALITY CONTROL, INGREDIENTS, FEED FORMULATION, FEED USE (FEEDING HUSBANDRY) AND TECHNICAL ASPECTS OF FEED MANUFACTURE.

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Feedback to catfish feed producers/farmers

Almost all of the small-scale (SME) catfish feed producers met in Nigeria have a similar set of issues. This short set of notes attempts to address these in a generic fashion.

Background:

There is considerable room for, and great need of, improvement. The production of floating or at least water stable feed requires a totally different setup - both technically and in terms of the organization of activities around production.

The market for feed is enormous: Imported feed is normally used up until 3-4 mm size and this is <20% of the total feed needed to raise fish at current production levels. Combined with information about juvenile production , it has been estimated that Nigeria's present market for fish feed is > than 300,000 tons per year.

Over 90% of the farmers express a need for floating feeds – due to perceived;

- Less feed waste and pollution of ponds/tanks/raceways.
- It is easier to observe when fish are satiated – fully fed.
- They would like to be able to sell feed to other smaller producers who demand floating feed.

Floating or water stable feeds are also called "advanced feeds". They require different and more complex technology than are required for ordinary pelletized feeds such as those used for poultry, cattle and pigs.

All producers must realise that there is no easy or cheap way to obtain of the desired floating, water stable, extruded product. If existing pelletizers were capable of modification to do the required job, producers would have to face the fact that output would drop to <1/3rd of present capacity. In addition energy costs would rise substantially because of the need for more intensive drying.
An extruded, water stable, floating pelleted product is, of necessity, of initially higher moisture content when it leaves the pelleting die.Thus is not simply a matter of sourcing or adapting extruders/pelleting machines. If farmers had extruders capable of making floating feed, they would need specialised and improved drying equipment to ensure that the product did not end up as a large sticky mass. Immediately after extrusion the product needs to be spread out in a thin moving layer exposed to considerable warm air convection to prevent "lumping" before drying – investment in an extruder cannot stand alone.

It follows that the minimum investment in terms of equipment is: extruder with pre-conditioner and cutter; continuously running dryer and a steam boiler to produce steam for the pre-conditioner and to provide heat to the dryer. All of these components should be connected one to another as a production line.

An estimate for such a system on a small scale together with the necessary accessories, set-up and labour is a minimum investment of N 40.000.000 (forty million Naira). With the information obtained on raw material cost, energy and labour cost, and interest rates, the minimum annual production would need to exceed 500 tons to justify this level of investment.

The technical level, with respect to feed technology, of the people involved is presently very low, and the risks of making failed investments are high.

Examples of producers acquiring Chinese "dry pelletizers" and "extruders", and also FreshCo's experiment with a locally produced belt dryer as well as struggles with locally made "extruders", all demonstrate that for local production to be successful and to become established there is a considerable requirement for additional technical support.

It is possible to construct or modify local extrusion pelleters, but the effort and time required is enormous, whilst the outcome may still be unpredictable.

This handbook is therefore written with the aim of providing a starting point for those engaged in, or interested in, the production of floating fish feeds for the catfish sector in Nigeria. The objectives are:

- Provide technical data on the ingredients currently used and available in Nigeria as to their suitability or need for inclusion in diet formulation
- Basic guidelines for diet formulation
- Basic guidelines for production equipment and the technology required for production of floating feeds

It must be remembered that there are no quick fix solutions or shortcuts that will immediately produce a water stable, floating feed. Investment will be required in equipment, diet formulation and technical training. However the market exists to support this level of investment and all potential producers of feed should take time now to ensure that the correct equipment and technology are installed for the future.

Materials handling, storage and stock control

In general, feed ingredients and finished feeds are often very poorly stored and managed. It is worth remembering that there is little point purchasing expensive raw materials (such as imported fishmeal and vitamin premix) or finished feeds (such as Coppens) if poor handling is going to result in spoilage/loss of nutritional value prior to use. In this respect there are a number of simple points that must be emphasized:

- **Record keeping, labelling and stock control.**
  - All materials entering the store **must be clearly labelled** and information about them recorded so that data on, at the very least: source, type, date purchased, price, date of expiry are attached to a traceable batch number.
  - When feed is manufactured it must also be **batch numbered and clearly labelled** with details of manufacturing date, expiry date, formulation used, batches of ingredients used etc. It is essential to establish traceability so that records allow the chain; fish batch, feed batch(es), raw material batch(es) to be easily established.
  - Accurate labelling will enable stock rotation to ensure the principle of 'first in, first out' i.e. that the **material that has been in store the longest is used first**.
  - For stock control purposes **all material removed from store must be entered into a balance sheet** (daily if possible) so that the remaining stock is always known. This enables planning of replacement purchases and also allows checking for untraceable stock losses (possible theft etc.).

- **The feed store**
  - The building must be waterproof, well ventilated and secure. The recommended design is a building with the long axis facing the prevailing wind and with low level ventilation on the windward side and high level ventilation on the leeward side. This ensures optimal air circulation. The building should have a solid, preferably concrete, floor.
  - Materials **must be stored off the floor** (on pallets or racks) and **not in contact with the walls** (to prevent them getting damp). Air must freely circulate around the materials, there should be room to walk around a stack of stored materials.
  - **Stacks must be limited in size** (surface area) and depth (height of stacked sacks). If this is not done materials in the centre or at the bottom will get damp, will heat and will spoil (mould, oxidation etc). A block of stored sacks should not exceed $1.5m^2$ and approximately 1m in depth. If you need more height in your storage area then use a

racking system. Controlling the size of stacks of sacks also aids access to the materials so that your stock rotation goals can be met.
    - The **feed store must be kept clean**, all spilled materials/split sacks etc should be dealt with immediately.
    - **The feed store should not be in the same building as the feed production area**. Feed production involves moisture, steam and dust and these are detrimental to good storage.
    - Finally, if customers visit your feed mill there is no doubt that a well kept and presented store will impress them with the quality of your operation. A dirty, poorly kept, store does exactly the opposite.

- **Quality control**
    - **All materials entering the store should be subject to careful visual inspection**. Damaged materials (damp, split sacks, signs of insect/rodent infestation etc) must not enter the store until the problem is remedied.
    - The odour (smell) of incoming materials is also a good indicator of quality. Anything that smells wrong should not enter the store until the problem is remedied.
    - Where possible, samples of materials entering the store should be taken (using standard sampling techniques), labelled and retained. These samples should be analysed for MOPFA (moisture, oil, protein, fibre and ash), energy and possibly total viable spore count.

Feedstuffs and feed ingredients

Most catfish feed producers visited were manufacturing feed based on similar ranges of raw materials (not all listed below). The following table indicates the ingredients encountered, the range of prices quoted and provides comments on the utility of each.

Ingredient	Price range (N.kg^{-1})	Comment
Fishmeal - Indonesian	145	72%CP[1], Uncertain provenance/composition – **Advice** Do Not Use
Fishmeal – Danish (999)	290-320	72%CP, **Advice** Use sparingly no more than 30% in fingerling – juvenile rations, 20% in grower feed
Blood meal[2]	35	84%CP, **Advice** Uncertain quality, good blood meal is hard to manufacture, use no more than 5%
Bone meal	20-30	**Advice** Unnecessary, do not use
UFAC UK Seepak	200	65%CP, **Advice** Unknown composition, animal by-product meal? Caution.
UFAC UK Monomega	200	45%CP, **Advice** Unknown composition, plant (soy) based meal? Caution.
Oilseeds		
Soybean meal	55-70	40-44%CP, **Advice** Use as primary plant ingredient
Full fat soybean meal	70	<40%CP, **Advice** No advantage over soybean meal, if not properly cooked then antinutritional factor issues. Fatty raw materials reduce binding and expansion properties of feed pellets, use no more than 20 %.
Groundnut cake (GNC)	25-40	40%CP, **Advice** Care, GNC frequently a source of aflatoxin and poor quality, use no more than 20%. As mentioned above, due to the fat content, use no more than 25 % in total together with full fat soybean meal.
Cereals etc		
Maize	25-40	4 months ago only 25N.kg^{-1}, **Advice** Use as primary cereal/carbohydrate ingredient. To get the best binding and expansion use no less than 15 %, rather 20 %.
Whole wheat (US import)	25-26	**Advice** At such a low price use if maize prices high or availability an issue. It is the only realistic replacement for maize.

[1] CP = Crude Protein

[2] Locally produced from cooked coagulated blood, separated and sun-dried. Likely to be of very poor quality.

Wheat offal	9-18	**Advice** At this price use to substitute up to 1/3rd of maize
Biscuit dough	23-35	**Advice** At this price range use only if cheaper than maize/wheat overs
Indomie (noodles)	43	**Advice** Do not use. More expensive than maize or wheat, a pure carbohydrate source of no real value.
Rice bran	9	**Advice** Very low value ingredient for catfish. Do not use even at this price.
Dried brewer's yeast	35	30%CP, **Advice** At this price use no more than 5%, recommendation: omit to simplify formulation
Cassava starch	120	**Advice** Do not use. Maize/wheat are better and if properly cooked during pelleting contribute all the binding required.
Molasses	30	**Advice** For pelleted (pressed) feed molasses can be a good pellet conditioner (reduce dust, improve pellet quality) at up to 10% of ration. Little value in extruded feed.
Supplements		
Supplemental lysine	500	**Advice** Unnecessary, do not use
Supplemental methionine	650-700	**Advice** Unnecessary, do not use
Broiler starter vitamin premix	610	Use double broiler rate **Advice** Check against fish vitamin requirements, possibly adjust inclusion level.
Fish specific vitamin premix	960-2900	**Advice** Compare levels with the requirements listed below, buy the most effective premix containing protected vitamin C.
Vitamin C	$400.100g^{-1}$	**Advice** Use protected vitamin C (e.g. monophosphate) to give no more than $100mg.kg^{-1}$ vitamin C
Vitamin C – protected (coated or monophosphate)	2150-3200	**Advice** Use only if premix does not give a final level of protected vitamin C of $100mg.kg^{-1}$ of diet.
Oyster shell meal	7-13	**Advice** Unnecessary, do not use
Di-calcium	120	**Advice** Unnecessary, do not use

phosphate		
Salt	14-40	**Advice** Unnecessary, do not use
Enzyme mixture	$750.500g^{-1}$	**Advice** Unnecessary, do not use
Toxanil	460	Salmonella toxin binder, **Advice** Unnecessary, do not use
Albac	3000	Growth promoter?, **Advice** Unnecessary, do not use
Oxytetracyclin	355	Antibiotic, **Advice** Unnecessary, do not use

Animal Products

Catfish are carnivorous and thus animal protein, especially fishmeal, in the feed is both attractive to the fish (they like the taste) and makes it easy to satisfy their dietary protein and essential amino acid requirements in the feed formulation. Because it is a key ingredient it is sensible, despite issues of cost and availability, to use good quality fishmeal and the commonly employed Danish 72%CP fishmeals are an excellent example of this. Experiences with other fishmeals (Chinese and Indonesian) have been varied and the Chinese fishmeal is reportedly responsible for numerous fish mortalities.

However, fishmeal is not essential in catfish feeds and with careful formulation could be replaced largely by plant protein (such as soybean) or terrestrial animal by-product meals (especially blends of hydrolyzed feathermeal and poultry by-product meal). The issue is one of maintaining quality and acceptability in the feed. Addition of 5-10% of a highly palatable meal (such as shrimp head meal) or coating pellets with 3-5% fish oil (currently unavailable in Nigeria) will maintain the feeding response if fishmeal levels are lowered. The use of imported animal by-product meals should be investigated. Ultimately, an animal by-product processing industry in Nigeria would be very valuable.

Oilseeds

Groundnut cake (GNC) is a notoriously variable product and often (if slightly wetted) a source of aflatoxin contamination through growth of toxin producing *Aspergillus* sp. Its use should therefore be restricted and no more than 20% included in catfish feeds as well as great care being taken to source a good quality product. Special care should be taken with GNC included in fry feeds and broodstock feeds where poor quality GNC (and aflatoxins) will be more harmful.

There would appear to be no advantage to the use full fat soybean given that there is no price benefit and the fact that soybean meal is higher in crude protein.
Both GNC and full fat soybean meal reduce binding and expansion properties in feed pellets and should be included in total at no more than 25 %.

Cereals and Carbohydrate Sources

Depending upon price and availability whole maize would be first choice in catfish feeds followed by whole wheat and to a lesser extent by wheat offal. Indomie (noodles) and other pure carbohydrate sources (such as cassava starch) have no nutritional value for catfish. The whole cereals (maize and wheat) if properly heated during pelleting should provide all of the binding required. Biscuit dough and rice bran are similarly not of value in catfish feeds.

Supplements

It is here that the most money is presently being wasted in Nigerian catfish feed production.

Mineral supplements

Many catfish feed formulations contain oyster-shell meal, bone meal and di-calcium phosphate notionally as sources of calcium and phosphorus. These are unnecessary. Fish have low requirements for calcium and phosphorus compared to land animals (they have much less bone) and requirements for these two mineral elements will be met from either the water or from endogenous sources in the diet (fishmeal is an especially good source).

Salt (NaCl) is also added to some catfish feeds. This is of zero nutritional value to catfish, there is no dietary salt requirement. Salt might, to a very slight extent, protect poorly dried feed (i.e. >10% moisture) from microbial spoilage but the protective effect is minimal. Salt should be omitted.

Amino Acids

Many catfish feed formulations contain supplemental methionine and/or lysine. These are unnecessary and should be omitted. In reasonably formulated catfish feeds, especially any containing ≥10% fishmeal, these essential amino acids will be present at adequate levels and supplements are not needed. In any case, evidence suggests that free supplemental amino acids are very poorly utilised (if at all) by fish.

Toxin binders, growth promoters, enzymes, anitbiotics etc

None of these are necessary, effective or recommended in catfish feeds. The only possibly useful additives might be anti-fungal agents, especially those that are effective by reducing water activity (have a very high affinity for water).

Vitamin Premixes

The two issues here are:

- Does the premix meet the requirements of catfish in general for vitamins?
- Does the premix meet the requirements of catfish specifically for vitamin C (ascorbic acid)?

The table below indicates the levels of vitamins that should be supplied in a catfish feed.

Vitamin	**Inclusion per kg diet**
Fat soluble vitamins	
A (Retinol)	20,000IU
D (as D_3) (Cholecalciferol)	4,000IU
E (α tocopherol)	150IU
K_3 (as menadione sodium bisulphate)	10mg
Water soluble vitamins	
Thiamine (B_1)	20mg
Riboflavin (B_2)	15mg
Niacin (B_3) (as nicotinic acid)	100mg
Calcium pantothenate (B_5) (approx. 26% pantothenic acid)	150mg
Pyridoxine (B_6)	20mg
Cyanocobalamin (B_{12})	0.015µg
Biotin	0.5µg
Folic acid	6mg
Inositol	50mg
Choline (as choline chloride)	600mg
Vitamin C (ascorbic acid)	100mg (e.g. coated ascorbic acid, 35% activity included at 286mg)

Note: *The levels given in this table are the maximum levels that would be required. It is possible that these could be reduced without compromising catfish growth especially when the intrinsic residual vitamin contents of the feed ingredients are taken into account.*
Note that the premix must also contain an artificial antioxidant and the most usual additive in this respect is BHT (Butylated hydroxytoluene) to give a final level in the feed of 125-150mg.kg^{-1} (and certainly no more than 200mg.kg^{-1}). These vitamins are bulked with a carrier (such as a cereal bran or calcium carbonate etc) to produce a dilution that can more easily be mixed into the feed at, for example, a premix inclusion rate of 5kg.t^{-1}.

Special comments on vitamin C (ascorbic acid)

There is absolutely no point in adding free, unprotected, L Ascorbic Acid (pure vitamin C) to catfish feeds. This vitamin is simply too easily oxidised and highly water soluble so that any quantity added to the feed either in a premix or separately is wasted. Much less than 10% of any pure vitamin C added to the feed will be present by the time catfish consumes or eats it.

Only protected forms should be used, either coated or modified (such as ascorbyl monophosphate – StayC). These protected forms have lower activity than the pure vitamin and this will be stated on the labelling. Coated vitamin C is typically 35% vitamin C so that for a final vitamin C level in the feed of $100mg.kg^{-1}$ you would need to add $286mg.kg^{-1}$ of the coated product.

It is widely believed that a condition known as ‘broken head’ disease in Clarias catfish can be prevented by adequate supplementation of the feed with vitamin C. Evidence suggests that the condition is prevented by $50mg.kg^{-1}$ vitamin C. A level of $100mg.kg^{-1}$ is thus recommended here to be certain that this issue is dealt with.

If the premix contains sufficient vitamin C in a protected form to give a final level in the feed of $100mg.kg^{-1}$ then no further supplementation is required. If it does not, then protected vitamin C should be added to the feed at the required level.

Despite many widely held beliefs there is no evidence that megadoses of vitamin C (i.e. levels in excess of $100mg.kg^{-1}$) are of any benefit in the feed. Exceeding the $100mg.kg^{-1}$ level is simply a waste of money, vitamin C is a small, water soluble, easily excreted molecule that is not stored – excess vitamin is thus rapidly excreted.

Example feed formulations for Clarias catfish

As a rule, simple formulations are preferred, the fewer raw materials you have to deal with the simpler the whole operation becomes.

Ingredient	**Inclusion level ($kg.t^{-1}$)**				
	Fry (to 1mm)	**Fingerling (to 3mm)**	**Juvenile (to 5mm)**	**Grower (to 8mm)**	**Broodstock (8 or 9mm)**
Fishmeal (72%)	450	400	300	200	350
Soybean meal	230	200	220	240	230
GNC	150	150	200	250	150
Maize	165	245	275	305	262.5
Premix[1]	5	5	5	5	7.5
Total	**1000**	**1000**	**1000**	**1000**	**1000**
Total CP (%)	**50**	**46**	**42**	**38**	**44**
Total cost ($N.kg^{-1}$)[2]	**170.5**	**155.8**	**128.9**	**102**	**145.3**

1 – The premix is assumed to have an inclusion level of $5kg.t^{-1}$ and to provide protected vitamin C at a rate equivalent to $100mg.kg^{-1}$ of finished feed. The broodstock diet contains the premix at 150% of the recommended level to make sure that these fish, especially the females, suffer no deficiency - particularly of water soluble vitamins.

2 – The cost here is of raw materials only and does not include the processing costs. The following assumptions are made for cost and crude protein content of raw materials in the above formulations.

Ingredient	**Cost ($N.kg^{-1}$)**	**CP (%)**
Fishmeal (72%)	310	72
Soybean meal	65	44
GNC	35	38
Maize	35	12
Premix[1]	1000	0

1 – Cost based on HiNutrients complete fish vitamin premix that includes protected ascorbic acid

Feeding Husbandry

In addition to producing a feed formulation of appropriate nutritional value this must also be processed in such a way that it has the correct physical characteristics. This is covered in the following section with respect to feed processing. Once a feed with the correct nutritional and physical characteristics has been manufactured there remains the issue of the most appropriate approach to delivering it to the fish. This involves issues of feeding method (hand, demand, automatic feeding), feeding frequency (times of day, how many times per day) and feeding amount (feeding to table values a set % of the bodyweight per day; feeding to satiation/appetite).

Feeding rates/frequencies are modified by a range of parameters that interact in a complex fashion. These include fish size (weight), water temperature and the digestible energy density of the feed (amongst others). Alongside these are factors that relate feeding husbandry to social behaviour in catfish, especially social dominance. A feeding regime that allows dominant fish to defend the food resource will lead to greater growth differentiation (size variation at harvest) than one that provides all members of a population with equal access to food. On top of all of these considerations are superimposed economic drivers as feeding regime affects both growth rate (time to harvest) and food conversion efficiency.

Given how complex this area is, it is difficult to make useful, practical, recommendations. The following table provides a starting point.

Recommended daily ration for African catfish (% body weight .d^{-1})						
Temp	**Fish size (g)**					
°C	**1g-10g**	**10g-25g**	**25g-50g**	**50g-100g**	**100g-300g**	**300g-800g**
16	1.0	0.6	0.4	0.3	0.2	0.2
18	3.0	1.6	1.0	0.8	0.6	0.5
20	5.0	3.0	2.0	1.5	1.2	1.0
22	6.8	4.5	3.0	2.4	2.0	1.7
24	8.1	6.0	4.0	3.0	2.5	2.2
26	9.5	6.6	5.1	3.6	3.2	2.8
28	10.0	7.0	5.5	4.0	3.5	3.1
30	9.8	6.8	5.3	3.7	3.2	2.9
32	9.5	6.5	5.0	3.5	3.0	2.8

(Rhodes University, 2001)

The same source suggests that feeding frequencies should be twice per day in the grow-out phase (>100g) with more frequent meals for smaller fish. For catfish, especially in their early stages fry/fingerling, feeding rates are very important to reduce cannibalism. Hungry fish exhibit increased rates of cannibalism.

In general, for maximal growth catfish should be fed, by hand, to appetite (apparent satiation) twice per day during grow-out. Each meal should last around 20 minutes and satiation is judged subjectively by a drop in feeding response when more feed is added. For optimal food conversion efficiency the feeding rate should be around 75% of the maximal (satiation) level. For the very largest fish (>800g) feeding once per day in the morning would be sufficient.

Feed technology for production of water stable (floating) feeds

Production lay out

Organisation of production and equipment should be done in such a way that continuous production for hours at a time can be achieved. A good and consistent feed quality is not possible when only a ton or a few hundred kg's are pelleted in a run. The useful output decreases, while labour and energy costs rise, for short production runs.

First of all production must be carried out in a closed and ventilated building. The floors and al least the lower 2 metres of walls must be washable. Ingress of insects, birds and rodents must be prevented. Lighting must be provided so that production can take place day and night.

Planning the layout of the feed production building must consider both the location of the raw material store and finished feed storage. Feed production lines should be linear with product moving in sequence from one end to the other. This production line can be a single, straight, long line; a 90 degree angle line, or a "U" shaped line where finished feed ends up adjacent to the raw material intake.. The latter solution is only recommended where raw materials are stored in closed bins/silos or where the area is big enough to keep a good separation between raw material inputs and finished product.

There are three major components to the production line:

- **The "dusty" and dry area,** with dosing, grinding and mixing. This is the area where raw materials are being prepared to pellet. This area can be in a separate building if required.
- **The wet area,** with pelleting. At the beginning and end of a run there will be a certain amount of very wet feed that can be semi- dried and reused, if it is clean. After a production run the pelletiser and the area around it should be thoroughly cleaned with water.
- **The dry and clean area,** with drying, cooling and packaging.

Dosing

Most units visited had batch sizes of 1,000 kg. This is acceptable if dosing, grinding and mixing are seen as independent operations, or if the complete production is regarded as batch production. Unfortunately it was often noted that mixed material, ground or semi-ground, was left in the work area without any form of identification. This must never happen.

In contrast in a continuously running process, the size of a batch is normally about 20-30% of the line capacity per hour. This batch size is prescribed in order to secure an even flow of material to pelleting and to secure complete usage (pelleting) of prepared materials.

The ideal way to dose is from dosing silos directly into a hopper scale controlled by a computer. After weighing the batch is transported to mixing before grinding. Dosing silos are employed for the main ingredients such as fishmeal, maize, GNC, soybean meal and wheat offal. These silos should contain a minimum quantity equivalent to 12 hours production.

Alternatively, the manual approach is to weigh ingredients to a batch, and to place this on one or two pallets clearly marked with formula name, date and amount.

Mixing before grinding

It was observed at a number of locations that grinding of fish meal was not carried out because farmers believed it was fine enough as it was, or because their grinders would block due to the fat content of the product. Fishmeal is, however, not normally ground on screens <2-3 mm by the supplier, whilst for extrusion/pelleting particles of about 0.5-0.7 mm are required.

A way to achieve this is mixed grinding: All the main ingredients, except vitamins/minerals and premixes, are mixed before grinding. Average mixing time in a vertical mixer is normally 6-10 minutes, in a horizontal mixer 3-6 minutes. The advantage is that hard materials, such as maize and wheat, will help keep the screen holes open when mixed with materials like fishmeal.

Grinding

The most common grinders seen were hammer mills. None of these had either magnets or stone traps and none had controlled feeding. Only the second grinder (evaporator) had suction.

It is possible to grind in one step with mixed grinding and with suction on the hammer mill. Controlled feeding is essential to get the best out of the mill: too little feeding is a waste of energy and too much feeding results in heating of material and blocking of the screen.

Stone traps and magnets are essential to protect the expensive screens.
Screen sizes recommended are as follows: for 2 mm pellets, 0.75 mm; for 3-5 mm pellets 1.0 mm; and for bigger pellets 1.0-1.25 mm.

Mixing after grinding

The batch, after grinding, should be transported to final mixing. Here premixes and other (if used) micro ingredients are added and mixed. Vertical mixers normally require quite a long time to make a uniform mix, about 15-25 minutes (remember to empty the mixer tip and add back to the mixer again), horizontal mixers 6-10 minutes.

Checking of quality of final mixture and determination of the correct mixing time:

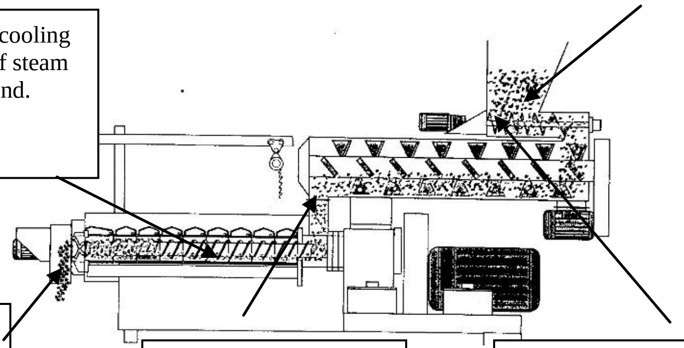
Add 100 whole maize corns to a batch (500 kg) before final mixing. After emptying the contents into 20 bags of 25 kg, screen the bags through a 3x3 mm sieve. Hopefully you will find 5 maize corns in each bag - if not, adjust mixing time and try again.

Extrusion pelletizing

Extrusion is the only known way to make water stable slow sinking or floating feed pellets. The process can best be described as a continuous high temperature, short time, cooking/baking and shaping process.

In the following text is presented information that could be used as a guide line for both local manufacturing of extruders or as check-points when looking for imported machines.

<u>Main parts in an extruder constructed for aquatic feed:</u>



The locally manufactured "extruders"/pelletizers are mainly transporting the dry or semi-dry mix towards the die plate with a little compression and with only a very small degree of cooking.

Compression and cooking of the mix just before it passes through the holes in the die plate <u>is essential</u> to achieve the expansion that makes pellets float and due to gelatinization of starch brings binding and physical strength to the pellets.

For good cooking conditions, pre-conditioning is needed. Here water and steam are added and mixed into the material until it reaches a temperature of 55-65° C. The moisture content of the mix should be 20-25 % when it enters the extruder.

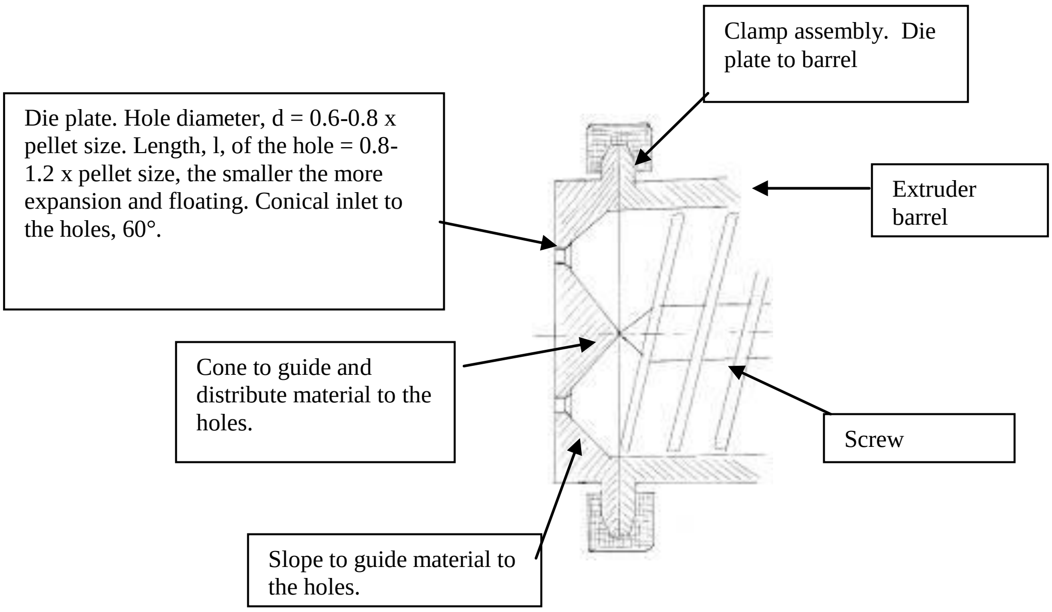
Construction of barrel and screw must be done so that energy from the electrical motor creates shear and friction, which is transformed into heat in the mix. The required motor power is approximately 0.04 KW/kg output.

The barrel must have a restriction that prevents the mix just moving along with the rotation of screw and approximately 20-30cm from the die plate there should be a restriction to prevent the cooking mix going backwards.

NOTE! Temperature and pressure behind the die plate can/should become very high – so stay away from this end of the extruder until a steady flow of material is appearing and you are confident of the mechanical strength of the machine.

Adjustable cooling of the extruder barrel is necessary to control the cooking/compression zone. If there is no cooling of this zone the mixture will move backwards and in the end it will block rotation of screw. The heated cooling water from this section can be used in the pre-conditioner via a reservoir.

<u>The die plate is an important part of the process.</u>



The following table gives guidelines which can be used for designing die plates. The number of holes, or the total hole area, depends on the actual extruder and its performance. The total hole area is approximately 70% less for die plates made for floating feed as compared to those for slow sinking feed.

The finish of the inner die surface and the holes themselves should be polished, and the plate should be surface hardened to make it last for more production hours. Die plates must be kept clean and free of corrosion.

Pellet size	**Slow sinking feed**			**Floating feed**		
	Hole diameter mm	Length of straight hole mm	Depth of conical inlet mm	Hole diameter mm	Length of straight hole mm	Depth of conical inlet Mm
2 mm	1.6	2.0	1-2.0	1,2	1.2	1-1.5
3 mm	2.3	3.0	2-3.0	1.8	1.5	1.5-2.5
5 mm	3.5	5.0	4-5.0	2.8	3.0	3-4.0
7 mm	5.0	7.0	6-7.0	4.0	4.0	4-5.0
9 mm	6.0	9.0	8-9.0	5.0	5.0	5-6.0
Hole area	100%			70%		
Minimum content of cereals (starch) in formula	14%			18%		
Addition of water and steam	15%			20%		

After cooking and expanding the material will have passed through the holes to a set of rotating knives (cutter), which cut the spaghetti like material into appropriate lengths. The rotation speed of these knives must be adjustable to adjust the length of pellets. To reduce the required knife rotation speed, it is normal to have 3-9 knives rotating on the same shaft. The optimal **length of feed pellets is 1.2-1.6 times the diameter.**

Drying

There are several ways to dry feed pellets continuously:

- Fluidized bed dryer, suitable up to 1 ton/hr, simple to operate.
- Counter flow dryer, cheap and useful, but will damage the pellets.
- Belt dryer, the best option but complicated and expensive.

Drying principles are the same for all approaches: pellets are layered, typically 5-10 cm thickness, and hot air at 80-100°C is blown up through this layer. Drying means removal of water, and the only way to achieve this is to exhaust the water-saturated hot air.

The best and most gentle drying is obtained with a low temperature dryer, < 80°C, and a long drying time.

The level of drying should be measured, and the simplest way is to use an infra-red moisture analyzer that in just a few minutes gives a reliable result. For feed meant for sale or longer storage, the water content of the dried product should be a maximum 8-10%.

If the feed is going to be used within a few hours, a water content of 12-14% is acceptable.

Cooling and Bagging

Cooling of dried product must be done to room temperature. This can be an integrated part of the drying process or a separate process. Most commonly employed is separate cooling using a counter-flow cooler.

After drying/cooling it is normal to have a vibrating sieve to remove dust and broken pellets which can then be reused. Dry feed, dust and crumbles are incorporated in formulas at a restricted percentage (3 – 10%) either as an added product or to partly replace fish meal and soybean meal.

The method of handling finished feed depends on where and how the feed is going to be used. For own and immediate use open small containers/baskets can be used as long as labelling with clear information about weight, feed type and date of production is done for each container.

Feed that is going to be sold or stored for a longer period must be bagged in sealed plastic or paper bags with proper labelling. The weight per bag should be 25 kg, bigger bags will result in bad stacking on pallets, broken bags and loss of feed. The simplest way to close bags is by sewing.

Bagging capacity must always be more than twice the production capacity per hour.

Fish Feed Technology – A review of the Nigerian Experience

Extrusion/cooking, is the only well known and proven way to produce floating or water stable feed pellets.

The companies visited in Nigeria, who had their own production of feed, have largely similar setups.

None, except Fexod Fedek Ventures, Ibadan with their home made machinery, could make floating feed. Akin-Sateru Farms have an imported extruder and dryer, but did not manage to make floating feed. The general picture was that no one had either the setup or process equipment suitable for making floating feed in a way that makes sense.

Generally storage of raw materials and production took place in more or less the same open area. Only FreshCo Foods had constructed a separate and closed building for production, but here they also stored raw materials close to the production line and finished products. The risks of contaminating finished feed, especially with fungus/mould but also with bacteria, are obvious.

A typical setup for production of farm made feed.

Local raw materials such as Maize, GNC and Soybean cake or meal were packed in bags of varied and generally very bad quality. The result is loss of material (which accounts for more than 80% of the feed costs), pollution of the surroundings and contamination of materials by birds, flies and other insects, mice and rats.

The production lines generally consist of a two step grinding with mixing in between, a pelletizer (semi-extruder) and some simple arrangement for drying used in the rainy season. For the remainder of the year feed is sun dried on tarpaulins on the ground.

There is little or no control of dosing and mixing, and there is very little attention to the quality of grinding. All grinders/hammer mills we saw were locally made and none of them had magnets or stone traps in the inlet zone to prevent damaging of the screens.

The pelletizers that were in use can be best described as enlarged meat/food mincers such as those that virtually all housewives used until the 1960s, they are simply driven electrically. FreshCo Foods had pelletizers that perhaps could be modified to make more efficient extruders due to their modular construction.

The technical quality of feed pellets produced locally is best described as bad. First of all they are not strictly pellets (length of feed pellets should be 1.2-1.5 times the diameter), since there is no uniform cutting to length, except perhaps manually. Pellet structure is loose and friable because of a lack of compression and cooking in the pelletizer. The significant use of GNC at moderately high inclusion levels also affects binding because of the fatty structure of this raw material.

Only at one place, Fexod Fedek Ventures, Ibadan, did we see relatively fine and floating pellets. Here was assembled on a very small scale (50- 70 kg/hr) all that is needed for continuous production of extruded/cooked feed. The only thing the owner/operator required was a more stable electrical supply, more space and, of course, working capital.

We also saw Chinese so-called dry pelletizers at Alami Farms Ltd. and at Animal Care. Felico Industries was going to purchase one, and the price indicated was N 800,000 = EUR 4,700. This kind of equipment is obviously a complete waste of money if the aim is to make water stable or even floating feed. The construction is primarily designed for small-scale production of wooden pellets made of wet sawdust (see picture).

Chinese “dry pelletizer”

One of the sellers of these machines was Hi-Nutrients, Lagos. The sales argument presented was that “dry pelletizing” of feed required no drying afterwards. This type of pelletizer results in almost no compression and absolutely no cooking. They create a smooth looking pellet surface, because holes in the die plate were nicely done and polished, but pellets had no mechanical strength and crushed into dust at the slightest pressure. To compensate for the lack of strength, pellet binders were added to the formula, but since there was no significant addition of water before pelletizing, these binders would have absolutely no effect.

Handling of feed after pelletizing was generally manual in baskets or buckets. Drying was carried out in various primitive and greatly inadequate ways. If feed is used within hours of manufacture, the need for drying is very limited, and the kind of methods we saw, including sun drying, would be enough for small- scale production (100-150 kg/h) whilst requiring considerable labour.

In the places visited we saw finished feed stored in small amounts., Feed was stored in piles on the floor, baskets, buckets and open fibre bags. No matter how it was stored, we never saw any labelling or other information indicating what kind of feed it was or details about the amount, production date etc.. However, Freshco did have simple labels available (see appendix 7).

The feed formulations that we were given were in general good for extrusion/cooking. The content of starchy products, such as maize and whole wheat, starch being an essential ingredient for making extruded/cooked pellets, was normally in the range of 15 – 20 %. Such levels of starch are required to more easily manufacture floating pellets. However, the ‘good’ levels of starch were compromised by the use of GNC and especially full fat soy because the fat in these products, when added in large quantities, makes expansion and binding of pellets difficult.

GNC is clearly one of the most common, cheap and available protein sources. There is little doubt that it is used at higher levels than the feed producing farmers reported when asked about their formulations. On the other hand, it is clear that fishmeal is used at lower levels than claimed due to price and availability. GNC at inclusion rates above 20% will clearly make it very difficult to manufacture a feed pellet with enough expansion to make it float or sink slowly and with sufiicient physical strength, which is a parameter when feed is sold and distributed.

There is very little attention to the construction of die plates. The die plate and its holes determines the size of pellets and also degree of expansion (= floating ability) if there is a cooking process in the pelleting machine. The die plate in the picture below was typical of what we saw. Except for dirt and corrosion the major faults are too many holes (to much open area), straight holes with no guidance of material and holes with the same diameter as the wanted pellet diameter. If there had been cooking/extrusion in the pelleting machine, the hole diameter should have been 1.5-2.5 times less than the desired pellet diameter. **It is the expansion that happens due to the release in pressure when cooked material leaves the die plate, which makes feed pellets float.**

A typical die plate, flat with a maximum of straight and rough holes.

A improved die plate was manufactured by the consultants during the visit. It was tested at FreshCo Foods, but since controllable cooking was not achieved in the pelleting machine, it was difficult to see the improvements in pellet structure. When material instantly started to cook, the rise in pressure created leaks in the pelleting machine.

A new plate with centre cone and conical inlets to holes. Number of holes reduced from more than 100 to 27. There are only holes where material is moving inside the extruder.

Notes: