NILE TILAPIA CULTURE IN CAGES

INTRODUCTION

Culture of tilapia in cages has become quite popular over the last few years and it is uncommon not to see at least a few cages in every natural water body you come across. Red tilapia (“pla taptim”) are the main species in Central, North and South Thailand, but Nile tilapia are more commonly cultured in the North-East.

Capital investment in cage farms is much lower than that required for pond culture, as no land rental and development costs are necessary. Rearing costs are more expensive in cages however, as the fish must be fed on expensive floating extruded feed and the fish get little, if any, natural food. For this reason it is only economic if the price of tilapia is high. This explains why red tilapia are the main species in Central Thailand. Nile tilapia are cheap and so cage culture is not cost-effective unless a farmer has a special market that is prepared to pay a premium.

Tilapia are very adaptable fish and can breed in cages, despite the high fish density and lack of spawning substrate. Female fish grow slower than male fish and the result of these two factors is reduced and uneven growth of the fish. To overcome this problem, Nam Sai Farms produces all male fish by feeding male hormone-impregnated fish meal for 21 days to hatchlings. The fish at Nam Sai are tested on a monthly basis by gonad squash method and are very close to 100% male. Furthermore, they are male for life, despite what some people would have you believe. Growth of these fish is much quicker and more uniform than mixed sex fish.

**Cage culture or pond culture?**

Most farmers are attracted to cage culture, as it requires low capital investment and there are few restrictions on raising fish in natural water bodies. Of course, there are many disadvantages and the following table compares the two rearing systems:

<table>
<thead>
<tr>
<th></th>
<th>Cage</th>
<th>Pond</th>
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<tbody>
<tr>
<td>Capital investment</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Running costs</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Max. fish density (kg/m3)</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>Risk of disease</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Risk of stock escape</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Growth rate</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Pollution risk</td>
<td>High</td>
<td>Low</td>
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Tilapia grow fast in cages due to the superior water quality and fingerlings stocked at 20-40g attain a market size of 700g in 4 months. Production costs in ponds are much lower, however, as natural planktonic and benthic food contributes significantly to the fish’s diet. Tilapia raised in cages eat very little natural food and high quality commercial floating feeds are necessary, with a complete balance of nutrients, to get good growth and food conversion. Tilapia can be raised in ponds with fertilization and very cheap feed inputs, but growth is a little slower and yields are generally less than 1 kg per m3 of water, compared to 20 kg in cages.

Much is spoken about the superior taste and quality of cage-reared fish. That is true to some extent, although off-flavours are not uncommon in cage-reared fish and it is important that a farmer is aware of this during site selection. Muddy or earthy flavours are caused by elevated levels of
geosmin and MIB in the water (causes of off-flavour are discussed in detail in the section on fish flavour). Establishing a farm where these chemicals are prevalent could spell disaster for a business that intends to produce good quality fish.

SITE SELECTION

Success or failure of a cage farm will be determined to a large extent by site selection. The following factors should be considered:

1) Water

Most tilapia cage farms are located on rivers, large canals and reservoirs. Water flow and quality will be hugely different at each of these types of site. This will have an impact on growth, survival, skin colour, meat texture and flavour.

- Rivers

Deep, relatively slow flowing rivers are best for cage rearing tilapia. If the water flow is too fast, then the fish will tire from swimming and the net cages will be lifted up by the current. Ideally the water should be as clear as possible and sufficient water depth available in the dry season. Avoid sites close to the sea where salinity gets above 20 ppt, as during dry years it may rise to critically high levels (30 ppt or more).

All rivers in Thailand exhibit seasonal changes in water clarity, water quality, flow and sometimes salinity. The Ban Pakong River for example, from Prachinburi down to Chachoengsao is tidal and brackish for part of the year. During the early rainy season, the water is very silty, causing stress, reducing appetite and leading to fish mortality. This is followed by increasing water flow and masses of floating water hyacinth and other debris that inevitably get stuck against the cages. By mid-September the river is in full flood and the water flow at its highest. Access may be difficult and risk of cage damage high. On top of these problems there are occasional agriculture and industry-related pollution problems that can cause massive fish kills. These are the dangers to be aware of and avoid if possible. Different rivers will have their own particular characteristics. The River Mekong for example, has much better all-year-round water flow than the Ban Pakong River and in this respect is superior. It is located in North and North-East Thailand where it is much colder than Central Thailand during November to February and on the downside growth would be
slower during this period.

One of the advantages of growing tilapia in rivers is that the water flow keeps the fish well exercised and this leads to firmer meat quality. Furthermore, off-flavour is uncommon as blue-green algae do not thrive there. Most cases of off-flavour occur in the dry season when water flow is low and of poor quality due to agricultural effluent contamination.

On some rivers, such as the Ban Pakong for example, farmers find that tilapia skin colour changes throughout the year. If the water is very silty and pale in colour during the rainy season, then both red and Nile tilapia go very pale. During the dry season, when the water is much clearer, red tilapia will be very vivid in colour and Nile tilapia go very dark. These changes may have a large impact on market acceptance and influence demand for fish.

- **Canals**

A canal is just a shallow, slow-flowing river and it is now quite common to see them used for cage farming fish. They are mainly earthen irrigation canals, although large concrete canals supplying water from reservoirs could also be used. Water quality is not generally as good as in rivers and fish growth is often slower. The biggest drawback is the shallow water and poor water quality during the dry season. Many canals shut their gates to stop saltwater intrusion from March onwards and water usage is high at this time. Water quality deteriorates as a result and fish mortality may occur unless emergency aeration is available. Off-flavour can also be a problem from time to time. Canals do have one advantage over rivers in that water clarity is usually better in the rainy season and more even over the year. As a result, fish skin colour will be fairly uniform.

The principle purpose of irrigation canals is to supply rice farmers and other water users. Cage farmers cannot expect preferential treatment regarding use of water gates to maintain water quality. Indeed they are actually exacerbating the poor water quality due to the wastes from their own farming activities. It is important that a farmer has good background knowledge of a canal and it’s seasonality before going ahead with any cage farming venture.
Reservoirs and lakes offer good cage sites for tilapia, as water quality is usually very good. They are limited in number, however, and getting permission is often not a formality. In Thailand natural lakes are uncommon, but many large reservoirs are located throughout the country. There are also a multitude of small local reservoirs that could be utilized by cage farmers, just as long as they hold sufficient water at the end of the dry season. There are many countries around the world with very large freshwater lakes that can and are used for cage culture of tilapia. Investment is high, however, as much stronger cages are required to resist storm damage and logistics for feed, equipment and fish supply is more difficult.

Water is generally deep, of high quality and very clear in reservoirs. Although there is little flow, the fish grow fast and very deep cages of 5 m or more are possible. The clear water has a big effect on skin colour, as red tilapia go very vivid red and for the same reason Nile tilapia turn very dark.

When siting a cage farm on a large reservoir or lake, try and find a sheltered location in a bay, perhaps where a stream enters for good water flow. Waves can become very destructive during big storms on reservoirs due to the large fetch. Blue-green algae blooms can also occur and can cause fish kills due to oxygen depletion. A small incoming stream may provide a lifeline.

Some reservoirs and lakes are not suitable for cage culture, as fish raised in them pick up strong muddy flavour due to high levels of MIB or geosmin (see section on off-flavour). This can be purged from the fish by keeping them in clean water for 3-4 days, but it is an expensive activity that would be otherwise unnecessary if a suitable site was chosen in the first place.

2) Fingerling supply

Due to the relatively large mesh size of cages, tilapia are stocked as 20-40g fingerlings. Fish of this size are more difficult and expensive to transport than small fry. Ideally there should be a nursery farmer in the local area who can supply fingerlings. If not, then the farmer will be forced to nurse his own fish and this can be tricky, particularly in rivers. Cages offer zero disease security (fry are sensitive) and strong water flow can be problematic when using fine-meshed netting. External parasites are particularly severe during the cold season and mortality can be extremely high. Some farmers get around this problem by investing in nursery ponds very close to the cage-farming site.
3) Market

Like any other business, a tilapia farm should only be located where there is a good market for fish. In the case of cage-reared tilapia, the product is a large-sized (400g to 1kg), high quality fish that is not cheap. This means that middle-class, affluent people will be the major consumer (unless produced for export) and being located close to any major town, tourist area, etc would be a big advantage.

4) Access

Good site access will be a big benefit to a cage farm, as it will simplify supply of materials, such as feed, materials and young fish. It is most common for cage-reared tilapia to be sold live, often in small amounts and good access will not only reduce the cost, but customers are more likely to pay a visit to the farm if it is close to a road.

Many cage farmers pay local people a rental fee for siting cages outside their properties. They benefit not just in terms of access, but in terms of added security, use of electricity and sometimes use of adjoining land for storing feed, workers housing, etc.

Access to sites on rivers can often be problematic with regards to moving fish, feed and materials on and off the site. One solution is to use a winch made from a bycicle wheel which pulls a hook up an anchor line.

Service by boat will be the only option in more remote sites and this will increase transport costs and remove the option of selling produce farm gate.
CAGE NET DESIGN

A cage is simply a net bag made from 2-3 cm mesh (from corner to corner pulled tight). Smaller meshes than this are expensive and block quickly, larger than this and you will have to stock very large fingerlings.

Knotted polyethylene net is the cheapest and most commonly used. Polypropylene is more expensive, but is more durable and may provide more resistance against gnawing puffer fish or predatory animals attempting to bite holes in the cage netting. Unknotted netting is better, if available, as it does not abrade the fish. If pond-reared fish over 150g are stocked in knotted cages, they suffer from lost scales, blindness and high mortality due to rubbing against the mesh as they try to escape.

Cages can either be purchased ready-made or constructed by the farmer himself. It can be a bit tricky, as netting is stretchy and it takes some experience to make a net that keeps its shape.

The length and width of the cage will conform to the size of the floating platform structure. Depth will depend on water flow and the depth of the water. Most cages on rivers are 2-3 m deep. On reservoirs, where the water is deep, it is possible to use cages over 5m deep. Ties made of 6-8 mm polyethylene are used to tie the top of the cage to the floating platform. Large concrete weights can be suspended from ties at the bottom of the cage to stop it rising up.

A fine mesh barrier 50-90 cm wide should be sewn in around the top of the cage to stop feed floating out.

FLOATING PLATFORM DESIGN

The floating platform has two functions. Its main use is to maintain a standard amount of cage in and out of the water, despite changes in water level. It also provides a stable base for working on. Floating platforms consist of a frame structure and floats. They vary in design depending on how much money is available to spend, environmental conditions at the site and the level of stability required for working. The following designs are available with increasing expense:

1) Bamboo and foam

This is the cheapest method of making a floating platform, but it is not good for working on and may require the use of a boat. Foam is cheap and can be purchased in blocks. It has a short lifespan of less than 1 year and breaks down to leave small balls of foam that litter the environment. The foam can be packaged in plastic bags to increase its lifespan.
Large thick bamboo ("mai dong") is lashed together to make the frame. The more bamboo used, the easier it is to walk around the cages, but it is heavy and takes a lot of foam to keep above water. Alternatively, the bamboo itself can be used for floatation, but there is always a risk of the platform getting swamped by waves and the bamboo will soak up water getting less buoyant with time.

2) **Galvanized steel pipe and barrels**

This is the most commonly used design in Thailand and employs locally available materials. 1” galvanized steel is relatively cheap and provides a robust, stable and non-rusting platform that sits at least 30 – 50 cm above the water surface. The pipes are laid in pairs and connected together using scaffolding joints. Cross bars are laid at intervals to increase strength and the barrels sit between the paired pipes. Planks or aluminium sheet can be used to make walkways that are laid or bolted to the pipes.

The barrels are actually the most expensive part of the platform, particularly plastic ones, and an ideal design would use the least barrels. Most cages are between 3-5 m wide, but can be made larger if necessary. An alternative is to use ferrocement floats made by rendering a block of foam enclosed in steel reinforcing.

In some large lakes and reservoirs, wind and wave action may be quite severe and it may be advisable to upgrade the strength of these cages by using thicker steel for the frame or by incorporating strong walkways as part of the structural design.

On large rivers, floating logs and other debris can cause damage to cages. One solution to this is to
add a “v” shaped steel deflector at one end of the platform. This is used to good effect by cage farmers on the Mekong River. They also add a small house on one end and the whole structure is movable.

3) Plastic floating collar

There are various types of plastic cage collars available that can easily be fitted together to provide a good stable walkway and working environment. They are relatively expensive and are usually not locally available.

4) Round floating collar cages

These cages usually incorporate 1-3 PVC or HDPE pipes of large diameter that form a ring from which the cage is suspended. They are usually large in size from 10 to 30 m in diameter and provide high resistance to wave action due to their high flexibility. The type incorporating 3 rings are very buoyant, allowing deep cages to be used and they can withstand waves of 3.5 m in height.
Round floating collar cages were originally designed for rearing salmon in the sea, but many countries are using them for raising tilapia in large lakes where the conditions are very rough during storms. They are not very suitable for rivers and have yet to be used in Thailand, as they rely on the use of specialized materials and few people have the knowledge to construct them. This may change in the future, as farmers try to scale up their production and reduce costs. One large cage 20 m² in diameter and 5 m deep could raise as many fish as 30 Thai cages of 5 x 5 m and 2 m deep. They can be fitted with an automatic feeder so that labour costs are reduced to a bare minimum.

5) **Square steel with floatation blocks**

This is another type of cage originally used by the salmon industry in sheltered sea locations. They are quite large in size from 100 up to 625 m² and are constructed from galvanized steel. The heavy duty versions can withstand waves up to 3 m high, whilst light-weight versions only 1.5 m. The floatation blocks are made from foam-filled plastic or fiber glass and the whole structure with its wide walkways is very stable and durable. They are not used so much for rearing tilapia, as they are expensive, but no doubt they pay themselves off in the long run, as they have a very long lifespan.
NURSERY

Most farmers stock 20-40g (3-5 inch), graded fingerlings in their cages. Smaller fish than this would escape through the netting. They could actually be stocked larger than this so that the grow-out period is shorter and the fish more even in size at harvest (they must be of even size to begin with), but transport of live fish gets more difficult and expensive as fish get bigger.

Most farmers nurse tilapia to fingerling size in ponds and this is explained in the pond culture rearing manual. For farmers who do not have pond facilities and prefer to nurse their own fish, then the only option is doing it in fine-meshed cages.

1) Nursery cage materials & design

Nursery cages are no different in design to grow-out cages, except they are usually smaller in size and use small-meshed netting. Ideally they should be covered over with 4-5 cm netting, as young fry are highly susceptible to bird predation. Most farmers use 1.5 m deep cages (1 m of this will be under water) made from 20 strands per inch PE netting. If hapas are deeper than this, any water flow would be a problem. After 2 weeks the fry can be stocked in nets with larger mesh size and this allows cages to be up to 2.5 m deep.

The following options are available with regard to fry nursery netting:

- **20 strands per inch (SPI) polyethylene** – this cheap material can be stitched together using a sewing machine, as the mesh size is very small. It is not stretchy and so is very easy to work with. The downside is that the material quickly gets fouled and can be a problem in strong water current.

- **4 mm polyethylene raschel** – this material is ideal for nursery. It is relatively cheap and can also be stitched using a sewing machine. It is a little more expensive and takes longer to sew (the hems need stitching first) than 20 SPI. Water exchange is good with this material due to the large mesh size and fry can be stocked at higher density. Only fish of 0.5 g or more can be stocked, as some small fish will escape through the mesh.

- **Knotted & knotless, small-meshed (1 cm) polyethylene** – this material is very robust, but quite abrasive to the fish, particularly if it is knotted. The material is stretchy and very similar to the material used for grow-out cages. Construction of cages is a little tricky and only fish of 1g upwards can be stocked.
• **Knotless nylon netting** - this material is twice the price of polyethylene netting per kilogram, but it is very soft and not abrasive. It is not very durable, however, and is less tolerant of UV light. The material is very stretchy and making cages is not easy. Again, only 1g fish and upwards can be stocked due to the relatively large mesh size.

2) **Nursery rearing technique**

**Nursery period 1**

This period lasts 2 weeks and takes fry of 0.25g up to 1g. The fry are stocked in cages made from 20 spi PE netting at a density of 500 – 700 fish/m2. The fish are fed 3-4 times daily on a powdered diet that is easily made up from fish meal, rice bran, corn meal, soy bean meal, etc. The feed should have a crude protein content of 30-40%. There is quite a lot of feed lost using powder and some farmers feed very small shrimp or frog pellets instead.

**Nursery period 2**

This period takes 4 weeks for the fish to grow from 1 g up to an average of 25 g, at which point they are large enough to stock in grow-out. They are stocked at 500 – 700 fish/m2 in either 4 mm raschel or 10 mm polyethylene nets. The same density as for small fry is possible because the large mesh provides for better water exchange. Any small pellets, with reasonably high protein can be used. Many farmers use frog pellets to begin with and then change to the smallest catfish pellets (32% protein) as the fish get bigger. Many companies are producing very small floating pellets specifically for this purpose, but they are quite expensive.
3) Grading fingerlings

It is very important that 4” fingerlings are very even size when stocked in grow-out cages. Graders can be simply made using fish net or plastic netting stretched over a frame. Alternatively they can be made from parallel PVC or metal bars that allow small fish to pass through the gaps.

Whatever type of grader used, the following guidelines should be followed:

- Stress and damage to fish can be reduced by using graders in the water.
- Don’t use plastic mesh that has sharp edges.
- Use a mesh diameter of 20–30 mm for grading fish from 10–35 g.
- Don’t put too many fish in the grader at once.
- Don’t feed the fish prior to grading.
- Rest the fish for a few days after grading them before transferring to grow-out.
- If multiple gradings are required, then use the largest mesh grader first, followed by the next size, etc.
- Graders can be designed with layers so that a few sizes of fish can be graded on one go.

3) Transporting 4” fingerlings

Large, fingerling tilapia are usually transported in tanks with aeration or oxygenation. They can be packed in bags with oxygen like fry, but it is not recommended. Not only is it more expensive and time consuming, but tilapia have sharp spines and thick plastic bags will be required.

There is no ideal type or size of tank to use, but 1 m³, square chemical containers are most commonly used for transporting by truck. Not only are they cheap and strong, but fit well in the back of a pick-up or 6-wheel truck. Whatever type of tank used, a splash guard around the top of the tank is essential, otherwise water will spill out every time the truck rounds a bend or goes over a bump.

Some farmers actually use the back of a pick-up as a tank and either plug up leaks with plasticine or install a liner in the back of the truck.

Smaller tanks and plastic baskets are particularly suitable for short distances within a farm. Plastic bins with water and fish can lifted on and off a truck by two people quite easily. Plastic baskets are excellent for transferring fish to and from tanks on a truck, as they are less abrasive than scoop nets. Hapa bags can be fitted inside smaller tanks and the fish simply lifted out for transfer to cages.

Aeration can be provided by means of a 12 v or petrol engine-driven blower. 12 v blowers are connected up to the vehicle battery and are particularly reliable. Air stones are usually used for air diffusion. If the air temperature is hot, then this will raise the water temperature and ice is recommended to keep it down.

Alternatively, bottled pure oxygen can be used, as this enables a larger number of fish to be transported per tank. Only fine bubble diffusers should be used or the oxygen will run out very fast. If suitable commercial diffusers are not available then they can be made by making tiny holes in aquarium tubing with a needle.
The following table gives recommendations on stocking density for tank transport:

<table>
<thead>
<tr>
<th>Size of fish (g)</th>
<th>Tank density (kg/m³)</th>
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<tbody>
<tr>
<td></td>
<td>Aerated</td>
<td>Oxygenated</td>
</tr>
<tr>
<td>0.2 - 1.0</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>1-10</td>
<td>110</td>
<td>140</td>
</tr>
<tr>
<td>10-50</td>
<td>130</td>
<td>160</td>
</tr>
<tr>
<td>50-200</td>
<td>140</td>
<td>180</td>
</tr>
<tr>
<td>200-500</td>
<td>170</td>
<td>220</td>
</tr>
<tr>
<td>500-1,000</td>
<td>200</td>
<td>250</td>
</tr>
</tbody>
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A combination of aeration and oxygenation works very well. A conventional blower set up with air stones is used to supply air, but the level of oxygen is raised by connecting up the system to an oxygen cylinder. There are two advantages to this method. Firstly, there is less chance of oxygen reaching supersaturation and secondly, the air helps blow off carbon dioxide produced by the fish.

The following considerations should be made with regards to tank transport:

- Maintain the dissolved oxygen level above 5 mg/l in transport tanks.
- Too high dissolved oxygen kills fish very quickly and an oxygen meter is recommended for safety when using pure oxygen.
- Reduce the tank water temperature to 23 °C using ice to improve survival and increase stocking density.
- Starve fish for at least 6 hours before transport.
- Ensure there is back-up aeration by installing an additional blower or extra oxygen cylinder.
- Avoid transporting fish during the hottest part of the day.

**GROW-OUT**

Growing tilapia from fingerlings to market size in cages is very simple just so long as water quality is good and floating commercial pellet is used as feed. A typical grow-out period from 25 to 700g takes 4 months, although this will increase somewhat during the cold season.

Most farmers stock cages and don’t touch the fish until harvest. This requires less labour and reduces stress on the fish. An alternative strategy is to stock a higher density to start with and thin them out later. Although better use is made of available cage area, the fish will grow slower and so is not recommended.

1) **Stocking density & fish yield**

Young size-graded fish of 20-100g are ideal for stocking in cages. Larger fish take less time to grow and are more even in size at harvest. Smaller fish than this would require a smaller mesh size to avoid the fish escaping and is more expensive. Stocking fish of over 150g in knotted cages is not
recommended, as the fish will abrade against the net and mortality will be high. This is not a problem in cages made from knotless netting however.

Stocking density will depend on the expected yield of fish per cubic metre of water. This is dependent on a number of factors:

- **Water quality** – a higher density of fish can be raised per cage at sites with good water quality.
- **Water flow** – Higher densities of fish are possible at sites with good water flow such as rivers.
- **Cage size** – Smaller cages can hold a higher density of fish, as water exchange is more frequent.

The following table provides estimated yields of tilapia from various sized cages:

<table>
<thead>
<tr>
<th>Size of cage (m)</th>
<th>Yield (kg/m³)</th>
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<tbody>
<tr>
<td></td>
<td>Good water</td>
</tr>
<tr>
<td>2 x 2</td>
<td>50</td>
</tr>
<tr>
<td>4 x 4</td>
<td>40</td>
</tr>
<tr>
<td>5 x 5</td>
<td>30</td>
</tr>
</tbody>
</table>

The number of fish to stock in a cage is simply the number of fish expected at harvest plus extra fish to account for mortality. The number of fish expected at harvest can be calculated from the yield data in the table using the following equation:

Number of fish at harvest (fish/m³) =

\[
\text{Expected yield (kg/m³)} \div \text{Size of fish required (kg)}
\]

For example:

A cage farmer has found a site with good water quality and minor water flow. He estimates a yield of 28 kg/m³ from cages 5 x 5 m and 2.5 m deep (2 m in water). He wishes to grow fish to 700g mean size (0.7 kg).

\[
\frac{28}{0.7} = 40 \text{ fish/m³}
\]

He estimates a survival rate 84% (16% mortality):

Number of fish to stock (fish/m³) =

\[
\frac{40}{84 / 100}
\]
Volume of cage = 5 x 5 x 2
= 50 m³

Total fish to stock in cage = 47.62 x 50
= 2,381 fish

2) Feeding

Much higher quality feeds are necessary for rearing tilapia in cages compared to rearing in ponds. This is because fish in ponds are stocked at low density and have a large range of natural foods to eat on top of those given by the farmer. There is very little natural food in cages and the fish are at much higher density. Any feed given should have a full compliment of nutrients, particularly amino acids and lipids. Furthermore, the feed will have a large bearing on the nutrient and taste quality of the fish produced.

Nearly all tilapia cage farmers use floating pellets with a crude protein content of 26-32%. The reason is that it is very easy to assess the feeding response of the fish and avoid against waste. Sinking feed can be used, but feeding trays are essential if one is to avoid feed being lost through the bottom of the cage. Cages should have a barrier made of fine nylon that is sewn into the cage around the water line. This will prevent pellets from floating out of the cage.

Commercial pellet is supplied in a variety of sizes from 2 mm upwards and protein content is generally higher for smaller pellets. This is because smaller fish require higher protein levels for good growth. Pellet size should match mouth size. If a pellet is too big, then the smaller fish may not be able to ingest it and so growth of the stock will be very uneven.

Most farmers feed their fish three times per day, but two feeds may be sufficient during cold weather. The amount of feed given to fish on any one feed is usually determined by the feeding response. Most farmers have a good idea how much feed will be eaten from experience, but this will vary depending on temperature, water quality conditions and many other factors. By observing the feeding response of the fish, it is possible to feed very efficiently. At first the fish will be very energetic, but as they get full, they begin to slow down. This is the point at which to stop feeding. If too much feed is fed, then the conversion of food to meat will be less efficient. At Nam Sai we give as much feed as the fish can eat in 10 minutes.

Feed is the single most expensive cost involved in rearing tilapia in cages. Profit will be determined to a large extent by how efficiently the food is converted into meat. We call this the food conversion ratio (F.C.R.) and it is simply the amount of feed needed to get an increase in fish weight of 1 kg. One can expect a food conversion of between 1.1 and 1.5 for a decent floating pellet with 30% crude protein. It can be calculated from the following equation:

\[
F.C.R. = \frac{\text{Amount of feed eaten (kg)}}{\text{Gain in weight (kg)}}
\]

From the above example, a farmer stocks 2,381 30g tilapia in a 5 x 5 x 2 m cage. He harvests 1,027
kg of tilapia at harvest and uses 1,250 kg of feed in total:

F.C.R. = \frac{1,250}{1,027} - \frac{(2,381 \times 30)}{1,000}

= \frac{1,250}{879}

= 1.31

By constant monitoring of F.C.R., farmers can assess how good their rearing techniques are and can thus improve them. They can also compare different brands of feed, different sources of fish, etc. The outcome will be a much more efficient system and higher profit.

Keeping track of how much feed is fed to individual cages can be tricky, particularly on large farms and the following techniques can be used:

- Hang an empty bottle next to each cage. Put a bead in the bottle for every measure of feed given. A small bead could be used for half a measure. At the end of a certain time period, the number of beads can be counted to find out how much feed the cage ate during that time period.
- Keep a plastic tank (with lid to keep animals out) next to each cage for holding feed. Note down how much feed is added to the tank. This could be once every 2-3 days and so data collection is kept to a minimum.
- Use a cup that corresponds to a set amount of feed. Write down the number of cups fed to each cage after feeding. This is time consuming, but provides more detailed information on the amount of feed fed per day, at different times of the day, etc.

3) Automatic feeders

Nearly all farmers in Thailand feed their fish by hand. This can become very time consuming and labour intensive on large farms. Automatic feeders have been used in the West for many decades, as labour costs there are very high. There are many types and they are generally quite expensive.

There is one type of feeder, however, called the demand feeder, which can be made at home from local materials. A demand feeder is one in which the fish press a lever and feed themselves. Depending on the size of the hopper, 2-3 days supply of feed can be held in a demand feeder at any one time. The following diagram and photos illustrate how they are made:
It takes surprisingly little time for the fish to learn how to press the lever

4) Backup aeration

For cage farmers who are located on rivers and reservoirs where water quality is good throughout the year, no backup aeration systems are necessary. On some canals and rivers, however, pollution and general poor water quality can be a recurring problem. In most cases this is typified by very low dissolved oxygen below 0.4 mg/l. Keep an eye on both tilapia and wild fish behavior. Fish breathing at the water surface is indicative of low DO.

Tilapia are very tolerant of low DO, but at high density in cages they cannot survive for more than an hour or two. Any fish that die will further depress DO and the rest will soon follow. Some farmers have installed aeration systems in their cages as an emergency backup system. Most commonly a blower driven by a petrol engine or electrical motor is used to supply air to diffusers in the cages. Alternatively, water agitators or paddle wheels could be set up around the outside of the cages, but beware of theft. If water flow is quite strong, then aerated water will simply flow downstream. A plastic barrier installed on the upstream side of the cages will reduce this somewhat.
PROBLEMS ENCOUNTERED

There are many unique problems encountered by cage farmers that are less common or not found when raising tilapia in ponds.

1) Ripping of cage nets

It is not uncommon for tilapia to escape from cages due to ripping of the net. The most common reason for this is aquatic predators such as giant snakehead, crocodiles, snapping turtles, etc. They quickly learn that the cage contains food and they can make short work of netting with their sharp teeth. Once they have learned this ability, then they can cause huge destruction going from one cage to another. Anti-predator netting in which the whole farm or cage modules are surrounded by a large, thick-meshed netting is the only guaranteed method backed up with control of the predators in question.

A problem sometimes encountered by cage farmers in rivers is puffer fish gnawing at the nets. This inevitably leads to fish escaping. High grade polypropelene netting is reported to reduce this problem.

In larger strong flowing rivers, debris floating down the river can cause damage to cages. This can be reduced significantly by building a “V” shaped, partially submerged deflector on the upstream end of the cages.

2) Theft

Cages farms are usually located on public waterways and contain high value fish that can be caught very easily. Put these things together and you high risk of theft. Site selection is important and many cage farmers locate alongside land they either own or rent. Electricity for security lighting is then easily installed and staff can live in close proximity to the cages. An alternative solution used on very large rivers is to build a light weight, floating house for staff. Electricity could still be installed from a nearby residence, but battery power is more commonly used.

3) Disease

There is absolutely no biosecurity associated with cage farming. The fish are suspended in a natural water body that will contain many fish species, often including tilapia. Any diseases present in the wild fish population will be passed on to the farmed fish. Any treatments carried out on the fish may alleviate a problem, but re-infection will occur from wild fish. Diseases can also be passed from one cage farm to another very easily.

Fortunately, tilapia are a very disease resistant fish, but they are not immune. External parasites are common in young fish and Streptoccus, a bacterial disease, is very common during the hot season and early rainy season. More information can be obtained from the tilapia disease identification and treatment manual.
FISH HARVESTING & MARKETING

Harvesting fish in small cages is a very simple procedure. It can be done by simply pulling up one side of the cage until the fish are all congregated and can be scooped up with a basket or scoop net. Alternatively, a bamboo pole can pulled across the cage to confine the fish in the corner.

Cages offer a big advantage over ponds, in that fish can be harvested very easily with very little stress to the fish. They are also much more suitable for supplying a retail market, as most farms will have many cages with small volumes of fish of varying size in each. Market traders, restaurants and the general public generally want small numbers of fish or varying size on a regular basis. Cage farmers should take advantage of this, as it enables them to cut out middle men and get a higher price for their fish.

Cage farmers also have another marketing advantage over pond farmers in that muddy off-flavour is much less common. These advantages tend to offset the higher production costs for tilapia reared in cages.

HEALTH CONSIDERATIONS

Some people worry that the use of male hormone for 21 days in sex reversal could be a health risk to the consumer. This was disproved many years ago, as it was found that the levels of male sex hormone in market-sized monosex fish was actually lower than in males in mixed sex populations.

In reality tilapia are a very healthy food to eat. Like most fish, they are relatively low in total fat and relatively high in polyunsaturated fatty acids. Nutrient content will be determined to some extent by the feed given, as cage-reared tilapia eat very little natural food. For example, omega-3 fatty acids are very important in brain function and have been found to decrease blood triglyceride and cholesterol in animals and humans. They are found in marine fish oils and most feed companies spray them on the pellet to both improve their nutritive value and palatability.

Many consumers worry about the presence of antibiotics and pesticides in the food they eat. Fortunately, tilapia are very disease resistant and there is no need to use either pesticides or antibiotics during the grow-out period, particularly now vaccines are available for bacterial disease. Nevertheless, chemical contamination of fish is still possible due to effluent discharge from agriculture, industry and the general public.