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Life Sciences und  
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# **Finding an adequate Tilapia feed for rural fish farmers in Mombasa**

**Internship at Baobab Trust**

By

**Thomas Furrer**

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**Supervisor: Dr. René D. Haller, Baobab Trust, Bamburi/Mombasa**

## Abstract

Seven different possible fish feeds for tilapia (a hybrid from Nile tilapia, *Oreochromis niloticus* crossed with Sabaki tilapia, *Oreochromis spilurus*) were carried out on an internship on Mtopanga farm at Baobab Trust, Bamburi. The ingredients tested should be easily available to local farmers in Mombasa and should take into account that valuable nutrients produced on a farm should not be fed to livestock as these are urgently needed in local communities. As a valuable animal protein which can be produced on decaying organic material, black soldier fly larvae, *Hermetia illucens* was tested on tilapia. The daily growth rates on the tanks with the lowest stocking density proved to have the best food quotient. Further the feeds containing the cheapest ingredients were found using the food quotient of the feed and the prices of the ingredients. But as the feeding trials were only carried out between 20 and 35 days, longer feeding periods should be carried out for more validity. Also parameters such as water temperature, dissolved oxygen and pH were not measured. But since the results are aimed at being used by local fish farmers in Mombasa, who on their side have no measuring facilities, the trial has certain relevance and is an effort for proposing integrated, organic agriculture as opposed to commercial production. The aim is to motivate local communities in Kenya to become independent of the feed producing companies as these are mostly unaffordable for them and to help them to cover their need for valuable animal protein in their nutrition and in that of their families.

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# 1 Introduction

## 1.1 Background of the host institution Baobab Trust

The Baobab Trust is a Non-Profit Organisation and focuses on passing on skills on sustainable ecosystems to the surrounding communities of Bamburi, Mombasa in Kenya. Their main focus is on integrated farming, promoting environmental awareness, improving health issues and proposing alternative energy. The Baobab Trust has a holistic approach to these issues as food security, health, education and conservation are all linked with each other and cannot be dealt with as being isolated from each other.

At Mtopanga farm the Baobab Trust has set up a demonstration and training site on organic agriculture in order to pass these skills on to the local farmers of Bamburi and the surrounding communities. On this farm different products are produced minimising the impact on the environment and also recycling all waste products so as to utilize these for a further product – using Mother Nature and the nutrient cycles in intact ecosystems as a role model. Some of these nutrient and energy cycles which are being practised are biogas production, aquaponic systems or the family fish ponds where fish and poultry are being kept to benefit from each other's waste.

## 1.2 Tilapia

Tilapia is a fish of the tropical and subtropical regions and has been used for producing highly nutritious animal protein in all corners of the world. The annual production of tilapia in Africa has increased rapidly from 165'000 tonnes in the year 2000 to 419'000 tonnes in 2008 (FAO, 2011). This is due to the many advantages in keeping tilapia. Tilapias are very tolerant to harsh environmental conditions. They can survive a wide temperature range but best growth is around 29° to 31°C (Shelton & Popma, 2006). A salinity level of up to 32 parts per thousand can be tolerated by the Nile tilapia, *Oreochromis niloticus*, according to Suresh et al. (Suresh & Kwei Lin, 1992). Another advantage of tilapia is its tolerance to low dissolved oxygen levels. But growth rate is reduced below 25% oxygen saturation reports Lim et al. (Lim & Webster, 2006). This is exceptional in fish production as tilapias are able to utilize atmospheric oxygen. Even high turbidity levels can be tolerated although we should keep in mind that growth rates of tilapias plunge when conditions become too hostile.

The environmental factors for growth however are different from the optimum for reproduction. So although growth can continue in hostile environments, it is advisable to let tilapias brood in friendlier environments in order to achieve satisfactory results in number and quality of offspring.

The diet of tilapia though is subject to the most controversy. Some scientists, like Carpaji et al. insist that tilapia can and should be fed on a purely herbivorous diet (Carpaji & Widmer, 2011). Other scientists such as Jauncey and Ross say that only animal protein, especially essential amino acids (12 essential amino acids namely Lysine, Arginine, Histidine, Threonine, Valine, Leucine, Isoleucine, Methionine, Cystine, Phenylalanine, Tyrosine and Tryptophan) can fully cover the nutritional needs of the

tilapia (Jauncey & Ross, 1982). However, El-Sayed has stated that different mineral additives have proven to substitute certain essential amino acids (El-Sayed, 2004).

### 1.3 Aim of the research

The aim of the research is to find an adequate fish feed for raising tilapia on rural farms around Mombasa which have little investment capital to buy the expensive fish feed. Therefore ingredients were used which are easily accessible and are not in conflict with human nutrition. So instead of using the most energetic food or the food with the most protein content, ingredients were used which will not use up valuable farm products or highly valuable proteins aimed at feeding rural communities. The ingredients should be by-products with nutrients that can still be utilized instead of going to waste or into the composting cycle of integrated agriculture. As it is stated above (1.2 Tilapia), animal protein should be mixed with herbivorous ingredients so as to cover the essential amino acid needs of the tilapias. But in rural communities in Mombasa animal protein is too valuable for feeding to fish. Interestingly Spinelli et al (Spinnelli, Mahnken, & Steinberg, 1978), has found that the highly valuable fish meal in fish feeds for salmoids can be substituted by fly larvae (*Musca domestica*). He proclaims that the larvae were nutritionally equivalent to fish meal protein. The student in this report has therefore concentrated on black soldier fly larvae *Hermetia illucens* for the needed animal protein in the feeding trials.

## 2 Materials

During the internship at Baobab Trust the student did trials on different possible fish feeds. According to the available infrastructure these were carried out on 5 different tanks containing a hybrid tilapia which is a mixture of two different tilapia species. The hybrid on Mtopanga farm derives from the Nile tilapia, *Oreochromis niloticus* crossed with Sabaki tilapia, *Oreochromis spilurus*. Two single aquaponic systems each featuring a fish tank of 1 m<sup>3</sup> volume were stocked with 31 (tank 1) and 30 (tank 2) male tilapia of a similar size. A further aquaponic system containing 3 cement tanks was stocked with 216 tilapia (145 males and 71 females) in tank A, with 214 (140 males and 73 females) in tank B and with 636 fingerlings in tank C. Tests on different feeds were carried out to compare the growth rate between tank 1 and 2 and between tank A and B as these had approximately the same size and the same number and sex ratio of tilapia. Tank C was stocked with the fingerlings that were remaining and a single feeding trial was undertaken with these small tilapia (average weight 5.7 g).

### 2.1 Infrastructure

#### 2.1.1 Aquaponic tank 1 and 2



Image 1: Aquaponic system 1 with tomato plants



Image 2: Aquaponic 2 system with spinach

The aquaponic systems 1 and 2 were the first tanks to be stocked thus having the most time for feeding trials. Here only male tilapia of the largest available size on Mtopanga farm were used as females reduce growth after reaching maturity and are therefore used for breeding instead of fattening. To initiate feeding trials they were fed with the old fish feed F2 (table 1) in order to get them used to pellets and to increase their condition factor as feeding was not carried out regularly before. In order to have a high growth rate clean water should be given both for oxygen supply and to control turbidity. So initially six times a day approximately 315 litres were released, filtered through volcanic rock and pumped back to the fish tank by means of a hand pump. But because the pumping was very tiring the number of times the water was pumped each day was reduced to four times daily – twice in the morning, once after lunch and once in the late afternoon. The nutrients in the water were removed by microorganisms living on the surfaces of the volcanic rocks and different vegetables were grown in the filtering tanks which reused the nutrients from the tilapia faeces for their growth (tomatoes, spinach and pumpkin). After every three weeks the tilapia were removed and the total length, standard length, depth, width and the average weight was measured. From the total weight and the average total length the average condition factor was calculated, which was then used for the individual weight. Before returning the tilapia to the plastic tanks these were drained and cleaned so as to reduce turbidity and algae in the tanks. But because of physical stress during measuring and weighing and therefore a higher need of oxygen content in the water the tilapia received constant circulation of water for four to five hours after the measuring procedure. At the first time tilapia were measured there were therefore 35 loses. When constant water circulation occurred after measurement there were no more loses.

### 2.1.2 Aquaponic tanks A, B and C



Image 3: Aquaponic tanks A, B and C from back to front

These 3 concrete tanks, each with a water volume of approximately 9 m<sup>3</sup> are built one after the other with an overflow on the previous tank to feed the next one. This means tank A has the cleanest and tank C the dirtiest water – in other words tank A was low in nutrients for algae production while tank C was high in nutrients which results in the most algae production. A foot pump is used to pump water back from tank C to the reservoir feeding tank A. Due to lack of man power it was mostly filled with water from the bore hole and the water from the fish tank C was used to water the crops of the shamba, so that the nutrients in the fish water could be utilized for farm produce.

## 2.2 Equipment

For the measurement of the tilapia in the feed trials a measuring table was constructed. As a separate project of the student a small workshop for carpentry was installed and a small number of tools were bought for this.



**Image 4: Measuring table for finding the total length, standard length, depth and width of tilapia**

Finding an accurate scale for the weight of the tilapia was difficult. So the tilapia were weighed all together in a basket which was hung on a spring scale. The spring scale was only accurate for measuring a big number of tilapia because it could only pinpoint the weight to 250 gram. So after weighing the average weight of tilapia was calculated. But for weighing the fish feeds a means of measuring below the given weight of 50 grams for the double pan balance at the farm was needed. So bullets of lead from a nearby shooting range were collected and then melted in a hot fire. After this the lead was poured into a clay hollow where it was left to cool down. Later on the lead was hammered into a bar and the student went to find an accurate digital scale at butcheries in Mtwapa. Pieces of 5 grams, 10 grams and two pieces of 20 grams were cut with a hacksaw blade. With these 4 new weights the scale could now measure 5, 10, 15, 20, 25, 30, 35, 40 and 45 grams. This was a great help in measuring both the ingredients of the fish feed and the pellets for daily feeding as before the scale only had a minimum weight of 50 grams and was therefore not very accurate.



**Image 5: Double pan balance at the farm with lead weights for measuring below 50 grams**

Further a fish net was used for sampling the tilapia of tanks A, B and C. After the tilapia were attracted with feed the net was thrown over them and the sides which had weights sank to the bottom of the tank trapping the tilapia which could then be measured and weighed.

## 2.3 Available feed ingredients

### 2.3.1 Animal protein

The available animal protein containing essential amino acids for tilapia at Mtopanga farm was black soldier fly larvae *Hermetia illucens*. As the production of larvae was subject to fluctuations the percentage of soldier fly larvae in the formulas had to be reduced. This could be due to different organic matter which was fed to the black soldier flies. As a matter of fact the soldier fly larvae production was highest when a dairy cow died and the stomach and inner organs of it were fed to the soldier flies. So in the feeding trial of feed formula F4 which were started in December the dry matter percentage of soldier fly was adequately high (35%), whereas the percentages in the feed trials F5 and F6 which were commenced in January had to be reduced to 25% due to no more dead livestock.



**Image 6: Black soldier fly larvae *Hermetia illucens* with white larvae from the previous larvae stage**

### 2.3.2 Other available feed ingredients

Beside the soldier fly larvae a number of locally available ingredients were used for comparing the suitability for growth in tilapia. The old and new fish feed pellets of Pwani Feeds Ltd. were fed and compared. Then with F3 and F4 the protein percentages of two formulas were compared using 20% soldier fly larvae and 78% chicken food and 35% soldier fly larvae and 63% maize bran respectively. The soldier fly percentages were different in these two trials as chicken food had already a high percentage of protein and the total amount of protein in F3 and F4 was kept constant for comparison. With the feed formulas F5 and F6 25% soldier fly larvae was used in both trials and supplemented with mchicha *Amaranthus spp* and maize bran (maize bran is available in maize millers in most countries in which the staple food is maize meal). Mchicha is a farm product of Mtopanga farm and therefore available. After the plants for seed production were dried and the seeds were removed, there were still a lot of small seeds that remained on the plant which could therefore be used for trials. The mchicha proved to be a bad binder when pelleting was done so a local source of starch had to be found to manufacture the pellets. For this reason 20% cassava flour *Manihot esculenta* was used. In the last trial fingerlings were fed a mixture of spinach and chicken food (F7) as a lot of spinach was produced on Mtopanga farm which had black scab and therefore could not be sold. These feeds with the exception of the readily pelleted fish feeds from the Pwani feeds factory F1 and F2 were mixed with 1% baobab fruit pulp *Adansonia digitata* and 1% cement. Baobab is very rich in minerals and vitamins and it is present at the staff compound of the Bamburi Cement Ltd. The cement was added for additional mineral content (proposed by Dr. R. D. Haller). It helps to bind the pellets while also acting as a further mineral content for adequate digestion. The cement is also available on Mtopanga farm as smaller constructions need to be done from time to time and the cement factory at Bamburi being one of the partners of the Baobab Trust.

**Table 1: Ingredients in percentages of the feed formulas F1-F7 with their respective protein content**

	Feed	New Feed	Old Feed	S.F.	C.F.	M.B.	Mchicha	Casava	Spinach	Baobab	Cement	Total	protein %
Tank 1	F1	100										100	26.0
Tank 2	F2		100									100	/
Tank 1	F3			20	78					1	1	100	21.0
Tank 2	F4			35		63				1	1	100	27.3
Tank A	F5			25			53	20		1	1	100	20.7
Tank B	F6			25		73				1	1	100	18.5
Tank C	F7				49				49	1	1	100	9.0
	protein %	26.0	(26?)	42.1	16.1	10.9	17.6	3.9	2.2	5.2	-		
	Reference	a	/	b	c	d	e	f	g	h			
New Feed:		Fish Feed Pellets produced by Pwani Feeds Ltd. Mombasa after 3.12.2010											
Old Feed:		Fish Feed Pellets produced by Pwani Feeds Ltd. Mombasa before 3.12.2010											
S.F.:		Soldier Fly larvae, <i>Hermetia illucens</i> produced on Mtopanga farm											
C.F.:		Chicken Food, layers mash produced by Faida feeds Kitale											
M.B.:		Maize bran, from local maize miller											
Mchicha:		Mchicha, <i>Amaranthus spp.</i> grown on Mtopanga farm											
Casava:		Casava, <i>Manihot esculenta</i> bought from Kongoea market in Mombasa											
Spinach:		Spinach, <i>Spinacia oleracea</i> grown on Mtopanga farm											
Baobab:		Baobab, <i>Adansonia digitata</i> fruit pulp, harvested from the Bamburi Cement Ltd. staff compound baobab tree											
Cement:		Cement from Bamburi Cement factory Ltd.											

**Reference for protein content:**

- a Pwani Feeds Ltd. Mombasa (Fish feed)
- b (Sheppard, Newton, Thompson, & Savage, 2003)
- c Pwani Feeds Ltd. Mombasa (Layers mash)
- d (Harris, Asplund, & Crampton, 1975)
- e (EAP, 2010)
- f (Harris, Asplund, & Crampton, 1975)
- g (USDA, 2011)
- h (Abdalla, Mohammed, & Mudawi, 2010)

### 3 Method

#### 3.1 Feed Production

Feed production was always carried out in the same way. First the materials were dried either in the solar drier or on a black plastic in the direct sun (there was no rain in the testing period of November to February so direct sun light was abundant). So mchicha and spinach were laid out so that the moisture could evaporate and to keep them from being affected by fungi. After the materials were dry they were pounded in a traditional wood pounder. The fine powder was then weighed and mixed according to the formulas. After mixing the ingredients a little water (approximately 5% of the mass) was added and stirred well. This humid cake was then passed through a manual spaghetti machine shown below. For this purpose it was better to have at least 300 grams of feed as the machine was small and pellets could only be made if feed was enough to fill the chamber.



**Image 7: Spaghetti machine with pellets**

**Image 8: Solar drier on Mtopanga farm with soldier fly larvae and fish pellets drying**

After the pellets were made these were then dried so to get rid of the added water. Again this occurred either in the direct sun or if it was late it was dried in the solar drier so that rats and other animals did not eat them.

The soldier fly larvae were produced under a chicken house so that their droppings could feed the larvae. The larvae are also fed farm wastes like rotten eggs and vegetables, dead fish and chicken or other carcasses that were found in the near surroundings of the farm. In this way the chicken manure and other organic wastes could be utilized in producing a by-product which could act as chicken feed or in the case of this research it could be used as a fish feed ingredient.



**Image 9: Black soldier fly larvae seeking a dry place and falling into a harvesting container**

After the soldier fly larvae were harvested they were killed in hot boiling water. Then they were washed so as to remove the decaying organic materials from their origin. In a last step they were boiled for 2–3 hours on the biogas cooker of Mtopanga farm. This was done to kill off bacteria and other germs and keep them from infecting the fish feed. After this the procedure of drying and pounding was done just like the other ingredients.

### 3.1.1 Feed formulas

Recommended protein levels in diet for tilapia by Jauncey and Ross (1982).

Fry-0.5g	50%
0.5-10g	40%
10-30g	30-35%
35-market size	around 25%

Although these average requirements of protein levels must be considered, Jauncey states that tilapia are able to utilize protein levels below this optimum for good growth. Tilapia of size 1.5-6g with a 20% protein level still grew at the growth rate of a 40% protein diet (Jauncey & Ross, 1982). In this trial tilapia fingerlings of an average weight of 5.7 grams received a dietary protein level of 9%. They were kept in tank C which had the most nutrients of all the tested tanks. The nutrients of tank A and B all discharged into it, the stocking rate was only 0.44 kg/m<sup>3</sup> and the fresh water turnover rate was only 1.59% (table 2). Therefore the essential amino acids in the form of zoo- and phytoplankton can be considered as sufficient.

For tilapia over 35 grams, Jauncey recommends a protein level of around 25% with other sources implying 20-25% as optimal for environments with supplementary benthic food (Ann E. Clark, Ollad, & Wicklund, 1990), e.g. low stocking density thus more plankton. However an increased salinity up to 37

p.p.t. has proved to lower the needed amount of dietary protein in tilapia dramatically. For the rest of the tilapia, all between 44.1 up to 116.7 grams the protein level was between 18.5 and 27.3% protein (see table 1). To all feeds except F1 and F2 in each case 1% baobab fruit pulp and 1% cement was added (see 2.3.2 Other available feed ingredients).

### **F1 and F2**

These two fish feeds were bought readily as pellets. The company called Pwani Feeds Ltd. In Mombasa stopped producing the F2 in December 2010 and from there on produced F1. The fish feed ingredients of F1 could be requested from the company as below:

- Protein            26%
- Fat                6%
- Moisture        10%
- Ash               12%
- Fibre             6%
- Energy Levels 2600 kcal
- Methionine     0.6%
- Lysine            1.3%
- Phosphorus     1%
- Salt               0.5%

The exact composition of the old fish feed F2 could not be made out but it is assumed the composition is similar to the one for F1.

### **F3 and F4**

In this trial a high percentage of chicken feed (Pwani Feeds Ltd.), supplemented with 20% black soldier fly larvae was compared to a maize bran diet with a high content of soldier fly larvae (35%).

### **F5 and F6**

Both F5 and F6 had 25% soldier fly larvae. These were supplemented with either maize bran or mchicha, *Amaranthus spp.* To bind the mchicha seeds 20% cassava flour was added.

### **F7**

This feed could not be compared to any other feed, because of a lack of similar tank size. It contained a high percentage of spinach (49%) which is low in protein but very high in minerals and vitamins. Further there was also 49% of chicken feed (Pwani Feeds Ltd.) in F7.

### 3.2 Installation of the tanks

Before the feeding trials could be started the available fish had to be sorted and stocked in the 5 different tanks. A similar size of tank and a similar stocking density, size and sex ratio of tilapia had to be chosen from the available fish and the available infrastructure so that growth rates of tilapia could be compared in similar conditions. Prior to feeding trials the tilapia in tanks 1 and 2 were fed with F2 (the old Pwani fish feed) to get them used to pellets. Tanks A, B and C were pre-fed F7 (a mixture of mchicha and chicken food). As shown in table 2 below the largest male tilapia were used in the small tanks 1 and 2 which had a high fresh water rate. The stocking density in tanks A and B were smaller as the fresh water percentage per day was little. Tank C with the remaining fingerlings had the lowest stocking density while also having a very small fresh water percentage per day.

**Table 2: Table of tanks with information about tilapia size, stocking density and % of fresh water per day**

feed	Tank	No of tilapias	average tl (cm)	total weight (kg)	tank volume (m <sup>3</sup> )	stocking density (kg/m <sup>3</sup> )	fresh water/day (%)
F1	1	31	18.03	3.25	0.93	3.48	135.00
F2	2	30	18.83	3.50	0.93	3.75	135.00
F3	1	31	17.99	2.75	0.93	2.95	135.00
F4	2	30	18.74	3.25	0.93	3.48	135.00
F5	A	216	14.37	17.51	9.41	1.86	23.05
F6	B	214	15.63	15.23	8.31	1.83	6.02
F7	C	636	7.44	3.65	8.20	0.44	1.59

### 3.3 Feeding rate and procedure

The male tilapias in the trials of F1-F4 were fed 3 times daily until they rejected the feed. This was done to stimulate continuous digestion and to find their average daily intake of food. So the feed was weighed and after the tilapia stopped eating the remaining feed was subtracted to get exact food taken.

Tanks A and B were fed only 50 grams of F5 respectively F6 a day, as at the time of trial the soldier fly larvae production was limiting feed production. Tank C was fed only 25 grams a day. This forced the feed for tanks A, B and C to be distributed only once a day as we would have only fed the biggest tilapia at each feeding session if the little food was divided into 3 meals.

### 3.4 Sampling and measuring

For sampling the tilapia in tanks 1 and 2 (F1-F4) the water was released and all fish were measured and the total weight was taken. In doing so the tanks could be cleaned regularly every 3 weeks so that turbidity in the densely stocked tanks could be reduced.

Tanks A, B and C were sampled using a throwing net which was utilized after tilapia were attracted by feeding pellets. In these 3 tanks the sampling was 20% of the population. Because the sex ratio in tanks A and B was almost 2 males to 1 female, 29 males and 17 females were measured in the sampling. In tank C containing 363 fingerlings 131 samples were taken. In these sampling procedures the time factor and the handling was very crucial. If tilapia were not handled with care or if the time for

them being in a small bucket (without sufficient dissolved oxygen) was too long, their recovery was very slow. The handling and the fast work with the tilapia are therefore important factors during sampling and can lead to high mortalities. After the losses in the installation of tanks 1 and 2 in the beginning, no more losses were experienced.



**Image 10: Attracting tilapia with fish feed for throwing the net (sampling of tanks A, B and C)**

The parameters that were taken during sampling were: sex, total length, standard length, depth, width and total weight. In tank C though because these tilapia (average total length 7.44 cm) were too small for distinguishing the sex and the parameters standard length, depth and width, only the total length and the weight over all 131 fingerlings were recorded.

### 3.5 Calculation

The total weight gain of the tilapia was now used for calculating the growth increase and the food quotient was found. The food quotient being the more important parameter as also the amount of feed fed is taken into account.

As the exact weights of the individuals were never measured, all weights are average weights. To calculate the condition factor, the average weight and the average total length of the tilapia was used, so all condition factors are average condition factors as well.

Food quotient = total feed mass (g) / weight gain (g)

Condition factor =  $100 * (\text{average mass (g)}) / (\text{average total length}^3 \text{ (cm)})$

## 4 Results

### 4.1 F1 compared with F2

The average weight of the tilapia (only males) for tank 1 (F1) was initially 104.8 grams while it was 116.7 grams for tank 2 (F2). After the first 20 days F2 was still leading with 125.0 grams compared to 112.9 grams. But in the last 15 days of the feeding trial the average tilapia weight in tank 1 (F1) overhauled the one in tank2 (F2). It was 137.1 grams for F1 and 133.3 grams for F2.

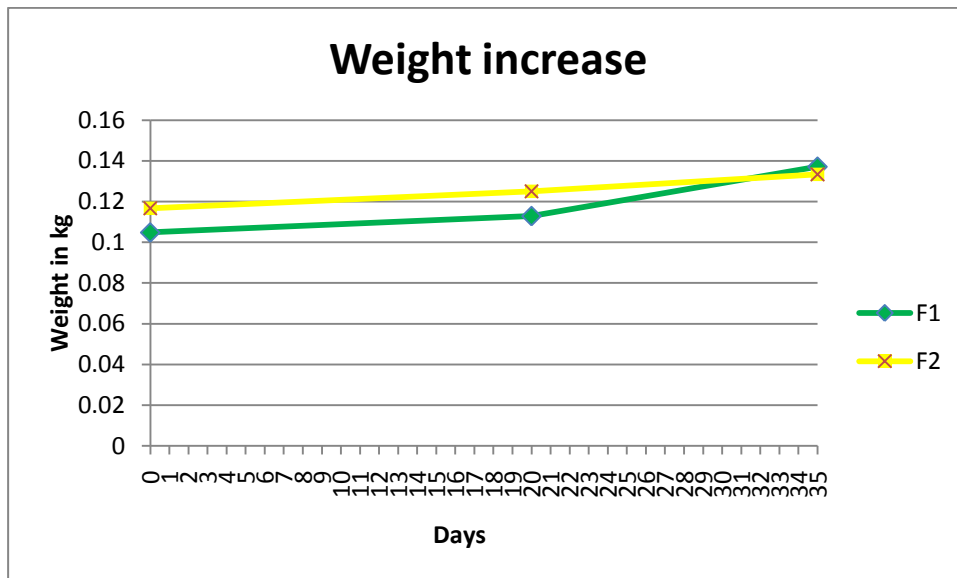


Image 11: Comparison of the average weight increase of F1 and F2

The food quotient for the first 20 days of the trial was very similar for F1 and F2 (3.34 and 3.40 respectively). But for the next 15 days the food quotient became much better for both feeds. For F2 it was 2.08 and for F1 it even reached 0.59. Over the whole period of 35 days the food quotients for F1 and F2 were 1.28 and 2.74.

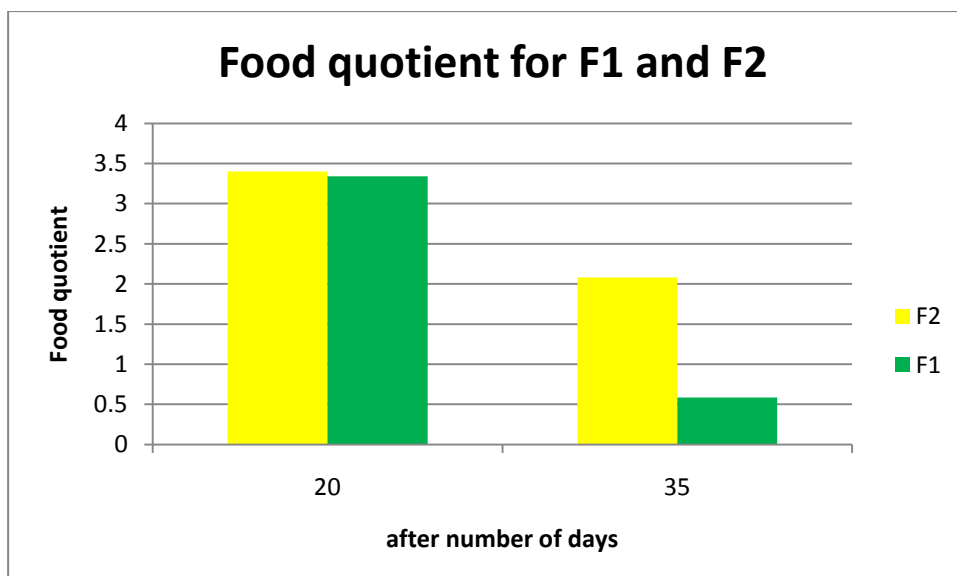


Image 12: The average food quotient for tank 1 (F1) and tank 2 (F2)

The average condition factor for the tilapia in tank 1 (F1) and tank 2 (F2) started off very close to each other; F1 had an average of 1.79 whilst F2 had 1.75. After 20 days it was nearly equal (F1 had 1.78 and F2 had 1.79). On the 35th day the average condition factor for F1 was clearly better with 2.21 compared to 1.96 for F2.

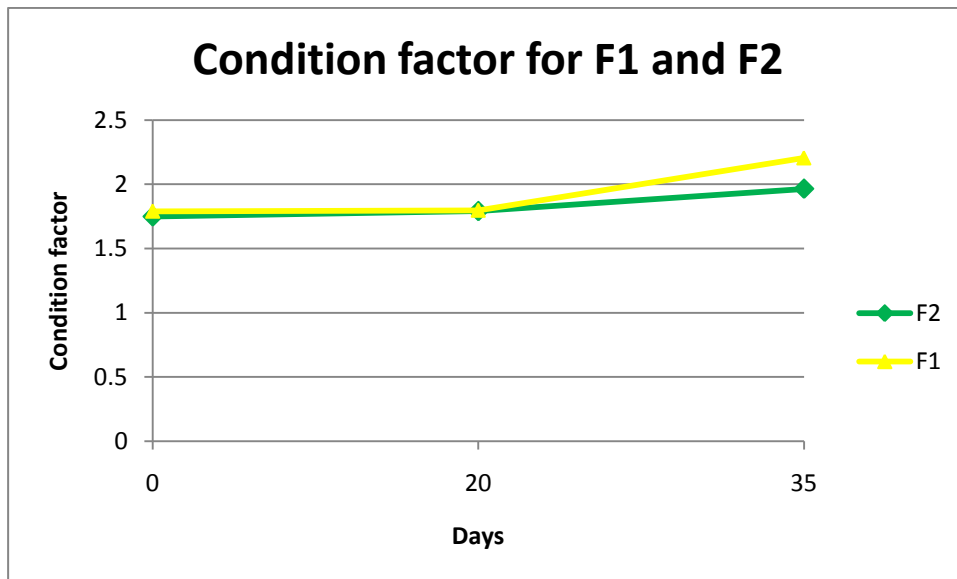


Image 13: Average condition factor for F1 and F2 in the beginning, after 20 days and after 35 days

## 4.2 F3 compared with F4

The weight increase for F3 was higher, from 88.7 to 104.8 grams. F4 accounted for an increase from 108.3 to 116.7 grams.

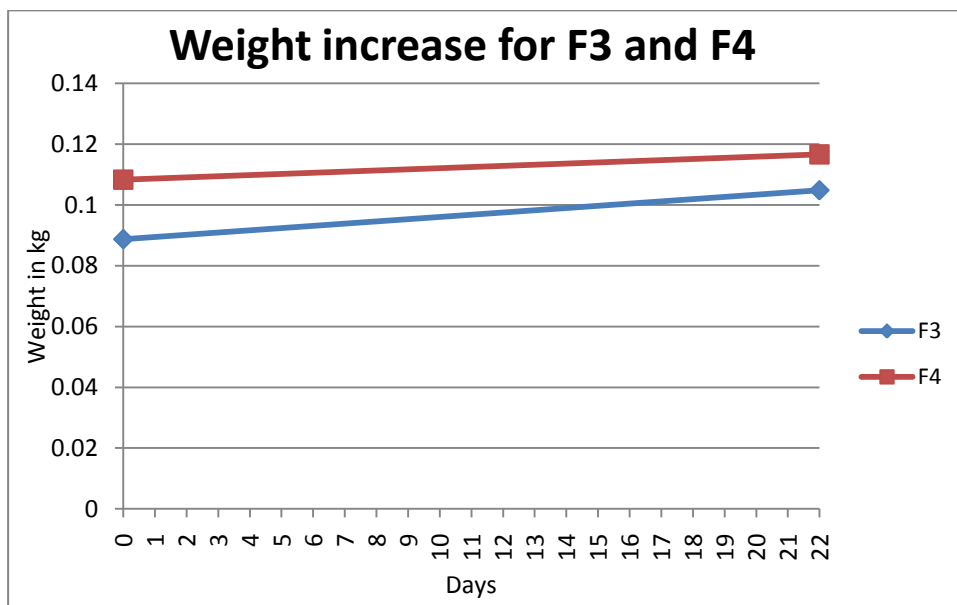
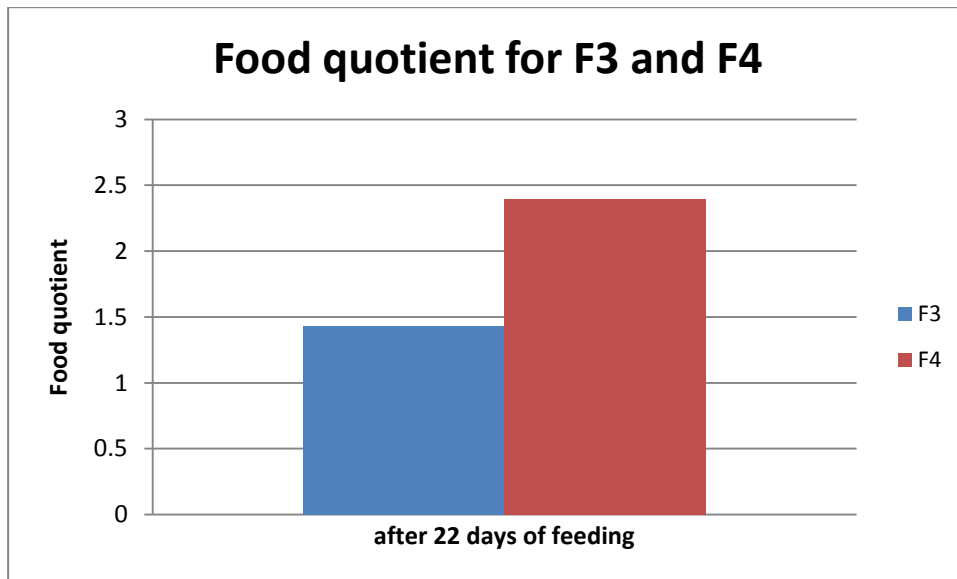


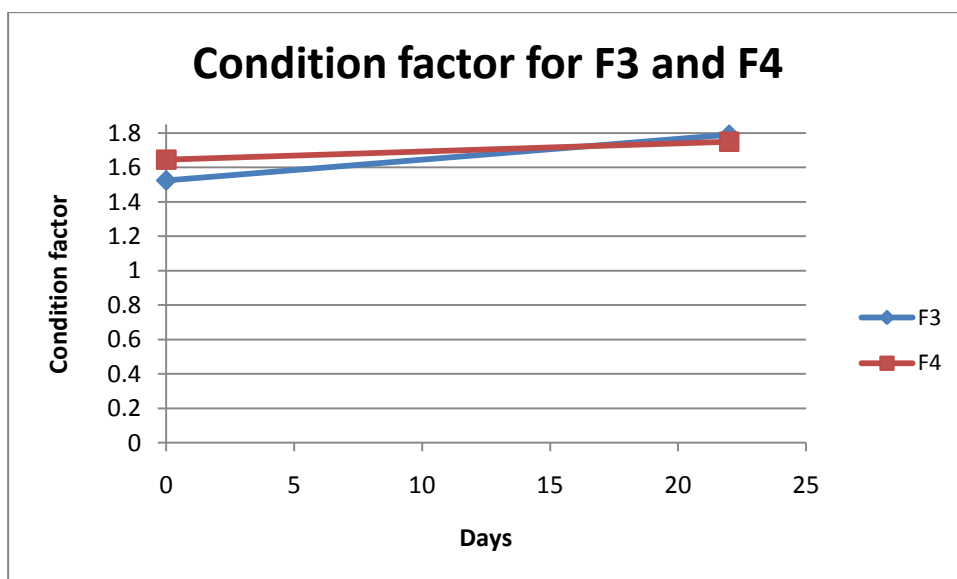
Image 14: Comparison of the weight increase of F3 and F4

The food quotient for F3 was clearly better with 1.43 compared to 2.40 for F4.



**Image 15: Food quotient of F3 compared with F4**

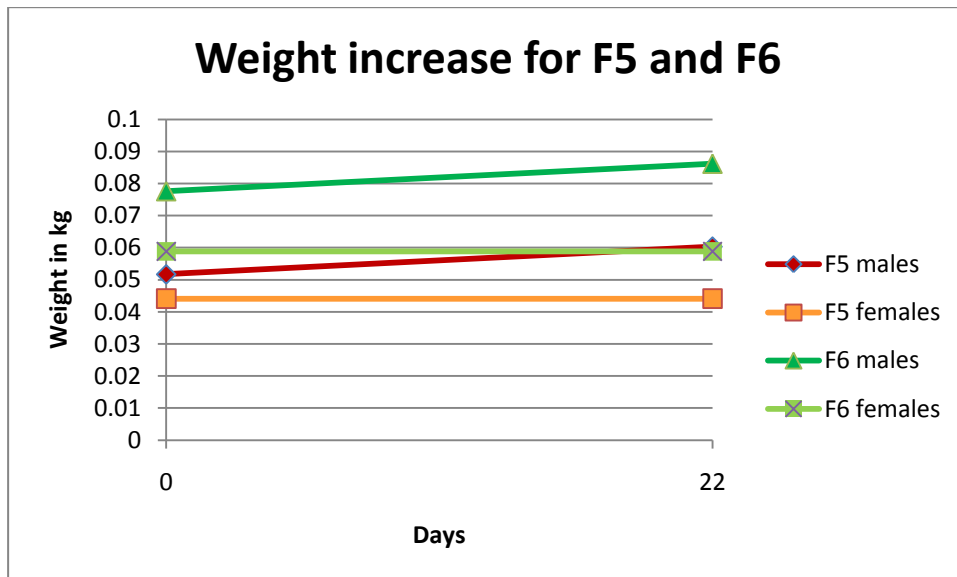
The condition factor for F3 overtook the initially higher condition factor for F4. F3 started off with 1.52 and ended with 1.79. For F4 it was 1.65 in the beginning and 1.75 at the end of the feeding trial.



**Image 16: Condition factors for F3 and F4**

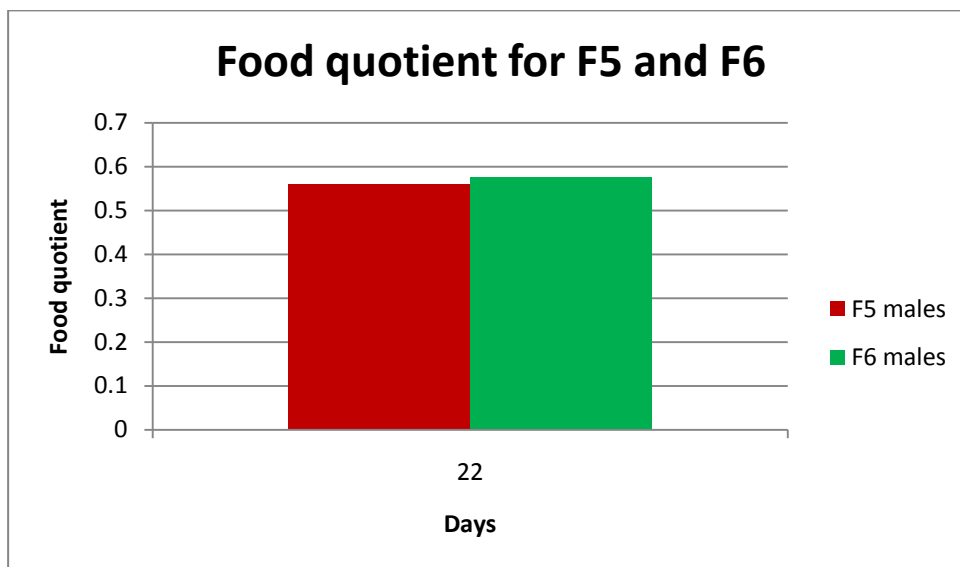
### 4.3 F5 and F6

In tank A and B there was a 2:1 sex ratio of males to females. In both tanks the males had a good growth. In both tanks the females did not increase in weight.



**Image 17: Comparison of the weight increase of F5 (males and females) and F6 (males and females)**

The food quotient could only be calculated for the males as the weight increase of females was zero. Both food quotient are very good (F5 it was 0.56 and for F6 it was 0.58).



**Image 18: Food quotient for F5 and F6 (males only)**

With the exception of the females in the feeding trial with F6, all others had a slight increase in condition factor.

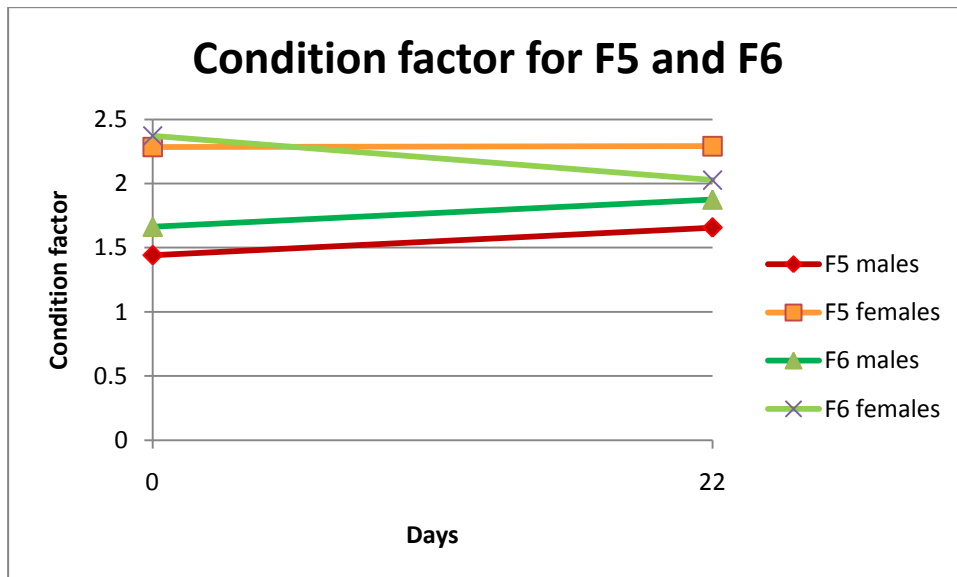


Image 19: Condition factors for F5 and F6 (males and females)

#### 4.4 F7

The weight increase for F7 was 100% in 22 days. The growth rate was so high because the fish were small and in their juvenile growth using the little feed fed only to supplement their diet of algae and microorganisms. A food quotient of 0.17 was achieved which is unrealistic if the fingerlings only had the feed F7 at their disposal.

## 5 Discussion

Over all the best food quotient was achieved by F7. The reason for this being that these fingerlings in tank C relied mostly on other foods than on the one given as this was very little (25 grams per day for 636 tilapia with a size of 5.73 grams). Their daily growth rate is therefore the highest, reaching 4.55 % of the body weight daily. If compared with table 2 (Installation of tanks) it is seen that the stocking density here was very low ( $0.44 \text{ kg/m}^3$ ).

The food quotient of F5 and F6 were 0.56 and 0.58. These are only for the males although the sex ratio was 2:1 males to females. But because the weight increase of the females could not be registered by the spring scale it was assumed that the females ate one third of the given food but invested their energy into reproduction instead of growth. The stocking densities in tanks A and B were 1.86 and 1.83. These densities were too low so there was enough space for the most dominant males to set up territorial nests and attract females for mating. According to the fresh water circulation of tank A and B (23.05% and 6.02% fresh water per day) the obvious conclusion would be that tank A should have a better food quotient. This is not the case as seen in table 3. As the feeding rate was kept at 50 grams per day (due to a lack in soldier fly production) for tanks A and B, these tilapia relied on additional foods in the respective tanks – their stocking densities being very low at 1.86 and 1.83  $\text{kg/m}^3$ .

**Table 3: Daily growth rate and food conversion for F1-F7**

feed	Tank	av. mass(g)	d.g.r.	f.q.
F1	1	104.84	0.88	1.28
F2	2	116.67	0.41	2.74
F3	1	88.71	0.83	1.43
F4	2	108.33	0.35	2.40
F5 (males)	A	51.72	0.76	0.56
F6 (males)	B	77.59	0.51	0.58
F7	C	5.73	4.55	0.17

d.g.r.                      daily growth rate (% body weight/day)  
f.q.                         food quotient

In both feeding trials with tanks 1 and 2 (Feeding formulas F1-F4), tank 1 had the better food quotient and daily growth rate compared to tank 2 (it was nearly doubled). This could be due to F1 and F3 being better feeds than F2 and F4. It could also be interpreted that tank 1 always had the lower stocking density than tank 2 (see table 2).

The new fish pellets of Pwani Feeds Ltd. (F1) had a disadvantage to the other feeds; it was very compact and hard making it very difficult for the tilapia to swallow. This could be seen while feeding be-

cause the tilapia spat out the feeds until they were almost dissolved in water. Because of this F1 was soaked in water before feeding as tanks 1 and 2 were always fed until the tilapia lost interest in the food. Another disadvantage of F1 and F2 was that both pellets were so heavy that they did not float and sank to the bottom of the tank. This can result in a considerable loss of feed as the nutrients would be used by phyto- and zooplankton or other microorganisms. So if the food is not eaten directly by the tilapia, it acts as nutrients and lowers the direct energy intake because microorganisms also need metabolic energy for their growth and this energy is therefore lost for tilapia growth.

The feeding trials range from 20 to 35 days. This period is too short to make a significant proposition. Feeding trials should be at least 3 months at a time. So it would be very interesting to see the results after a period of 3 months and compare them with similar feeding trials in African countries.

Also the parameters water temperature, pH, dissolved oxygen and turbidity should be monitored. The fresh water circulation should be more accurate as it is very difficult to pump 1260 litres of water per day by hand pump for just one tank. A solar panel with a constant water flow could be taken into account for accurate results. These are very expensive and are not affordable for small scale local fish farmers in Kenya. So it can be assumed that the conditions under which these results have been achieved are comparable to the conditions under which local farmers in Mombasa are producing tilapia.

As for the future it can be said that the feed (F1) from Pwani Feeds Ltd. has shown good growth results but is very expensive. Substituting with chicken food (as it is being done on Mtopanga farm with the family fish ponds) can also deliver good growth in tilapia – and the price is considerably lower. To be independent from any manufactured feed stuffs and relying only on farm by-products such as black soldier fly larvae, mchicha, cassava, spinach and maize bran would be the cheapest way of tilapia production as the salary for labour per hour in Kenya is very low.

Pwani Fish feed	KSh 32.00/kg
Pwani Layers mash	KSh 25.71/kg
Maize millers' bran	KSh 15/kg

**Table 4: Price per kg feed and per kg fish according to the food quotient (table 3)**

feed	Price/kg feed	Price KSh/kg fish
F1	32.00	40.96
F2	32.00	87.68
F3	20.05	28.68
F4	9.45	22.68
F5	0.00	0.00
F6	10.95	6.31
F7	12.60	2.16

If the labour is not taken into account for preparing the feeds the price of producing 1 kg of tilapia with the given feed would be as above. F5 has no ingredients that need to be bought so it is the cheapest way of production. Then F7 (whereas the stocking density must be taken under account) proceeds, followed by the feed F6 (maize bran and soldier fly). The use of maize bran and soldier fly in F4 with a different composition is clearly more expensive than F6. The most expensive feed is F2 (the old Pwani feed). This is so due to its bad food quotient.

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