# Optimizing the Use of Commercial Feeds in Semi-Intensive Pond Production of Tilapia in Ghana; From Nursery to Grow-Out

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Production System Design and Best Management Alternatives/Experiment/16BMA02PU

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## Objectives

1. To evaluate the survival, feed conversion, and growth of Nile tilapia raised in ponds on high-protein commercial feeds from fry to fingerling sizes.
2. To compare the growth and yield of Nile tilapia in grow-out ponds fed full ration on 30%, 28%, and 25% protein from commercial feeds in combination with fertilization.
3. To compare growth and yield of Nile tilapia in grow-out ponds with 30% protein from commercial feeds at full and 50% ration, in combination with fertilization.
4. To evaluate the palatability/acceptability, digestibility of experimental diets made from locally available ingredients fed to Nile tilapia; from fry to fingerlings.
5. To evaluate the survival, feed conversion, and growth performance of Nile Tilapia raised in ponds on experimental diets from fry to fingerling sizes.
6. To determine the phytoplankton and zooplankton composition and succession under objectives 1 and 5.
7. To evaluate the profitability of the different feeding strategies based on the outcomes of the experiments in objectives 1, 2, 3 and 5.

## Significance

Fish account for over 50% of total animal protein consumed in most developing countries (FAO, 2007). Fish and other aquatic animals make a significant contribution to food and nutrition security in many Asian and African countries, where large numbers of people are poor and undernourished (Kent, 1987; World Bank, 2006). In developed countries fish consumption is increasing because of associated health benefits. Fish is by far the most frequently consumed animal source of food consumed in Asia and Africa (Gomna and Rana, 2007; Hortle, 2007; Bell et al., 2009; Biederlack and Rivers, 2009 and Belton et al., 2011). Aside from being a means to secure nutritional gains and of income generation, poverty reduction and food security, aquaculture is increasingly becoming a means to increase domestic fish supply to low-income consumers and create jobs (WorldFish Centre, 2011). Tilapia production has increased worldwide with and is now considered the 2$^{nd}$ most farmed species in the world and it is expected to continue to grow in tropical areas (Watanabe et al., 2002; Fitzsimmons, 2013). With the growth of industry comes the need to improve on production systems and reduce production costs as well as reduce overdependence on dwindling fish meal and fish oil sources from the wild used in feed prodcution in the industry. This will mean more research to develop better production systems, improved value chain, alternative feed ingredients and minimal environmental impact.

The small and medium scale pond sectors of the aquaculture industry in Ghana still struggles to effectively integrate routine and profitable use of commercial floating feeds into farming operations, despite a growing availability of high-quality commercial feeds in the country. Recent AquaFish Innovation Lab studies of growth performance of Nile tilapia (*Oreochromis niloticus*) during the grow-out phase in Ghana showed the superiority of commercial floating feeds compared to farm-made sinking feeds (Ansah and Frimpong, 2015). Most farmers already acknowledge that commercial feeds would increase profitability during grow-out, hence a growing number of small-scale tilapia farms have tried commercial floating feeds or use them routinely in their production. For pond-based semi-intensive tilapia farms using commercial feeds, feed constitute approximately 60% of the cost of production and, due to importation of feeds or feed ingredients, this component of cost increases as the value of the local currency depreciates continually against major world currencies. There have been advances made in the use of agro-products as partial replacements of fish meal as the protein source in tilapia diets (Obirikorang et al., 2015).

A combination of high feed cost and lack of technical know-how in the efficient use of feeds and optimal fertilization has been identified as an obstacle to increased yield and profitability of small-scale fish farming in Ghana.

The importance of pond fertilization has been highlighted by several studies. FAO (2005) reported harvest outputs of 3 MT/ha for tilapia grown in fertilized ponds without any external feed inputs. The production of tilapia in fertilized ponds (5,135-9,000 kg/ha) was 2 to 4 times higher than in unfertilized ponds (2,240 kg/ha) (Das and Jana, 1996). Studies done by Diana et al., (1994) and Diana (2012) showed that fertilization rates of between 50-70% had fish yields comparable to ponds that received 100% of the recommended rates.

Secondly, in spite of the progress made in the development of the improved Akosombo strain of Nile tilapia in Ghana, pond farmers scattered through the regions still face a lack of access to adequate fingerlings of the appropriate size for expanded production. Since demand for fingerlings exceeds its supply and the fingerling size and sex reversal needs for cage and pond farms differ, most pond farms can only access fingerlings from the wild or are forced to purchase fingerlings that are too small (fry) and not properly sex-reversed, leading to high mortality, high in-pond breeding, and ultimately, low productivity. Overall throughout the country, not only are hatchery capacities limited but also no true nurseries exist. Therefore, high demand for fingerlings have driven down the size of fingerlings that hatcheries are able to produce and buyers are willing to take, leading to the sale of increasingly smaller sizes of fingerlings that are more susceptible to mortality when handled.

The most practical solution for pond farmers is to buy fry at 1.5 - 2 g and transport long distances. Others acquire broodstock and produce their fry on-farm. Techniques are needed for farmers to raise fry on quality feed to rapidly reach the sizes at which the tilapia sexes can be identified visually (15-30g) and separated before sexual maturity. For small-scale, pond-based farming, manual separation of the tilapia sexes for stocking continue to be the most viable approach for monosex grow-out since hormonal sex-reversal continue to deliver unpredictable success rates for pond-based farming of tilapia in Ghana. Profitable on-farm nursery of tilapia will require optimization of growth rate, survival rate, and feed conversion, whether undertaken with commercial or farm-made feeds.

In this proposed study, a series of experiments and economic analyses will be performed based on lessons learned from other developing countries, including previous AquaFish funded studies, to develop a locally verified base of knowledge for pond-based tilapia producers in Ghana.

## Quantified Anticipated Benefits

At the completion of this study, it is anticipated that improved knowledge of commercial feed use will translate into both increased yield and profitability through the production cycle. The Ghana Aquaculture Development Plan has a target of 100,000MT/year of domestic tilapia production by the end of 2018. Contribution of pond aquaculture to the current production of ~ 40,000MT/ year is less than 10%, in spite of high existing pond capacity and growing availability of commercial fish feeds. The US imports over 90% of seafood consumed and tilapia is among the top three fishes imported into the states (Harvey, 2016). Tilapia imports continue to grow e.g., in 2002, approximately 148 million pounds of tilapia was imported into the US compared with a little over 496 million pounds in 2015. The National Oceanic and Atmospheric administration of the Department of Commerce, in its 2016 - 2020 strategic plan for aquaculture development (NOAA, 2015), emphasizes the need to reduce reliance on fishmeal and oil as well as increase the number and types of ingredients available to feed manufacturers. This study will not only ensure that more small-scale pond farmers make profits through a more efficient use of local ingredients, commercial feeds and fertilization, but it will also raise the contribution of pond farms to national aquaculture development goals for the both Ghana and the US. It is also expected that the study will facilitate solutions to local feed problems for fish farmers through a routine use of profitable low-cost technology.

## Research Design and Activity Plan

The experimental components of this study will be carried out in earthen ponds, tanks and hapas. Objectives 1, 2, 3, 4, 5, and 6 are respectively matched with Experiments E1, E2, E3, E4, E5, and E6.

***Experiment E1***

*Hypothesis 1:* Growth rate of fry/fingerling will increase with decreasing stocking density.
*Hypothesis 2:* Survival rate of fry/fingerling will increase with decreasing stocking density.
*Hypothesis 3:* FCR will decrease with decreasing stocking density.
Experiment E1 will follow a completely randomized design with two factors: 1) Density at 25, 50, 75, and 100/m$^3$, and 2) Time (i.e. number of days till fish are observed) at 10, 20, 30, and 40 d (Figure 1). Each experimental unit is a hapa of size 1 – 4 m$^2$ in a pond of 1 m water depth. All fish will be stocked at the same size of approximately 2 g and fed twice daily to satiation (or the minimum percent of body weight by size recommended by the feed manufacturer) on a 45-50% protein commercial feed. After weighing subsamples for stocking, fish will not be sampled until the predetermined day of observation, to minimize handling mortality. At the predetermined time, data will be collected and the observed experimental units will be closed. All surviving fish from each observed unit will be counted and weighed and the data used to calculate growth, survival, and feed conversion ratio (FCR) for each treatment. The experiment will be repeated with fingerlings from at least one different hatchery to provide more robust results with up to six replicates per treatment. In the event of limitation of ponds, the experiment may be carried out in batches over six months to one year.

Figure 1 – Experimental design for Experiment 1 (E1).

| **Density** | **25 fry/m$^3$** | | | | **50 fry/m$^3$** | | | | **75 fry/m$^3$** | | | | **100 fry/m$^3$** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Days till Observed** | 10 d | 20 d | 30 d | 40 d | 10 d | 20 d | 30 d | 40 d | 10 d | 20 d | 30 d | 40 d | 10 d | 20 d | 30 d | 40 d |
| | 10 d | 20 d | 30 d | 40 d | 10 d | 20 d | 30 d | 40 d | 10 d | 20 d | 30 d | 40 d | 10 d | 20 d | 30 d | 40 d |
| | 10 d | 20 d | 30 d | 40 d | 10 d | 20 d | 30 d | 40 d | 10 d | 20 d | 30 d | 40 d | 10 d | 20 d | 30 d | 40 d |

***Experiment E2***

*Hypothesis 4:* Growth rate and FCR will not differ between 30%, 28%, and 25% feeds in a fertilized pond.

Experiment E2 will be carried out in experimental 150 – 200m$^2$ ponds. The experiment will be run at least 2 times for a total of 18 experimental units and 6 replicates per treatment. This is a one-factor experiment at 3 levels of protein (30%, 28%, and 25% protein) following a completely randomized design. Our experience in previous experiments have indicated that the first round of an experiment may not evolve as planned and at least a second round experiment may be desired to correct errors and increase power for statistical analysis. The 30% and 28% protein feeds are available on the market in Ghana from a locally-based feed producer with whom we have worked in the past. The 25% feed will be produced under a special arrangement with the producer. Fish for this experiment will first be stocked as 2 g fry in a hapa within each pond and fed on high-protein feeds until they attain approximately 30 g before being sorted by size and sex. Males will be stocked in the experimental ponds at 2-3/m$^2$. Thereafter, feeding will be 2 times a day (approximately 10:00 am and 16:00 pm) starting at 4% mean body weight (mbw)/day and reducing through the growth period to about 2% mbw/day at harvest. Fish growth will be monitored biweekly to about 350 - 400 g which is projected to take 5 months per experimental run.

***Experiment E3***

*Hypothesis 5:* Growth rate will not differ between the half-ration and full-ration 30% protein feed treatments in a fertilized pond.

*Hypothesis 6:* FCR will be lower for the half-ration treatment compared to the full-ration treatment in a fertilized pond.

Experiment E3 will be carried out in experimental 150 – 200m$^2$ ponds. The experiment will be run at least 2 times for a total of 12 experimental units and 6 replicates per treatment. This is a one-factor experiment at 2 levels of feeding (30% protein; full ration and 30% protein; half ration) following a completely randomized design. Stocking, feeding and monitoring will follow protocols described for E2 with the half ration treatment receiving half of the quantities of feed as the full ration treatment.

***Experiment E4***

*Hypothesis 7:* Palatability/acceptability will not differ among the different diets.

This experiment will be run on three experimental diets formulated using locally available and affordable ingredients. Diets will have different levels of combinations of the following protein sources: palm kernel cake (PKC), Copra cake (CC), Soybean meal (SBM), and Groundnut husk (GNH) and formulated to have iso-protein and iso-energy levels that are comparable to that of the commercial diet used in E1. Rice bran and wheat bran will be the main energy sources used. This will be a 2-week study and the experimental units used will be glass tanks at KNUST lab/farm using a completely randomized design. Each treatment will have three replicates.

***Experiment E5***

*Hypothesis 8:* Survival rate will not differ among the different diets.

*Hypothesis 9:* Growth rate will not differ among the different diets.

*Hypothesis 10:* FCR will not differ among the different diets.

Experiment E5 will also be based on a completely randomized block design following E1 (Figure 1) but with the best two experimental diets from E4. The diets will also be iso-nitrogenous and iso-energetic and comparable to the commercial diet used in Experiment E1. The commercial diet used in experiment E1 will also serve as the control for this experiment. The three experimental diets plus the control diet will be fed to fish in 1 - 4 m$^2$ hapas mounted in ponds of water depth of at least 1m. Fish will be stocked at approximately 2g and fed twice daily to satiation on a 45-50% protein until the end of the study. The duration of this experiment will be informed by results obtained from E1 (30 – 40 days).

***Experiment E6***

*Hypothesis 11:* Phytoplankton communities will not be different among diets in E1 and E5.

*Hypothesis 12:* Zooplankton communities will not be different among diets in E1 and E5.

Phytoplankton and zooplankton composition and succession in ponds will also be monitored following methods described in Frimpong and Lochmann (2006) and Ludwig et al., (2010); three random samples will be taken from each experimental pond in E1 and E5 before stocking and weekly after stocking.

***Location***
Experiments will be carried out in aquarium tanks and ponds at the Fish Farm at Kwame Nkrumah University of Science and Technology, Kumasi. Other partners' (e.g., Pilot Aquaculture Center of the Fisheries Commission, PAC) facilities will be used as needed.

***Methods***
All experimental ponds will be fertilized with the same AquaFish recommended protocol. After draining and drying ponds for 2 weeks to 1 month (depending on weather), agricultural limestone ($CaCO_3$) will be applied to the pond bottom and the slopes of the dykes at a rate of 100 g/m$^2$. Seven days later, the ponds will be filled to 1 m depth and stocked one week after fertilization begins. Fertilization will be applied once a week at 4 kg Nitrogen and 1 kg Phosphorus/ha/day, using urea and diammonium phosphate. The 1 m pond depth will be maintained with periodic topping up of water as needed. Routine water quality measurements will also apply to all ponds on a weekly basis using Hanna multiparameter meter HI 9828. Variables to be monitored include temperature, dissolved oxygen and pH. In addition, Secchi disk depths will be taken once a week to monitor the effectiveness of the fertilization. Experimental data on growth, survival and FCR will be analyzed for each experiment using Analysis of Variance (ANOVA) techniques. Repeated measures ANOVA will be run on data from the control and the experimental diets, after which a post-hoc analysis will be run to test for differences among treatments means.

Diet palatability/acceptability of experiment diets will be assessed subjectively by directly observing fish feeding responses/behavior and also by quantifying feed intake in tanks. Temperature, pH and dissolved oxygen will be monitored daily for two weeks. Phytoplankton samples (100 mL) will be preserved by adding 0.5 mL formalin and 1 mL Lugol's solution. Phytoplankton in the samples will be quantified and identified to genera level (Ludwig et al., 2010). For the zooplankton, samples will be preserved in 70% isopropyl (Frimpong and Lochmann, 2006; Ludwig et al., 2010). Zooplankton in the samples will be identified to the three major groups – rotifers, copepods and cladocerans.

The experimental data will provide input to economic analysis of relative profitability of the feeding strategies. Standard methods for profitability analysis, including enterprise budgets and partial budgets will follow Engle and Neira (2005). Feed prices for estimating the cost of production will be obtained both from the market and from the feed producer's pricing schedule. Current farm-gate prices of tilapia in Ghana at the time of analysis will also be obtained from the market. Based on available data, the 25% protein feed, for example, is priced about 15% less/kg compared to the 30% protein feed. It is straightforward then to determine the cost savings if pond farmers of tilapia can use the 25% feed for grow-out and achieve an insignificant difference in growth performance compared to the 30% feed. All data for profitability analysis will be organized in Microsoft Excel and Monte Carlo analysis using @Risk software embedded in Excel will ensure that various forms of uncertainty in prices and the experimental results will be accounted for.

**Trainings and Deliverables**
There will be 1 training/workshop for 100 tilapia farmers (hatchery operators, nursery operators and potential operators and fish farmers, and aquaculture students) on optimal stocking densities and optimal protein levels and feeding strategies. This will also serve as a means of disseminating results from the project. Deliverables will be:

1. A training/workshop will be conducted for at least 100 tilapia farmers in optimal production techniques;
2. Final Report;

3. At least four peer reviewed publications: (best fry stocking densities for optimum growth, performance of the new fingerling feed, best protein levels for optimal returns and plankton composition and succession);
4. Four MSc. and one BSc. students trained in tilapia production system design and management.

**Schedule**

| ACTIVITIES | 2016/2017 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | A | M | J | J | A | S | O | N | D | J | F |
| Inception meeting | | | | | | | | | | | | |
| Pond preparation for round 1 experiments | | | | | | | | | | | | |
| Stocking of fry and fingerlings | | | | | | | | | | | | |
| Preparation of experimental diets | | | | | | | | | | | | |
| Acceptability/Pal. trial- experimental diet | | | | | | | | | | | | |
| Weekly fertilization & Water quality monitoring | | | | | | | | | | | | |
| Biweekly fish growth monitoring | | | | | | | | | | | | |
| Plankton sampling and identification | | | | | | | | | | | | |
| Fish harvesting | | | | | | | | | | | | |
| Profitability Analysis | | | | | | | | | | | | |
| Data analysis | | | | | | | | | | | | |
| Pond preparation for round 2 of experiments | | | | | | | | | | | | |
| | 2017/2018 | | | | | | | | | | | |
| | M | A | M | J | J | A | S | O | N | D | J | F |
| Pond preparation for round 2 of experiments | | | | | | | | | | | | |
| Stocking of fry and fingerlings | | | | | | | | | | | | |
| Weekly fertilization & Water quality monitoring | | | | | | | | | | | | |
| Biweekly fish growth monitoring | | | | | | | | | | | | |
| Plankton sampling and identification | | | | | | | | | | | | |
| Fish harvesting | | | | | | | | | | | | |
| Profitability Analysis | | | | | | | | | | | | |
| Data analysis & report writing | | | | | | | | | | | | |
| FINAL REPORT WRITING | | | | | | | | | | | | |