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Source: Aquatic Ecosystem Health & Management, 25(4) : 60-67

Published By: Michigan State University Press

URL: https://doi.org/10.14321/aehm.025.04.60

AQUATIC ECOSYSTEM
HEALTH & MANAGEMENT SOCIETY

MICHIGAN STATE UNIVERSITY PRESS

Performance of diets composed of *Artemia* biomass and fish meal fed to juvenile marine Tilapia in cages

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Mariculture development in Kenya has previously relied on culture of fish in intertidal earthen fish ponds that are fertilized to enhance primary production and use of limited supplementary feeds. Most of the supplementary feeds used have previously been obtained from those of freshwater fish due to lack of marine fish feeds in the country. Cage culture is being introduced to utilize the open space in the sea and hence introduction of more species for farming, that require new feeding strategies that are feasible. Therefore the need to develop marine based fish feed formulations. Taking this into consideration, Kenya Marine and Fisheries Research Institute is developing a feed formula that brings ingredients from the coastal environment that are unique: i.e. seaweeds, coconut husks and Artemia *for development of a marine feed. Initial assessments of the developed feed indicate that marine Tilapia grows at 1.2 g day^{-1}, Rabbitfish at 1.9 g day^{-1} and Milkfish at 1.4 g day^{-1}. The formula is being refined and validated over time before being given out for commercial use in the feed industry to enhance production from mariculture. The treatments were carried out in replicate during a culture period of 138 days. Locally formulated and prepared diets containing 30% crude protein were applied. Treatment 2, a fish meal omena* (Rastrineobola argentea) *based feed showed better growth outcome as compared to treatment 1* (Artemia *based feed*) *in terms of weight gain, specific growth rate (0.93), survival rate (70%) and feed conversion ratio (2.2). Frequent data collection for both water quality and growth parameters is recommended to enable visualize better growth trends and culture conditions. Further research at different stocking densities with larger juveniles (50g weight) that can withstand the cage environment is recommended.*

Keywords: culture, fish feed, growth, fish.

Introduction

Increasing population, climate change, and use of wild fish for feed production has made the current fish production from aquaculture fail to meet the rising demand (Belghit et al., 2018; Naylor et al., 2021). To boost aquaculture production and enhance sustainability, formulation of good quality and affordable feeds that guarantee fast growth and survival is vital (Limbu et al., 2022). Nile Tilapia has been considered as an important species of fish in tropical aquaculture and has shown potential in fight against food insecurity, malnutrition, and poverty in Africa (Bene et al., 2005; FAO 2012).

Fish meal and fish oil are still considered as the most nutritious and having most digestible ingredients for farmed fish (FAO, 2020). However, their inclusion in formulated diets is decreasing mainly due to low supply and high prices. Their application is currently targeting specific stages of growth such as larvae and broodstock (FAO, 2020).

These ingredients have been showing a

Aquatic Ecosystem Health & Management, 25(4): 60–67, 2022.
ISSN: 1463-4988 print / 1539-4077 online. DOI: 10.14321/aehm.025.04.60

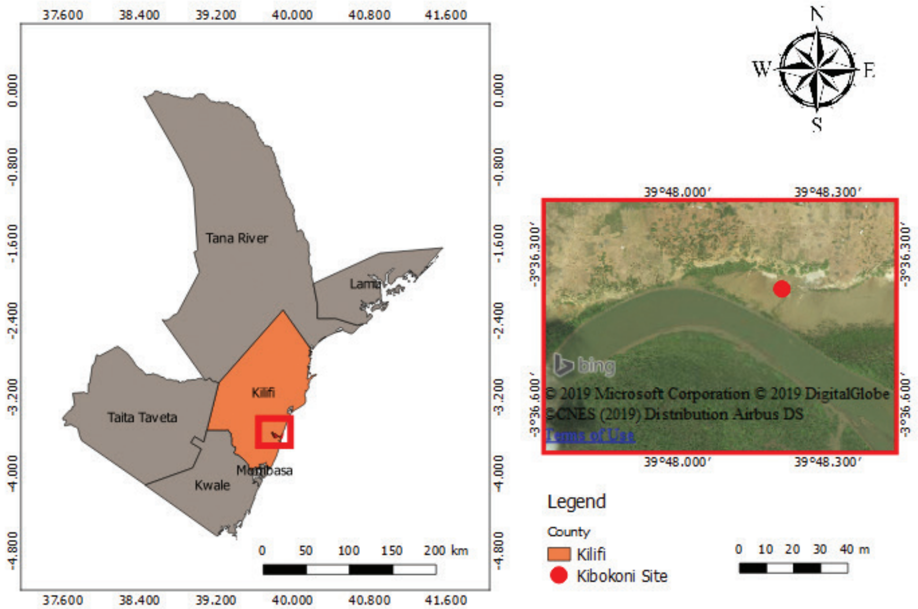

Figure 1. Map of the Study area.

downward trend for being used more selectively in production of aquaculture compounded feeds (FAO, 2018). In order to provide for the aforementioned demand of fish as food, the future of Tilapia production is in the ability to adapt in high salinity levels of 20 to 34 ppt (Abdel-Fattah 2006). Tilapia has been classified as a fish species with wide range of salinity tolerance from 0 to 35 ppm (Andrianto, 2005). The effects of salinity on fish growth have also been studied extensively by Tseng and Hwang (2008) and Tilapia has proved to be one of the common species that grows well in brackish water ponds (Al-Harbit and Uddin, 2005). In the Kenya marine waters, Nile Tilapia (*Oreochromis niloticus*) has been introduced into mariculture and previous research through pond culture in the intertidal areas has shown promising results. This has brought about the initiatives to try the same species in marine cages. In order to succeed in this marine aquaculture development, identification of quality affordable fish feeds that are locally available for use is key.

The present study aimed at reducing the proportions of fish meal and fish oil contents among the ingredients used without compromising the nutrient requirement of the farmed fish. It has been observed that improvements in feed formulations and in feed manufacture, combined with better on-farm feed management, will highly reduce the quantities of feed used per kilogram of farmed marine Nile Tilapia (FAO, 2018). This study therefore investigates the effects of two protein based diets; *Artemia* (brine shrimp) and fish meal from fresh water cyprinid locally known as *omena* and on growth performance of marine Tilapia under cage system in the sea.

Methodology

Study area

This experiment was conducted in community owned research cages located in Kibokoni (039° 50′ 32″ E 03° 36′ 12″ S) in Kilifi Creek, about 10 km west of Kilifi town, Kenya Figure 1

Experimental design

Breeding experiment

Four intertidal nursery ponds with a salinity of 38 ppt and an area of 120 m^2 were renovated to act as breeding ponds for fingerling production. The breeding experiment was conducted with an aim of developing brood stock, spawning, and selective breeding of F1 marine Tilapia generation fingerlings for stocking in the cages designed for the study (Mirera and Okemwa, under review). Feeding for the brood stock and spawned marine Tilapia fry was done with locally produced feed containing 30% crude protein.

Preparation of cage culture facilities and stocking of marine Tilapia juveniles

The design of the physical structure of the cages was determined by the oceanographic conditions of the culture site and the candidate species. Under this study a rectangular cage was preferred because of ease of construction, operations during the culture period and maintenance. The construction was done with one wooden structure holding 4 cages. The dimensions of the cages were 2.5m X 2.5m X 2m. The materials used were sourced locally and include; wooden poles, steel pipes, polyvinyl chloride tubes, sinkers and nylon nets of 6 mm mesh sizes stretched. Four cages were stocked with 1 month old marine Tilapia juveniles of 12 g average harvested from the breeding ponds. Each cage had an initial stocking density of 80 fish/m^3. Hence a total of 1000 fingerlings per cage. Two formulated innovative feeds (*Artemia* based diet and omena based diet) were administered after allowing 2 days acclimatization. The initial feeding rate was at 5% body weight per day.

Experimental diet preparation

The growth trial experiments were conducted with an aim of developing and testing two innovative fish feeds for growth and cost effectiveness. The choice of the feed ingredients was based on their nutritional composition, price, and local availability. The experiment consisted of testing two different innovative diets different from KMFRI feed with a formulated crude protein level of 30 %. Among other ingredients incorporated into the experimental feed, Diet 1 consisted of *Artemia* biomass sourced from *Artemia* production ponds as the main protein source while diet 2 consisted of dried omena powder as the main protein source. Seaweed was incorporated as a binder in both feeds.

During the feed preparation, all the ingredients were first ground into fine powder then other additives like oil, vitamin and mineral premix and calcium propionate preservative were added, fully mixed and then water was added to produce a uniform dough that was pelletized to produce feed pellets for the fish after drying under sun. Different

Table 1. Proximate composition of the two feeds and main ingredients used for the cage experiment.

Proximate composition	**Feed Ingredients**					**Treatment diets**	
Overall composition%	***Caridina nilotica***	**Fish meal**	***Artemia***	**Seaweed**	**Copra**	**Feed 1**	**Feed 2**
Crude protein	63.2	41.65	57.78	4.21	22.7	31.1	30.36
Crude lipid	5.5	12.8	9.33	7.49	18.6	6.67	4.23
Crude fibre	6.5	3.56	2.9	4.47	3.38	2.86	3.45
Ash content	10.8	5.4	5.4	5.19	4.61	4.52	3.65
Moisture content	7.5	13.84	11.94	19.03	13.41	17.33	13.64
Nitrogen Free Extracts	6.5	22.75	12.65	59.61	37.3	37.52	44.67

Table 2. Mean values with Standard deviations of water quality parameters sampled during the culture period.

Parameter	**Cage 1**	**Cage 2**	**Cage 3**	**Cage 4**
Temp (°C)	30.95 ±0.05	30.95 ±0.15	30.9 ±0.1	30.85 ± 0.05
D.O (mg l^{-1})	61 ±3.5	67.55 ±2.05	61.35 ±0.85	65.25 ± 3.25
D.O%	3.65 ±0.21	3.83 ±0.19	3.69 ±0.05	3.6 ±0.15
TDS	36140 ±130	36205 ±65	36205 ±130	36107 ±97.5
Salinity	36.71 ±0.15	36.85 ±0.04	36.78 ±0.12	36.7 ±0.18
pH	8.105 ±0.11	8.14 ±0.03	8.17± 0.03	8.17 ± 0.02

die sizes of 2mm, 4mm and 6mm were used based on the development stage of the fish for ease of feed consumption. Determination of the feed chemical composition (Table 1) was conducted using proximate analyses based on the procedures of the AOAC (1995).

Fish feeding and monitoring

Feed was administered twice daily at 09:00 and 03:00 o'clock in all the cages, a canoe was used for easy access to the cages. Feed 1 (*Artemia*) was administered in cages 1 and 2 while feed 2 (omena) was administered in cages 3 and 4. The daily feed quantity was adjusted biweekly after sampling. Sampling for growth performance was conducted twice every month throughout experimental period. An average of 30 individual fish from each cage were randomly selected, total length and standard length were measured individually using a fish measuring board, whereas the average body weight was measured by mass weighing using a portable hanging electronic scale.

Determination of growth parameters

Measurement of growth parameters was conducted on a fortnight basis. The Indices of growth from the fish culture duration determined in this study were; percent weight gain, specific growth rate, survival rate and feed conversion ratio. Mean weight gain (g) and their standard errors (±SE) for the fish samples from each treatment were determined at each sampling occasion. Graphical plots of mean weights against time were used to visualize growth. At the end of the experiment all the fish were harvested and weighed up to nearest 0.1g.

Specific growth rate

Specific growth rate (%body weight/day) was calculated using the formula, $SGR = (\ln WT_F - \ln WT_I)*100/T$ where WT_F= average final fish weight (g), WT_I = average initial fish weight (g), T= duration of the experiment (days).

Apparent feed conversion ratio

Feed conversion ratio is the ratio of the quantity of food distributed (g) to the weight gain of fish (g), over the culture period. This was used to judge the efficiency of feed utilization by fish for both diets. It was calculated by dividing the total amount of feed used (dry matter basis) and then dividing by the weight gain.

Survival

In the culture systems, survival was estimated by checking the culture facilities daily for dead fish and recording the number of dead fish and removing them. Final number was calculated by subtracting the number of dead fish from the initial

Table 3. Effect of the two treatments on growth and yield parameters of marine Tilapia

	Treatments	
Variable	**Feed 1**	**Feed 2**
Initial length(cm fish^{-1})	6.45	8.5
Initial Weight(g fish^{-1})	19.2	19.6
Final length(cm fish^{-1})	8.25	11.72
Final weight (g fish^{-1})	29.39	49.79
Weight gain	20.19	30.19
Daily growth rate (g day^{-1})	0.12	0.28
SGR % day^{-1}	1.16	0.93
FCR	3.7	2.2
Survival (%)	65	70
Gross yield (g cage 112d^{-1})	620.61	650.21

number stocked. Survival percentage was hence calculated by = Final number of fish/ initial number x 100.

Gross fish yield

This is the total biomass of fish at harvesting given by the formula: Final number of fish x final average weight (g).

Net fish yield

To obtain NFY, the biomass at stocking was subtracted from the gross fish yield. The final yield was then converted to Kg unit m^{-3}.

Sampling for water quality parameters

During the experiment water quality parameters were monitored on monthly basis in the culture facilities. Determination of water temperature, dissolved oxygen, pH, salinity, and total dissolved solids was done using a multi parameter kit Hanna instruments model. Cage management involved checking on presence of torn areas, lifting the cages and brushing off the mud and debris that had stuck and rinsing with water.

Economic performance analysis of the two feeds

An economic analysis was carried out on the basis of the two experimental diets. Cost of feeds was estimated based on figures from the retail market price where ingredients are mainly sourced from. Cost of production was estimated based on local market value price in USD. Produced fish were sold at the local market outlet and hotels. Total return from the fish produced was estimated by price of fish sold. Gross margin was estimated by subtracting the total feed cost from the total return.

Statistical data analysis

Means were determined through the descriptive statistical tool in excel and data presented as mean (±SE). Growth parameters; Daily Growth Rate (DGR), Feed Conversion Ratio (FCR), Specific Growth Rate (SGR), yield, survival, and economic performance were further analyzed by an independent t test for equality of means to test the difference between the two feeds.

Results and discussions

Proximate composition results

Mean values on wet weight basis of the proximate analysis done on the different treatments are presented in Table 1. *Caridina nilotica* (fresh water shrimps) was used to formulate the KMFRI feed that was administered to the fish in the breeding ponds. The feed had a relatively high crude protein (CP) as shown on the table. *Artemia* ingredient had high CP of 57.78 as compared to fish meal that had 41.65 which were the main ingredients used to formulate the two treatment diets. Diet 1 consisting of *Artemia* had a CP of 31.1 while diet 2 consisting of omena had a CP of 30.3.

Water quality parameters

Mean values of water quality parameters are presented in Table 2. Which indicates that they were all within the optimal range for fish culture. The results achieved from the different treatments in this study did not show any significant influence on the quality of water. This could have been attributed by the fact that the cages were placed in open water and hence dilution effect took place quite often due to the water currents. Major concerns have been about the risk of pollution of the environment by the aquaculture industry. Furthermore, conflicts with other coastal users are often reported, mainly with the tourism sector (Price et al., 2015).

Growth survival and yield parameters for Marine Tilapia cultured in cages

Growth and yield parameters of marine Tilapia and their combined performances under different treatments are shown in Table 3. There were significant differences between the two diets at ($p < 0.05$). Individual weight gain of 30.19 g, survival percentage 70% and growth rate of 0.28% were higher in treatment 2 (Omena feed) as compared to treatment 1 (*Artemia* feed) which had a weight gain of 20.19 g, Survival rate of 65% and DGR of 0.12.

Gross yield for treatment 2 was higher (650.21 kg m^{-3}) as compared to treatment 1 (620.61 kg m^{-3}). The graphical presentation of the mean weights in the different treatments is as shown in Figure 2.

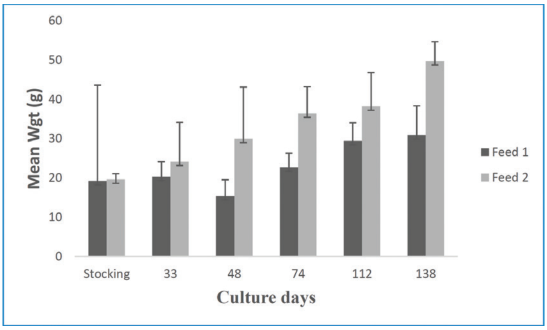

Figure 2. Mean weight of marine Tilapia in the different treatments during the experimental period.

The findings of this study show that the response of the fish to both feed treatments was not significant. This could be attributed to the weight of juveniles at stocking. The fish could have taken longer time to grow as it tried to adapt to the marine water environment. Treatment 2 (omena feed) showed better growth outcome as compared to treatment 1 (*Artemia* feed) in terms of weight gain, specific growth rate, survival rate and feed conversion ratio (FCR). The results demonstrate that use of omena proportion to the feed could enhance faster growth besides the cost implications of obtaining it as compared to *Artemia*. Besides *Artemia* having a high crude protein level, in this study it was used in its raw form collected as biomass from the ponds, this might have caused its low availability to the fish and hence not significant growth of the cultured fish. Both treatments did not have a direct influence on the survival of the fish. Survival was also not influenced by the stocking density of the fish which was similar in all the cages. Lower mean survival might have been a result of high competition for food and also while adapting to the ocean environment during the initial culture days where high mortality was recorded.

However, it was observed that feeding of fish is one of the most important management tasks to optimize; this is necessary in order to increase the efficiency of the production process (Tacon, 1990). The primary objective for most fish farms is always to produce high-quality fish at the lowest cost. Research has shown that feed typically accounts for 50–75 percent of the operating costs in an efficient farm (Craig and Helfrich 2002). Poor feed management can result in increased production costs (higher FCR, longer grow-out cycle, higher management costs and higher environmental impact from uneaten feed. Good practices of effective feeding are key towards reducing feed waste in aquaculture ventures (El-Sayed et al., 2015).

In this study, the highest net and gross yield of marine Tilapia was recorded in treatment 2 which could have mainly been due to the treatment feed administered which was available and efficiently used by the cultured fish. In addition, the treatment diets had been formulated with other plant products that were more beneficial to Tilapia being an omnivorous fish. SGR and weight gain was higher with treatment 1 which might have been as a result of the feed composition as *Artemia* is known to have higher crude protein levels as compared to omena. Better economic analysis results could have been achieved if the fish were given more time to reach market size.

Economic Analysis

Economic analysis was performed to evaluate the profit margin for the two treatment diets. The analysis showed that the profit margin was higher

Table 4. Economic analysis of the two treatment feeds

Variable	Feed 1	Feed 2
Price kg^{-1} feed (USD kg^{-1})	1.2	1.2
Unit protein cost (USD kg^{-1})	2	2
Total operation cost	0.36	0.54
Price kg^{-1} fish (USD kg^{-1})	5	5
Profit Margin (USD)	4.64	4.46

Calculation in US Dollar (1USD=100 Kenya currency) with diet 1 as shown in Table 4. This was as a result lower operational costs in production of diet 1 as compared to diet 2.

Conclusion and recommendations

The pond raised marine Tilapia juveniles responded well to the cage culture environment and the treatment diets administered. The findings of this study demonstrate that omena based diet resulted to better growth response as compared to *Artemia* based diet. The study shows that culture of marine tilapia is possible with appropriate cage siting and regular maintenance to avoid clogging of nets which might have hampered the survival of the juveniles. More frequent data collection for both water quality and growth parameters is recommended to enable visualize better growth trends and culture conditions. Further research at different stocking densities with grown juveniles (50g weight) that can withstand the cage environment is recommended. In order to identify a suitable marine fish feed, research with other quality and affordable locally available ingredients is recommended.

Acknowledgements

This research was financially supported by the Government of Kenya through Seed funding and the National Research Fund. Authors are grateful to the field staff and technicians of Kenya Marine and Fisheries Research Institute, Mombasa Centre, for their kind help and contribution to this research. We are also thankful to the community at Kibokoni Village, Kilifi County who provided support in terms of breeding ponds, management of the cages and providing security to the culture facilities.

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