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Feeding regimes for Singida tilapia (*Oreochromis esculentus*, Graham 1928) under controlled conditions: acceptance and utilization of natural feeds compared to dry rations

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Abstract
Singida tilapia was successfully bred and nourished under captivity in an attempt to find ways to bolstering its endangered remnant stocks and take advantage of its natural attributes to domesticate it for aquaculture. Finding appropriate feeds and feeding regime involved breeding and raising the fish under different diets. The species accepted dry rations used in culture of a closely related co-gener, Nile tilapia. ANOVA showed that Singida responded differently to different treatments. The best performing feed was use of a combination of artificial feeds and diatomous dominated algae that was selectively stimulated and raised through fertilisation of pond waters, giving a growth rate of 1.99g/day. Use of diatomous algae alone without supplementary feeding, Singida responded positively posting a comparatively good growth rate of 1.46g/day. This implies that Singida can be cultured with good biomass accumulation rate, making it a viable and alternate tilapia species for both commercial and rural aquaculture.

Keywords: Singida tilapia, feeding, nutrition, domestication, aquaculture

1. Introduction

Singida tilapia was originally the mainstay of the commercial fishery of the Lake Victoria region waters, from inception of commercial fishery in early 1900 until the early 1980s [1]. Singida tilapia is also considered as a delicacy and a preferred food tilapia fish for the riparian fishing communities who still seek it out in its refuggia despite its being critically endangered [1]. Domestication and aquaculture development of tilapiine species is considered among the top most successful endeavours in aquaculture development, both in terms of number of species successfully domesticated and importance of tilapia in both commercial and rural aquaculture production when compared to other groups of fishes [2]. Key in the success of the domestication and use of tilapiine species in aquaculture has been there relatively simple dietary requirements, nearly all of which are herbivorous in nature [3, 4]. Nutrition and feeding play a central and essential role in the sustained development of aquaculture and, therefore, fertilizers for stimulation of natural food organisms and artificially formulated feed resources continue to dominate aquaculture needs [5]. This is so because raring fish in captivity, especially when reared in high stocking densities, requires a high-quality, nutritionally complete, balanced diet to grow rapidly and remain healthy [6]. From the history of domestication of fishes for aquaculture purposes, it is apparently much easier to domesticate a low trophic level species than those that are high up in trophic status [7].

Singida tilapia is a highly valued indigenous species, and is the preferred tilapiine species among the fishing communities attendant to the remnant stocks of Singida tilapia where it is considered a delicacy [8]. Singida tilapia is predominantly herbivorous and with natural preference for diatomous algae [1, 4, 9] a factor considered valuable especially in the development of this species for rural aquaculture production. In effort to bolster the remnant stocks, conserve and restore the commercial production of Singida tilapia, the National Agricultural Research Organization, through the competitive grant scheme (CGS) is supporting a consortium of experts in Uganda in their efforts to domesticate, breed, culture and restock Ugandan waters with Singida tilapia [10, 11]. Observed that the best way of conserving this species was to produce them as pure species in an environment ex-situ away from its predators and competitors that exist in the species native range. However that presupposes that we can find natural waters with suitable natural conditions where no other competitor and or predator exist. For most of the waters in Uganda that approach will be difficult, and instead the efforts have been put in finding means to bolster the surviving remnant stocks and or develop aquaculture as a vehicle for continuity of this species. This according to our proposed approach will require understanding the feeding and nutrition preferences of Singida tilapia. This will be achieved by acquisition of knowledge of the natural feeding behavior of the fish species to be domesticated. The knowledge will aid in formulation and development of appropriate feeds for Singida tilapia at its different developmental stages to support growth in captivity.

Based on the understanding of feeding behavior of Singida tilapia in wild, we formulated, developed and optimized feeds and feeding regime for rural & commercial culture of Singida tilapia in Uganda. In the study while under captivity we simulated the natural conditions so as to exploit the natural food growth potential, especially, the production of the phytoplanktons and zooplanktion on which the Singida tilapia is known to feed for its sustainancy in the wild[12]. We tried out the Nile tilapia feeds formulations on the Singida tilapia (as both shared the same niche in the wild) so as to test acceptability and effectiveness in sustaining growth of this species under aquaculture conditions.

2. Materials and Methods

2.1. Natural foods response experiments

The experiments were carried out at Senya Fish farm (N00.36246, E031.67972) in Lwengo District beginning the month of September in 2014. The study comprised of three treatments with three replications of each treatment. The first treatment was based on appropriately fertilised pond with conditions that simulated the production of diatoms; the second treatment was based in a pond with conditions for simulation of diatoms growth but unfertilized water, and third treatment was using appropriately fertilized pond system without additions to simulate diatoms growth. The 3 treatments were simulated natural environment and fertilized systems (SF), simulated natural environment and unfertilized systems (SUF), and fertilized systems without simulation of the natural environment (FWS). Nine ponds of 100 – 200 m^2 were prepared by cleaning, de-silting, liming and then fertilised before use in the experiments. For simulation of conditions to allow for growth of diatoms, the six ponds for the first two treatments respectively were filled with a half inch layer of lake sand on their floors and then refilled with clean water. The ponds were fertilised using chicken manure at rate of 100Kg/ha/week and 100Kg/ha/week. Mortalities and basic water quality parameters including water temperature, alkalinity, nitrates, dissolved soluble phosphates [SRP], dissolved oxygen and pH were recorded daily.

2.2. Artificial feeds response experiments

The experiments were carried out at Senya Fish farm (N00.36246, E031.67972) in Lwengo District and Tukundane Fish Farm in Isingiro District beginning August 2014. At both farms, three hapas of 2x2x1m per treatment were stocked with 100 fry of Singida tilapia. The 3 treatments were fertilized systems with supplementary feeding (SWF), unfertilized systems with supplementary feeding (SPF), and fertilized systems without supplementary feeding (FPW). The hapas for fertilised treatments were placed in ponds fertilised using chicken manure at rate of 100Kg/ha/week. For supplementary feeding the rates were 8% body weight of powder fish fry feed of 35% protein for the first month and later changed to a rate of 5% body weight from second month till end of experiment in the month five using pelleted extruded commercial fish feeds of 30% protein. Feeding was done manually three times a day at 10.00 am, 1.00 pm and 4.00 pm. Daily feed consumption, mortalities and basic water quality parameters (temperature, dissolved oxygen and pH) were recorded daily with biometric measurements of 20 samples from each pond taken monthly. Hapas were cleaned of accumulated waste feed and faecal materials once every week.

2.3. Data collection and analysis

Fish fingerlings were weighed before stocking and after every two weeks. During the study biometric measurements of growth performance were done by bulk weight taking, but at the end of the experiment each fish were weighed individually. Total lengths (±1 mm) of the fish were also be measured using von Boyer trough and will be used to calculate condition factors. Before measurement during the experiment the fish will be anaesthetised using clove oil.

From the data obtained during the study period, the following parameters were used to evaluate the Singida tilapia growth performance: Weight gain (W) = Final Weight (Wt)–Initial Weight (W0) (g); Individual Weight Gain (IWG) (g/ex)=(Final Weight (Wt)–Initial Weight (Wo))/Total Fish; Specific Growth Rate (SGR)=100 × ln(Wt– Wo)/t (%BW/day)[13]

3. Results

3.1. Response to artificial feeds

Fish that were raised in ponds with simulated natural environment and well fertilised attained the biggest biomass, followed by fish raised in ponds which had simulated natural environment but were unfertilised and those with the smallest biomass were fish raised in fertilised ponds but without simulation of the natural environment (Table 1). This outcome indicated that the simulation of the natural environment of this species in the ponds played a major role in the nourishment of fish under captivity.

Table 1: Growth performance parameters of Singida tilapia (*Orechromis esculentus*) raised under different feeding regimes - SF – simulated natural environment and fertilized systems, SUF– simulated natural environment and unfertilized systems, and FWS – Fertilized systems without simulation of the natural environment.

Indicator	SF	SUF	FWS
Initial numbers	600	600	600
Final numbers	554	509	430
Survival (%)	92.3	84.9	71.7
Initial biomass (g)	3540.00	3522.00	3534.00
Final biomass (g)	128034.94	102578.77	83549.00
Biomass gain (g)	124494.94	100178.77	82319.00
Mean initial individual weight (g)	5.90	5.92	5.89
Mean final individual weight (g)	231.11	201.53	194.3
Average Daily Gain – ADG (g/day)	1.68	1.46	1.41
Specific growth rate – SGR (%/day)	2.60	2.44	2.29

3.2. Response to natural feeds

Fish raised in fertilised ponds with supplementary feeding had the biggest mean individual final weight, followed by fish raised in unfertilized ponds with supplementary feeding and coming in last were fish raised in fertilized systems without supplementary feeding with the least mean individual final weight (Table 2). These findings indicate that this species can be raised without supplementary feeding to table size fish but supplementary feeding is an important factor in biomass accumulation.

Table 2: Growth performance parameters of Singida tilapia (*Orechromis esculentus*) raised under different feeding regimes - SWF – fertilized systems with supplementary feeding, SPF– unfertilized systems with supplementary feeding, and FPW – Fertilized systems without supplementary feeding.

Indicator	SWF	SPF	FPW
Initial numbers	600	600	600
Final numbers	558	517	442
Survival (%)	93.0	96.7	90.3
Initial biomass (g)	1200g	1200g	1200g
Final biomass (g)	166323.06g	133990.89g	94305.12g
Biomass gain (g)	165123.06g	132790.89g	93105.12g
Mean initial individual weight (g)	2.0g	2.0g	2.0g
Mean final individual weight (g)	298.07g	259.17	213.36
Average Daily Gain – ADG (g/day)	1.99	1.73	1.42
Specific growth rate – SGR (%/day)	3.336	3.243	3.113

*Fish were fed at rates of 10%, 5% and 3% at month 1, month2-3, and month 4-5 respectively

3.3. Calculation of the Analysis of Variance (ANOVA)

Table 3: Summary table showing how the One-way ANOVA was calculated

Source	Sum of squares	Degrees of Freedom	Variance Estimate (mean Square)	*F* Ratio
Between	SS_B	$K - 1$	$MS_B = SS_B/K - 1$	MS_B/MS_W
Within	SS_W	$N - K$	$MS_W = SS_W/N - K$	
Total	$SS_T = SS_B + SS_W$	$N - 1$		

K is number of strains (Groups) = 5, N the total of means of samples = 40, SS = sum of squares, SS_B = SS between, SS_W = SS within, SS_T = SS total

For the natural foods treatments, ANOVA showed that the calculated F value was bigger than the F critical value (Table 4) indicating that Singida tilapia raised under three different natural foods treatments performed differently to the different treatments.

Table 4: Analysis of Variance of body weight gain indicator of growth performance of Singida tilapias raised under three different natural foods treatments

Source	Sum of squares	Degrees of Freedom	Variance Estimate (mean Square)	*F* Ratio
Between	0.041267	3 – 1=2	MS_B = 0.041246/*2=0.020623*	3.8688
Within	0.080000	18 – 3=15	MS_W = 0.080000/*15=0.006667*	
Total	0.121267	18 – 1=17		

* $p<0.05$ P = 0.03118612 $F_{critical}$ = 3.1059

Similarly with response to artificial feeds, ANOVA calculations showed that the calculated F value was far bigger than the F critical value (Table 5) indicating the fish responded differently to the three treatments in the experiment set-up.

Table 5: Analysis of Variance of body weight gain indicator of growth performance of Singida tilapias raised under three different artificial feeds treatments

Source	Sum of squares	Degrees of Freedom	Variance Estimate (mean Square)	*F* Ratio
Between	0.162866667	3 – 1=2	MS_B = 0.162866667/*2=0.081433*	1.22248E+14
Within	9.99201E-15	18 – 3=15	MS_W = 9.99201E-15/*15= 6.66134E-16*	
Total	0.162866667	18 – 1=17		

* $p<0.05$ P = 0.03118612 $F_{critical}$=3.1059

4. Discussion

The ANOVA analysis showed that the species performed differently under the different treatments in the study. The results showed that Singida tilapia's growth was enhanced by both natural and artificial diets albeit at different rates. This agreed with literature that this species accepts artificial feeds or dry rations [11, 14] and this makes it easier to domesticate as we have done in Uganda. Since the species does comparatively well on natural foods in well fertilised aquaculture production systems it reduces the amount of supplementary feeding making it a pro-poor target species for farming.

After the introduction of the Nile tilapia (*Oreochromis niloticus*) in the natural range of Singida tilapia (*Oreochromis esculentus*), the former was found to occupy the same feeding range of the later and outcompeted the native species [10-12, 15]. Similarly our study used the already formulated feeds for grow-out of the Nile tilapia to feed and raise Singida tilapia in captivity, which feeds where readily accepted by the later.

The combination of natural foods that is phytoplanktons and supplementary diet of dry rations gave the best growth rates indicating that like it is for culture of Nile tilapia, domestication and commercial culturing of Singida tilapia requires appropriate supplementary feeding. But the species can be raised without supplementary feeding for the rural poor who cannot afford supplementary feeding if the production systems are well fertilised to allow growth of preferred phytoplanktons mostly the diatoms [14-17].

The simulation of an appropriate environment for the growth of the preferred phytoplanktons, the diatoms [15-18] by the fish species gave the best growth rate for the treatments without supplementary feeding. Therefore for the culture of Singida tilapia especially for the rural poor who cannot afford buying supplementary fish feeds it is prudent that they simulate an environment that allows for the growth of the preferred phytoplanktons in their grow-out systems.

5. Conclusion and recommendations

The Singida tilapia can be raised in captivity by using well fertilised pond system with or without supplementary feeding with appreciable accumulation rate of biomass. Singida tilapia accepts artificial feeds though for commercial production Singida tilapia will require that the basic larger proportion of the feeding is based on natural stimulation of suitable phytoplankton growth within the production system plus supplementary feeding. For this was the most appropriate diet for grow-out of Singida tilapia according to the results of this study, where this combination gave the best growth rate. For rural or small scale aquaculture targeting the poor a well fertilised pond system with simulation of natural environment where the species thrives will suffice.

We recommend further studies to establish the best and most appropriate type of manure and appropriate application rates to allow for growth of the diatoms in ponds and other production systems for the species grow-out.

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