Feed maximization of combined culture of Nile tilapia *Oreochromis niloticus* and African catfish *Clarias gariepinus*

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Abstract. This study focused on determining the growth of Nile tilapia, *Oreochromis niloticus* (Linnaeus, 1758), combined with African catfish, *Clarias gariepinus* (Burchell, 1822), under two different feeding schemes: feeding based on biomass (T1) and feeding-to-satiation (T2). Data on the growth of the fish was observed before and after the study. Specifically, the study determined the specific growth rate (SGR), survival rate (SR), feed conversion ratio (FCR), gain-in-weight, and condition factor. SGR in T2 was higher (1.2%) compared to T1 (1.1%). SR was significantly higher in T1 (66.7%) than in T2 (60%) at $p<0.05$. Gain-in-weight (GIW) was higher in T2 (194.38 g) compared to T1 (149.09 g). T1 (1.42) has lower FCR compared to T2 (1.62), which indicates a better conversion of feed into flesh. Condition factors of *O. niloticus* in T1 are lower than those in T2 and are significantly different ($p<0.05$). T1's condition factors range from 2.37 to 3.14, while they were between 4.19-4.75 in T2. The condition of fish fed to satiation (T2) was more suitable than that of fish fed based on biomass (T1). The study concluded that T1 (feeding based on biomass) was more acceptable than T2 (feeding-to-satiation). It is advantageous to utilize the feeding based on the biomass scheme (T1) to lessen feed wastage, decrease operational cost, minimize the deterioration of water quality as well as attain better growth performance and survival of *O. niloticus* combined with *C. gariepinus*.
Key Words: condition factor, FCR, feeding based on biomass, feeding-to-satiation, SGR.

Introduction. One of the major goals of aquaculture nowadays is to attain sustainability through a contribution to food security by providing animal protein sources (Pradeepkiran 2019). Tilapia (*Oreochromis* sp.) remains one of the most cultured species and a major contributor to aquaculture particularly in Asia (FAO 2016). In the early days of fish farming, feed maximization through restricted feeding has been described and practiced in feeding cultured species.

Lately, single culturing of fish or monoculture has remained the selected farming practice, and utilization in aquatic niches and combined species has been set aside. Combined culture of different species is the rearing of two or more aquatic species in a pond and is a production technique used to increase overall fish production and profits. Moreover, two different feeding strategies may be used such as *ad libitum* and feeding to satiation. However, higher feeding requirements can be seen in *ad libitum* feeding which may promote negative effects on fish health (Oliva-Teles 2012; Azaza et al 2015). According to Gupta & Acosta (2004), most of the pond-based tilapia farmers in Bangladesh, China, Taiwan, Thailand, and Vietnam use the combined culture, while in the Philippines, most farmers grow tilapia under the monoculture system. Rakocy & McGinty (1989) explained that the process of increasing the overall production of a pond without increasing feed consumption can be seen in a combination of species also called the polyculture method.

Combined culturing of fish maximizes the use of available resources in a harmonized manner and develops beneficial interactions between two compatible species (Thomas et al 2021). It also introduces different aquaculture species in a pond or aquaculture systems that maximize the use of water, controlling the recruits, as well as increasing profitability (Husain et al 2016; Mansour et al 2021). Based on the findings of Shoko et al (2015), the number of unwanted recruits in the ponds can be reduced providing better growth rates and yields by combining different species of fish, commonly being termed as the polyculture method. This study was focused on determining and comparing the growth performance of Nile tilapia (*Oreochromis niloticus*), combined with African catfish (*Clarias gariepinus*), under two different feeding schemes: feeding based on biomass (T1) and feeding-to-satiation (T2).

Material and Method

Description of the study sites. The study was carried out in in six square tanks with an area of 1 m^2 each in the Freshwater Aquaculture Center (FAC) Hatchery Facility situated in Central Luzon State University, Bantug, Science City of Muñoz, Nueva Ecija 3120, Central Luzon, Philippines (Figure 1).

Figure 1. The location of the study was in FAC, CLSU, Science City of Muñoz, Nueva Ecija 3120, Philippines (Photo source: Google maps).

Experimental fish and set up. 15 *O. niloticus* and 15 *C. gariepinus* were sourced from the Freshwater Aquaculture Center (FAC), Science City of Muñoz, Nueva Ecija. Both species were at their juvenile stage with weight range of 5 to 10 g. There were two treatments in the study (Table 1). Treatment 1 (T1) or feeding based on biomass was applied for 10% of their body weight in the initial stocking (1-2 weeks) and was reduced to 8% (for 3-4 weeks), 5% (for 5-10 weeks) and 4% (for 11-14 weeks) until the end of the experiment. Treatment 2 (T2) applied feeding-to-satiation. Each treatment was replicated thrice under a Randomized Complete Block Design (RCBD) (Figure 2).

Stocking density and management procedure. *O. niloticus* and *C. gariepinus* weighing 5-10 g were stocked at stocking rate of ten fish per m^2 in the experimental units. The cultured fish were fed twice daily at 8:00 a.m. and 4:00 p.m. Fish mortalieties were monitored. Fish sampling was done every 14 days to monitor the survival, and growth and development of the cultured fish.

Water quality monitoring. Dissolved oxygen (DO), temperature, and pH of each culture unit was observed. DO and temperature were observed using YSI EcoSense DO200A DO Meter, while pH values were measured using a digital pH meter. Each parameter was measured twice a day before feeding the fish.

Data gathered in the study. The study gathered data on specific growth rate (SGR), survival rate (SR), feed conversion ratio (FCR), and gain-in-weight. The condition factor was also determined. The formulae that were used in the experiment to analyze the growth of *O. niloticus* were the following:

Survival rate (SR) = (no. of fish survived/no. of fish stocked) x 100

Specific growth rate (SGR) = [(final weight-initial weight)/final time (days)] x 100

Gain-in-weight (GIW) = final weight - initial weight

Condition factor (K) will be computed through the data obtained from the length-weight relationship. Individual values of K were obtained through the formula:

$K=100W/Lb^3$

Where: K - condition factor; W - the weight of the fish in grams (g); L - the total length of the fish in centimeters (cm); b - the value obtained from the length-weight equation Log W = b log L + log a.

Table 1

Experimental treatments of the study

Treatments	*Descriptions*
T1	35 Nile tilapia (*Oreochromis niloticus*) and 35 African catfish (*Clarias gariepinus*) fed based on biomass
T2	35 Nile tilapia and 35 African catfish fed to satiation

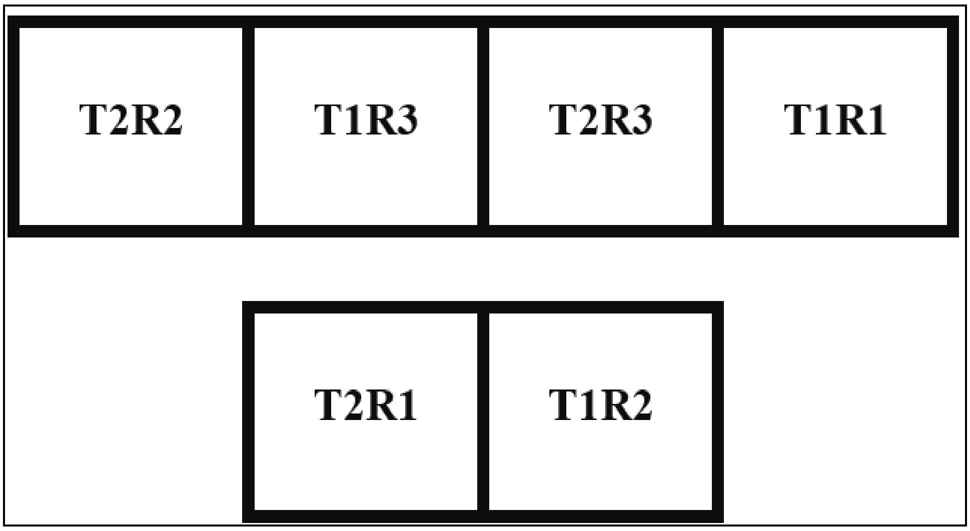

Figure 2. The experimental set-up.

Statistical analysis*.* Data generated were subjected to a T-test using the R-software version R 3.5.3 for comparison among means. Significance of differences were set at p<0.05.

Results and Discussion

Growth and survival. The experiment used *O. niloticus* as a main aquaculture species and *C. gariepinus* as a secondary species. SGR of *O. niloticus* had a mean value of 1.1±0.06% (T1) and 1.2%±0.05 (T2), while for *C. griepinus* they were 0.87±0.04 (T1) and 0.91±0.05% (T2), with no significant differences observed ($p<0.05$). SR of *O. niloticus* were recorded at 66.67±11.55% (T1) and 60% (T2), while *C. gariepinus* had 60% (T1) and 66.67±11.55 (T2), with significant difference observed in the SR of *O. niloticus* and no significant difference observed for *C. gariepinus* ($p<0.05$). *O. niloticus* fed based on biomass (T1) gained an average GIW of 149.09±16.86 g, while the fish fed to satiation (T2) accumulated a GIW of 194.38±4.58 g. *C. griepinus* had a GIW of 42.89±9.07 g (T1) and 51.38±4.19 g. Significant differences in GIW were observed in *C. griepinus* ($p<0.05$). Fish in T2 have gained more weight than in T1 due to higher feed intake. Although fish in T2 had a higher GIW, they also had a higher mean FCR of 1.61±0.1 (*O. niloticus*) and 1.36±0.11 (*C. gariepinus*), while the mean FCR in T1 was 1.42±0.32 (*O. niloticus*) and 0.8±0.1 (*C. gariepinus*) (Table 2). Furthermore, FCR of *O. niloticus* had no significant differences, but significant differences were observed in the FCR of *C. gariepinus* ($p<0.05$).

Table 2

Growth performance of *Oreochromis niloticus* and *Clarias gariepinus* throughout the experiment

Growth parameter	*Nile tilapia (O. niloticus)*		*African catfish (C. gariepinus)*	
	Treatment 1	*Treatment 2*	*Treatment 1*	*Treatment 2*
SGR (%)	$1.1±0.06^a$	$1.2±0.05^a$	$0.87±0.04^a$	$0.91±0.05^a$
SR (%)	$66.67±11.55^a$	$60±0.00^b$	$60.00±0.00^a$	$66.67±11.55^a$
GIW (g)	$149.09±16.86^a$	$194.38±4.58^a$	$42.89±9.07^b$	$51.38±4.19^a$
FCR	$1.42±0.32^a$	$1.61±0.10^a$	$0.80±0.10^b$	$1.36±0.11^a$

Note: SGR - specific growth rate; SR - survival rate; GIW - gain in weight; FCR - feed conversion ratio; different superscripts show significant differences ($p<0.05$).

Specific growth rate (SGR). SGR in T2 was higher (1.2%) than in T1 (1.1%) but showed no significant differences ($p<0.05$). According to Limbu et al (2015), the SGR of *O. niloticus* is significantly affected by the size of the predator *C. gariepinus*. They also mentioned that *O. niloticus* reared with larger *C. gariepinus* exhibit higher SGR compared to *O. niloticus* stocked with smaller *C. gariepinus*. Since both treatments are combined with small African catfish, the SGR values have slight differences.

Survival rate (SR). The decrease in SR in T2 could be due to the variations in water quality. than in T1. Survival of fish may also decrease due to stress during stocking (Sakala & Musuka 2014) in addition to the exceeding levels of water quality parameters such as temperature, pH and ammonia. Other factors such as feeding rate and stocking density can significantly affect growth and survival (Mengistu et al 2020). SR was higher in the fish cultured using the feeding scheme feeding based on biomass. Results clearly opposed the report of Santiago et al (1987), who observed that fish growth rates and survival were extremely poor at a 10% feeding level and improved significantly with increasing feeding levels up to 30% and leveled off with further increase in feeding levels.

Gain-in-weight (GIW). GIW was higher in T2 compared to T1. Zafar (2017), Huang et al (2015), and Passinato et al (2015) stated that the amount of feeding affects the weight gain of the fish, with higher feeding resulting in higher weight gain.

Feed conversion ratio (FCR). The FCR is a useful tool to assess the growth performance of fish (Zafar 2017) and one of the major factors in analyzing fish productivity (Mengistu et al 2020). FCR is generally defined as the ratio of the consumed feed over the gain in weight (Besson et al 2020). This can be affected by the environment, particularly water quality (Ronald et al 2014).

Most of the growth parameters of fish in the study were recorded higher T2, except for SR. However, Mensah & Attipoe (2013) revealed that feeding the fish to satiation exhibits poor feed utilization as they were only provided feed until their stomach was nearly evacuated.

Condition factor (K). The condition factor expresses the physiological state of fish during culture (Anani & Nunoo 2016). This is also the measure of the suitability of an environment to aquaculture species and a good indicator of stress in relation to water pollution (Tesfahun 2018). The condition factor of *O. niloticus* in T1 is lower than in T2 ($p<0.05$). The K values of tilapia in T1 ranged from 2.37 to 3.14, while in T2 they ranged from 4.1 to 4.75 (Figure 3). On the other hand, *C. gariepinus* showed a condition factor of 0.31-1.7 (T1) and 0.29-0.64 (T2). The condition of fish fed to satiation was better than that of fish fed based on biomass. Nile tilapia in both treatments had a high K value exceeding the ideal value K=1 for normally growing fish (Otieno et al 2014), indicating a good level of feeding and proper environmental conditions (Ujjania et al 2012). However, the condition factor of African catfish was lower than that of Nile tilapia. According to Gupta et al (2011), the variations in condition factors could be due to the availability of food organisms at a particular time as well as the difference in gonadal development. Also, condition factor values differ between a species or population (Sarkar et al 2013). On the other hand, an increasing condition factor presents an improvement in the nutritional status of fish (Saraiva et al 2016).

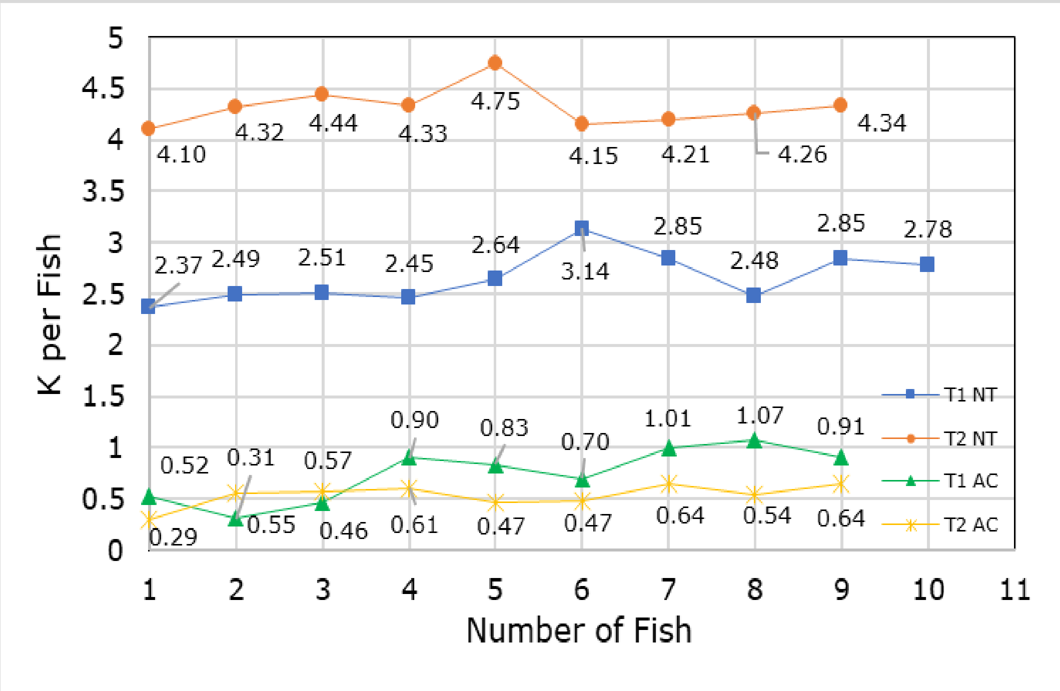

Figure 3. The condition factor (K) of *Oreochromis niloticus* (NT) and *Clarias gariepinus* (AC) in T1 and T2.

Water quality. Water quality is one of the most critical factors that predict the success of an aquaculture setup (Hu et al 2020). Maintaining proper monitoring and management of the culture environment is needed in any aquaculture system to increase its productivity and profitability (Abinaya et al 2019). The temperature recorded was 30.8±1.86°C (T1) and 30.9±1.97°C (T2). Temperature of both treatments was slightly higher than the ideal temperature of 27–30°C as stated by Nivelle et al (2019). DO levels were 9.98±1.07 (T1) and 11.58±1.50 (T2), within the ideal DO of ≥5 ppm according to Mengistu et al (2020). Recorded pH values were 9.78±0.42 (T1) and 9.80±0.47 (T2), above the optimum pH level (7.0-8.5) proposed by Choudhary & Sharma (2018). High levels of pH in the study may be associated with the mortality of culture species. There were no significant differences in temperature and pH. DO had significant differences ($p<0.05$) (Table 3).

Table 3
Temperature, DO, and pH levels of each treatment during the culture period

Parameter	*Treatment 1*	*Treatment 2*
Temperature (°C)	30.80±1.86[a]	30.90±1.97[a]
DO (ppm)	9.98±1.07[b]	11.58±1.50[a]
pH	9.78±0.42[a]	9.80±0.47[a]

Note: DO - dissolved oxygen; different superscripts show significant differences ($p<0.05$).

Conclusions. The study compared two different feeding schemes and determined that T1 (feeding based on biomass) provides better growth and survival than T2 (feeding to satiation). It is advantageous to utilize the feeding based on a biomass scheme that was assigned in T1 to possibly lessen feed wastage, decrease operational cost, minimize the deterioration of water quality as well as attain better growth performance and survival of *O. niloticus* combined with *C. gariepinus*. On the other hand, the combined *O. niloticus* and *C. griepinus* in one culture unit under any of the two feeding schemes (feeding based on biomass and feeding-to-satiation) achieved a good balance and good condition for the cultured fish species. For further investigation, the study should be carried out in earthen ponds to determine the growth, survival, and physiological condition of *O. niloticus* combined with *C. gariepinus* under natural conditions. Cost analysis should also be included to determine the economic viability of both feeding schemes.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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