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Comparative effects of exotic Raanan and local feeds on growth performances of Nile tilapia (*Oreochromis niloticus*) reared in engineered multi-constructed ponds for efficient water use

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Abstract

Purpose: Growth performance of 30 randomly sampled tilapias were examined fortnightly for 12 weeks.

Research methodology: Growth of male Oreochromis niloticus in two-by-two Completely Randomized Block Design (CRBD) with four treatments [New Water with Raanan (NWR), New Water with Local feed (NWL), Old Water with Local feed (OWL) and Old Water with Raanan (OWR)] was monitored in four ponds measuring 360 m2 each. Pond Temperature, pH, Dissolved Oxygen were assessed using the multi parameter-probe. Fish total body weights and lengths were measured using electronic scale and 30 cm rule.

Results: Temperatures ranged from 26.2 °C (OWR) < 26.4 °C (OWL) < 26.5 °C (NWR) < 26.8 °C (NWL). Highest mean pH of 6.7 was recorded in NWR compared to the lowest (6.1) in NWL. Dissolved oxygen was 3.0 mg/l for all treatments, except in OWR (3.7 mg/l). There were significant differences among entire physicochemical parameters ($p < 0.05$). The NWR produced highest tilapia body weights (88.3 g) followed by OWL (47.9 g), NWL (47.1 g) and OWR (44.0 g). Final fish body lengths were in order of OWR (9.1 cm) < OWL (9.2 cm) < NWL (9.7 cm) < NWR (12.1 cm) respectively with significant variations. Raanan cultured tilapia grew better than the local feed comprised of energy sources.

Limitations: Null hypothesis failed to confirm significant differences in fish growths ($p < 0.05$).

Contribution: Use of old water is recommended in absence of fresh, if pond is completely drained/limed to eliminate leeches, tilapia eggs, fry which may infest introduced fingerlings.

Keywords: *Growth performance, Male tilapia, Raanan, New water, Old water*

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1. Introduction

According to Naylor *et al.* (2000), as the world's human population continues to increase beyond 6 billion, its reliance on farmed fish production as an important source of protein will also increase. Projections of world fishery production in 2010 ranged between 107 and 144 million tones. Next to carp, tilapia is the second most farmed fish in the world. In countries like China, Egypt, Philippines, Brazil, Thailand and Bangladesh. Tilapia fish contribute substantially to the Food Security (Amisy Fish, 2017). The world aquaculture production of Tilapia fish is 4.2 million tonnes with an estimated value of around 3 to $ 3.5 billion (Amisy Fish, 2017). Most of the increase in fish production is expected to come from aquaculture, which is currently the fastest growing food production sector of the world. By the year 2030, aquaculture will dominate fish supplies and more than half of the fish consumed is likely to originate from this sector (FAO, 2000, Rao *et al*., 2012). The projected total production of feeds for aquaculture in the year 2010 ranged from 25 million metric tonnes (Tacon and Forster, 2001) to 32.6 MMT (IFOMA, 2000) against an approximate production estimate of about 13 MMT in the year 2000. Requirements for aquaculture feeds are likely to further increase due to an increasing trend towards the intensification of farmed production of omnivorous species in Asian countries, particularly China. According to Nyavor and Seddoh (1991), protein is an essential food nutrient which must be present in the right amount in the diet of every human being. It is needed for formation of enzymes, hormones, body building and repairs of worn out tissues and also serves as a source of energy to the body (Duodu, 2015).

The deficiency of protein in the diet of children results in “kwashiorkor”, a disease that makes growing children exhibit distended bellies, stunted growth, slow movement and emotional stress (Engar *et al*., 1991). According to FAO (1992), the specific animal protein requirement for a person is 49g per day. In Ghana however, protein per head per day from animal source is estimated to be 13.4g which is far below specification of the FAO (Rao et al., 2012). The very important role proteins play in our diet and insufficiency of protein in Ghana calls for an increase in the supply through tilapia production (Nunoo *et al*., 2014). The fisheries sector contributes significantly to Ghana’s economy in terms of food security, employment, poverty alleviation, GDP and foreign exchange revenues (Republic of Ghana, 2015). The contribution of Ghana’s fisheries sector is important, amounting to 4.5 percent of the GDP, 12 percent of the agricultural GDP and 10 percent of the labor force (Kassam, 2014). The sector also supports the livelihoods of 10 percent of Ghana’s population of about 26 million people. Also, worthy of mention is the sector’s gender balance (Ainoo-Ansah, 2013). While men are involved in fishing proper in the artisanal, semi-industrial and industrial sectors, women engage in onshore postharvest activities, undertaking fish processing, storage and distribution, even onto external markets (European Commission, 2015).

Fish farming started in Ghana when fish ponds were built in 1953 by the former Department of Fisheries in northern Ghana. Tilapia was the major target species and contributed over 80% of aquaculture production from ponds and culture-based fisheries worth about US $1.5 million a year (Ministry of Fisheries-Ghana 2012). The fishery sector contributes significantly in terms of food security, employment, poverty reduction, GDP and foreign exchange earnings towards the national economy. In the quest to improve performance rate of tilapia production to meet the expectant high fish protein demand and reduce its importation, researchers strive to augment the process with improved scientific aquaculture knowledge (Nunoo et al., 2014). According to Hardy (2000), the proportion of global fishmeal production used in fish feeds has increased from 10 to 35 per cent in the last seventeen years. A prediction of fishmeal needs for aquaculture feeds in 2010 was 2.8 million metric tons (MMT), approximately 44 per cent of the ten-year average global fishmeal production of 6.5 MMT. This was in spite of the predicted decrease from current levels of the percentage of fishmeal, included in the feed of all major aquaculture species. Hardy (2000) estimated that this amount of fishmeal would be approximately 1.3 MMT less than what is required had there been no decline in fishmeal use. At least this amount of fishmeal equivalent alternative protein sources (to the order of approximately 3 MMT was required in the aquaculture industry yearly as at 2010.

Existing problem of higher global demand for fish protein has been increasing over the years (WHO, 2000). This has resulted in a lot of pressure on marine fishery resources, such that the output from marine fishery is not able to support the ever-growing demand. The contribution of aquaculture, which has for a long period complemented fish demand, has also been overstretched in recent times. There is the need to accelerate aquaculture production of *O. niloticus* due to the global increase in demand for it (Rao et al., 2012). This has resulted in the formulation of a number of fish feeds in order to accelerate fish growth by enhancing growth-stimulating parameters including exotic feeds such as Raanan (Duodu, 2015). Synthetic formulations are expensive, scarce, may contain non-ecofriendly additives which may bio-accumulate in the food chain (Amisy Fish, 2017). Moreover, the use of these formulations may increase cost of input and increase the price of fish sold at the market (Duodu, 2015). It is urgent to identify natural formulations that would be cheap, accessible and eco-friendly.

Experimental studies improve the knowledge base of fish farmers in tilapia culture to boost their production through innovative utilization of accessible and eco-friendly rice bran and groundnut peel mixtures as compared to exotic Raanan feeds in Ghana (Dudou, 2015). When cost of feed reduces, it may impact on tilapia produce such that the average Ghanaian can afford to buy tilapia to increase their protein consumption (Nunoo, 2014). Additionally, Ghanaians could reduce the importation of fish and increase the exportation of tilapia which will significantly increase GDP (Asamoah et al., 2012). We presume that the contribution of aquaculture, has for a long period complemented fish demand, and not merely been overstretched in recent times to accelerate the production of *O. niloticus*. This has resulted in the formulation of composite fish feeds, such as exotic Raanan, which contain growth-stimulating ingredients (Cocker, 2014). Albeit, synthetic formulations are not only expensive or scarce but contain non-ecofriendly additives which may bioaccumulate in the food chain (FAO, 2013). Use of synthetic feeds may also increase cost of input and a resultant price hike in fish produce sold at the market (Dudou, 2015).

The purposive design of this study to investigate the effect of feed type [exotic/formulated feed (Raanan) and local feed (Rice bran and groundnut peels mix)] and water quality (old/reuse water and new/fresh water) on growth performance of all male *O. niloticus* was timely in order to provide technical solutions to some existing research gaps in in the development of a scientific working paper, and provide bases for further studies, especially on aspects of fish biology and ecology, microbiology/biotechnology, pond water quality and feed analyses. This study critically examined the effect of local and exotic Raanan feeds as well as old and new water types on the growth performance of *O. niloticus* males reared in engineered multi-constructed ponds for efficient water use based on assumptions with three underlaid null hypotheses (H_O: $\mu_1 = \mu_2 = \mu_3 = ... = \mu_r$) which failed to confirm that, these factors had significant effect on fish growth or efficient water use. Hence, the study could not fully address the effect of certain antibiotic chemicals and biological parameters on fish growth and the pond efficient water use. Investigation into the antibiotic resistant genes and fish gut fecal matter could not be carried out due to funding subjectivity.

2. Methodology

2.1. Study area

The research covered only Tano-Odumase in Sekyere South District in Ashanti Region of Ghana (Figure 1A and B). This study lasted for three months, but in the first two weeks of the research, fingerlings were stocked and continued for ten weeks. The district is about 16 miles away from the Kumasi Metropolis and Asante Mampong Municipality and is located midway between the two towns. According to the Meteorological Sub-agency, the district is found between latitude 6° and 7°N of the equator.

2.2. Materials

Materials used include 30 cm rule, water quality sampler, scooping net, rubber containers, fingerlings, fishing net, electronic scale and labels. Four ponds measuring 360 m^2 each were used. Two ponds were stocked with fresh water and labeled as New Water Raanan (NWR), and New Water Local (NWL) and the other two were stocked with old\reuse water and labeled as Old Water Raanan, (OWR), and Old Water Local, (OWL).

2.3. Determination of differences between the old and the new water treatments

The exact difference between the old and new water was based on the water sources. The fresh water refers to new water source drawn and introduced from an adjacent running river sited upstream of the fish ponds and aerated over duration of 24 - 48 hours before stocking ponds with fingerlings whereas the old water refers to water that had been drained from the fish ponds after one to two months of use and transferred onto an emptied stand by separate pond and allowed to aerate and bleach under sunlight for natural purification to occur between 14 - 21 days before it is reused to fill the pond for fingerling stocking.

2.4. Rearing and management of experimental fish

The feeding trial was carried out at the Pilot Aquaculture Centre (PAC) at Tano - Odumase using all male Nile tilapia (*O. niloticus*) fingerlings sex reversed with hormone treatment at average initial weight (3.6 g) and total body length (3.9cm). The fingerlings were kept in each pond measuring 360 m^2 of water capacity at a stocking density of 800 fingerlings, with three replicates per dietary treatment in each pond. The experimental period lasted for 12 weeks.

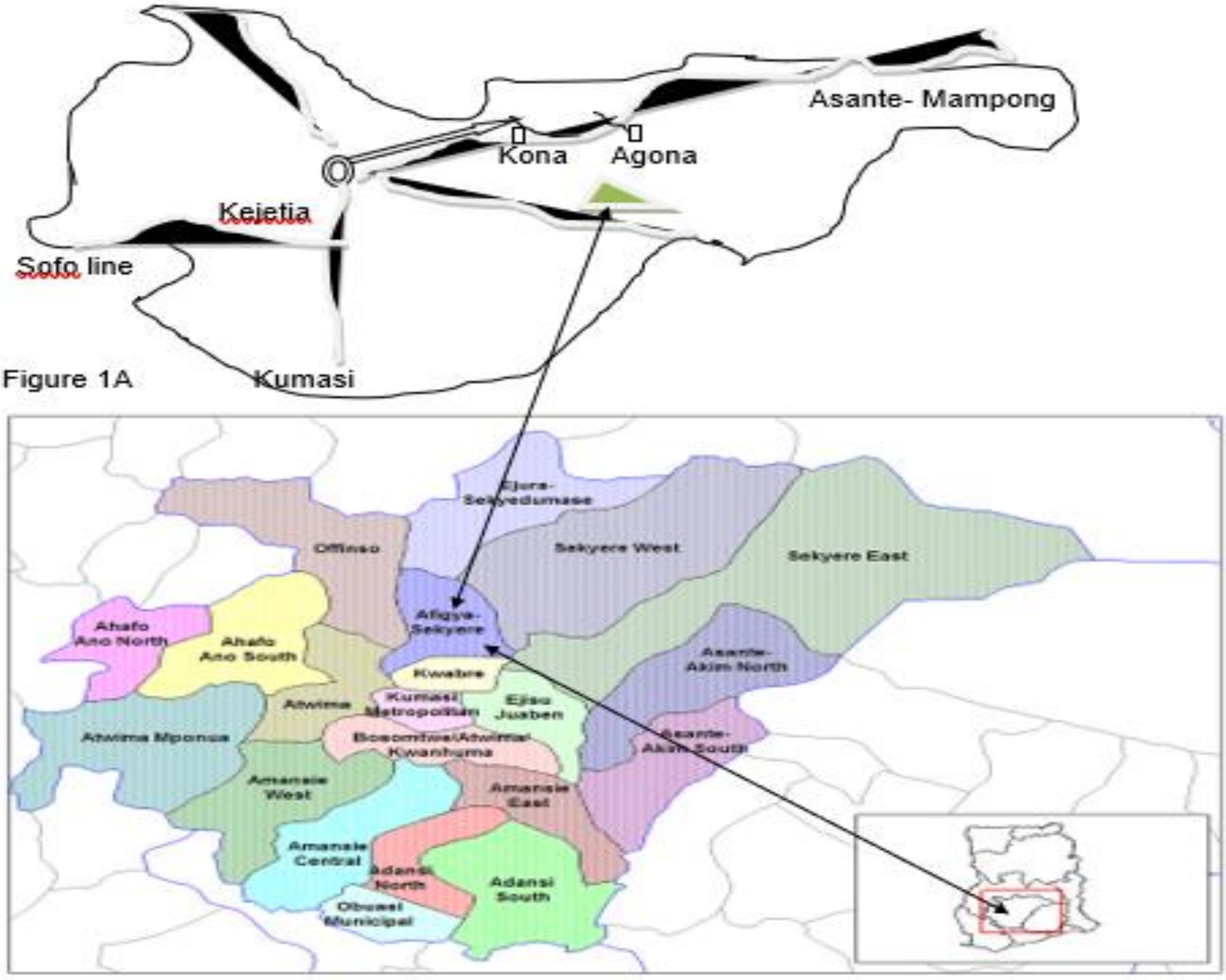

Figure 1B

Figures 1: Maps of the study area location from Ashanti Sub-Regional Catchment of Sekyere South District pointing the location of Kona Odumasi Aquaculture site in Ghana.

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2.5. Setting up of replicates in the ponds

The fingerlings were kept under continuous observation for one week prior to the onset of the experiment and then randomly distributed within twenty (20) hapas in four ponds (each hapa composed of an area of 8m square of water capacity) at a stocking density of 40 fingerlings per hapa with four replicates per dietary treatment type in each pond.

2.6. Water quality assessment

Quality of water was assessed using the multi-parameter probe water sampler just before stocking of pond wit fishes, in the course of fish growth and development, and at the end of the project at regular fortnightly intervals.

2.7. Experimental diet and feeding regime

Raanan feed and formulated groundnut peels and rice bran were used in feeding the tilapia. Feed weighing 14 g per pond per day was used; 7.0 g in the morning and then 7.0g in the evening as response feeding. The feeding regimes were respectively administered from the time of fingerling stocking for effective growth to maturity stages of the tilapia. Changes in feeding regimes with the various feed compositions were interspersed between 5-7 days interval and the feeds were administered twice within every (24 hrs) between (8-12 hrs) interval as the fishes graduated from one stage of growth up to maturity and harvesting stage of between 60-90 days duration.

2.8. Methods of data collection

Data collection commenced two weeks later when the fingerlings were stocked and continued for twelve weeks at a regular fortnightly interval. Water quality of the ponds were analyzed using the multi parameter-probe water quality sampler (Plate 2) at fortnightly interval. The total body lengths were measured using a 30 cm rule to read the straight-line distance from the tip of their snout to the tip of the caudal fin (Wattendorf, 2000) (Plate 1). The total body weight (in grams) of the fishes was taken randomly by picking any thirty fishes from each pond using a fishing net, scooping net, plastic bowl and weighing them on a digital electronic scale (CAS-S S-2000 JR. USA). The growth variables were measured from the start of the study, at 2 weeks regular intervals for 12 weeks when the fish attained physiological maturity.

2.9. Statistical data analysis

Statistical Package for Social Sciences 22 (SPSS, Chicago, IL) software was used to run two-way analysis of variance at a ($p \leq 0.05$) probability level to ascertain the significant differences earmarked between the raw data sets based on the standard deviations in weight and body lengths of fishes administered with different feed types and water stocks as influenced by pH, temperature and dissolved oxygen conditions which determine growth response rates of *O. niloticus* in the fish ponds.

3. Results and discussions

3.1. Physicochemical parameters of the pond waters

Replicate temperature, *p*H and dissolved oxygen with variance and standard deviations are presented in Tables1 and 2, respectively.

3.1.1. Temperature

A recurrent trend of temperature was recorded from the various ponds administered with different treatments combinations. It ranged from 26.0°C - 27.0°C in ponds with New Water and Raanan (NWR) and 26.2°C - 27.72°C for New water with Local Feed (NWL); 25.85°C - 27.01°C (Old water with Raanan) and 25.81°C - 27.22°C (Old water with local feeds) treatments (Table 1). Comparative mean temperatures for the various treatment combinations varied such that; 26.2±0.55 °C (OWR) < 26.4±0.75 °C (OWL) < 26.5±0.65 °C (NWR) < 26.8±0.62 °C (NWL). There were no significant differences between the average temperatures ($p < 0.05$) (Figure 2).

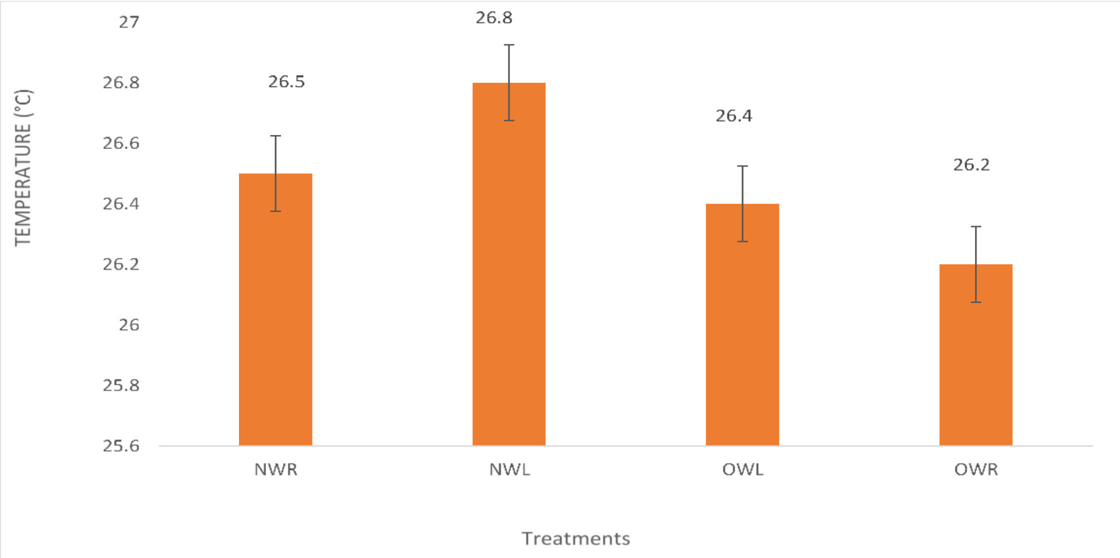

Figure 2. Effects of water types and quality on ponds temperatures

*3.1.2. p*H

The various fish ponds amended with different feeds showed minimal variations in *p*H spinning through the replicate descrete data 1 and data 2 sets while data 5 & data 6 points were recurrent within the coloumns. The *p*H ranged from 6.5 to 6.91 in NWR, and 6.03 to 6.35 in NWL. *p*H of the reused (old) water with Raanan treatment ranged from 6.33 to 6.84 and from 6.25 to 7.01in OWL (Table 1). Comparative pond type by feed type treatment combination effects on *p*H in Table 1 varied such that [*p*H/treatment was = 6.1±0.12 (NWL) < 6.6±0.17 (OWL) ~ = 6.6 ±0.33 (OWR) < 6.7±0.14 (NWR)] with significant differences between them ($p < 0.05$) (Table 2 and Figure 3).

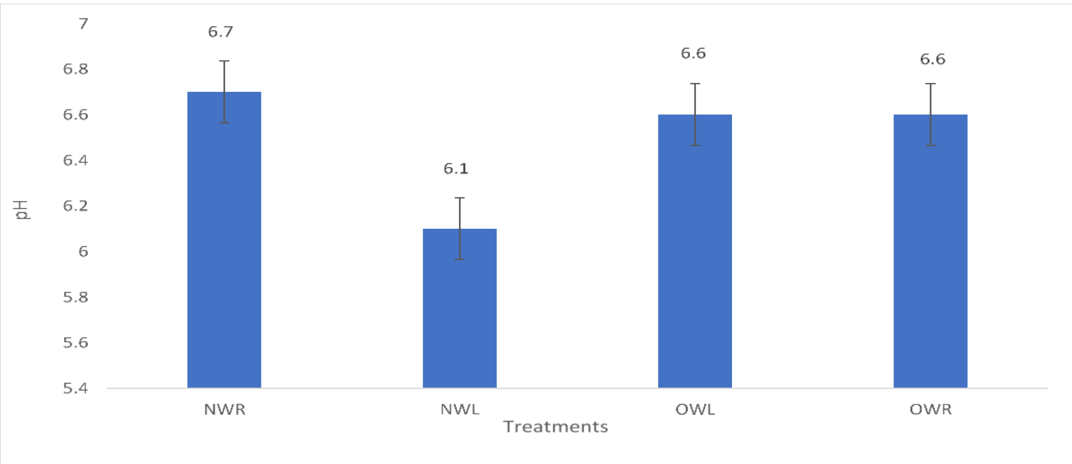

Figure 3. Effects of water types and quality on ponds *p*H

3.1.3. Dissolved oxygen

Dissolved oxygen concentration in all the pond types with different feed treatments for the replicate data 1 and 2 set of values were much closer while data 5 and 6 sets were recurrent, except in OWR which declined from 3.04 mg/l to non-detective (Table 1). However, it increased from 0.12 mg/l to 7.14 mg/l in NWR, and 0.24 mg/l to 6.52 mg/l in NWL treatments. Dissolved Oxygen in analysis of reuse water treated with Raanan (OWR), increased from 0.12 mg/l to 7.28 mg/l but gradually declined from 7.36 mg/l to non-detective (0.0 mg/l) in OWR (Table 1). Effects of the comparative fish pond types *viz avis* the feed treatment type on mean DO concentrations showed that [DO/treatment was = 3.0±3.31

(NWR) ~ = 3.0±2.81 (NWL) ~ = 3.0±3.39 (OWL) but, < 3.7±3.03 (OWR)] without significant differences between them ($p < 0.05$) (Table 2 and Figure 4).

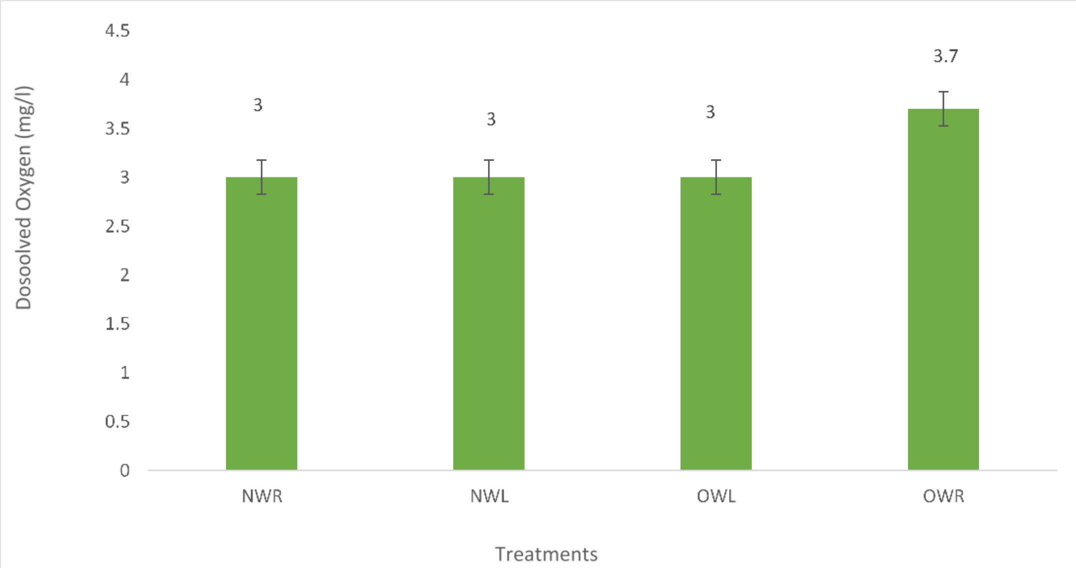

Figure 4. Effects of water types and quality on pond dissolved oxygen

Table 1. Replicate data of physicochemical parameters for all treatments.

Treatments	Replicate data sets	Physicochemical parameters		
		Temperature °C	*p*H	Dissolved Oxygen (mg/L)
NWR	Data 1	27.2±0.6	6.6±0.1	7.1±3.3
	Data 2	27.2±0.6	6.6±0.1	7.1±3.3
	Data 3	26.0±0.6	6.5±0.1	1.4±3.3
	Data 4	26.1±0.6	6.9±0.1	1.8±3.3
	Data 5	26.3±0.6	6.7±0.1	0.1±3.3
	Data 6	26.3±0.6	6.7±0.1	0.1±3.3
NWL	Data 1	27.7±0.8	6.1±0.1	6.5±2.8
	Data 2	27.7±0.8	6.1±0.1	6.5±2.8
	Data 3	26.2±0.8	6.2±0.1	0.9±2.8
	Data 4	26.4±0.8	6.4±0.1	0.2±2.8
	Data 5	26.3±0.8.	6.0±0.1	1.9±2.8
	Data 6	26.3±0.8	6.0±0.1	1.9±2.8
OWL	Data 1	27.2±0.7	6.7±0.2	7.3±3.4
	Data 2	27.2±0.7	6.7±0.2	7.3±3.4
	Data 3	26.0±0.7	6.3±0.2	1.4±3.4
	Data 4	25.8±0.7	6.8±0.2	1.6±3.4
	Data 5	26.1±0.7	6.6±0.2	0.1±3.4
	Data 6	26.1±0.7	6.6±0.2	0.1±3.4
OWR	Data 1	27.0±0.6	6.3±0.3	7.4±3.0
	Data 2	27.0±0.6	6.3±0.3	7.4±3.0
	Data 3	25.9±0.6	6.3±0.3	2.9±3.0
	Data 4	25.9±0.6	7.0±0.3	3.0±3.0
	Data 5	25.8±0.6	6.8±0.3	1.6±3.0

	Data 6	25.8±0.6	6.8±0.3	0.0±3.0

Table 2. Standard averages of physicochemical parameters recorded on table 1.

Treatments	Parameter	Standard average	Variance	Standard deviation
NWR	Temperature **°C**	26.5	0.3	0.6
	*p*H	6.7	0.0	0.1
	Dissolved Oxygen	3.0	10.9	3.3
NWL	Temperature	26.8	0.5	0.8
	*p*H	6.1	0.0	0.1
	DO (mg/L)	3.0	7.9	2.8
OWL	Temperature	26.4	0.4	0.7
	pH	6.6	0.0	0.2
	DO	3.0	11.5	3.4
OWR	Temperature	26.2	0.4	0.6
	*p*H	6.6	0.1	0.3
	DO	3.7	9.2	3.0

3.2. Growth performance of all male Oreochromis niloticus

The effect of water type and feed type, on the growth indicators of *O. niloticus* was further examined. Average final weights and lengths of fishes, with variances and standard deviations for *O. niloticus* are presented in Table 3.

3.2.1. The effects of feed type on growth parameters of Oreochromis niloticus

The effect of local feed on fish growth produced an average weight of 47.5 kg while Raanan fed tilapia yielded 66.1 kg final weight (Figure 5a). The analysis of variance (Table 3) proved significant differences between the fish body weights ($p < 0.05$). Despite Raanan recording the highest fish weight, its replicate fluctuating data lingered inconsistently within a standard deviation of 66.2 kg against 43.7 kg for Local feed (Figure 5a). Average body length of tilapia fed with the local feed was 9.5cm < Raanan (10.6 cm) (Figure 5b) with significant differences between them ($p < 0.05$) (Table 2).

Table 3. Effect of water and feed type on *O. niloticus* growth parameters

Treatments		Weight (g)			Length (cm)		
		Standard average	Varianc e	Standard Deviation	Standard average	Varian ce	Standard Deviation
Water type	Old Water	45.9	1293.2	36	9.2	26.6	5.2
	New Water	67.7	3163.6	56.2	10.9	29.3	5.4
Feed type	Local Feed	47.5	1135.5	33.7	9.5	26.5	5.1
	Raanan	66.1	3384.3	58.2	10.6	30.3	5.5

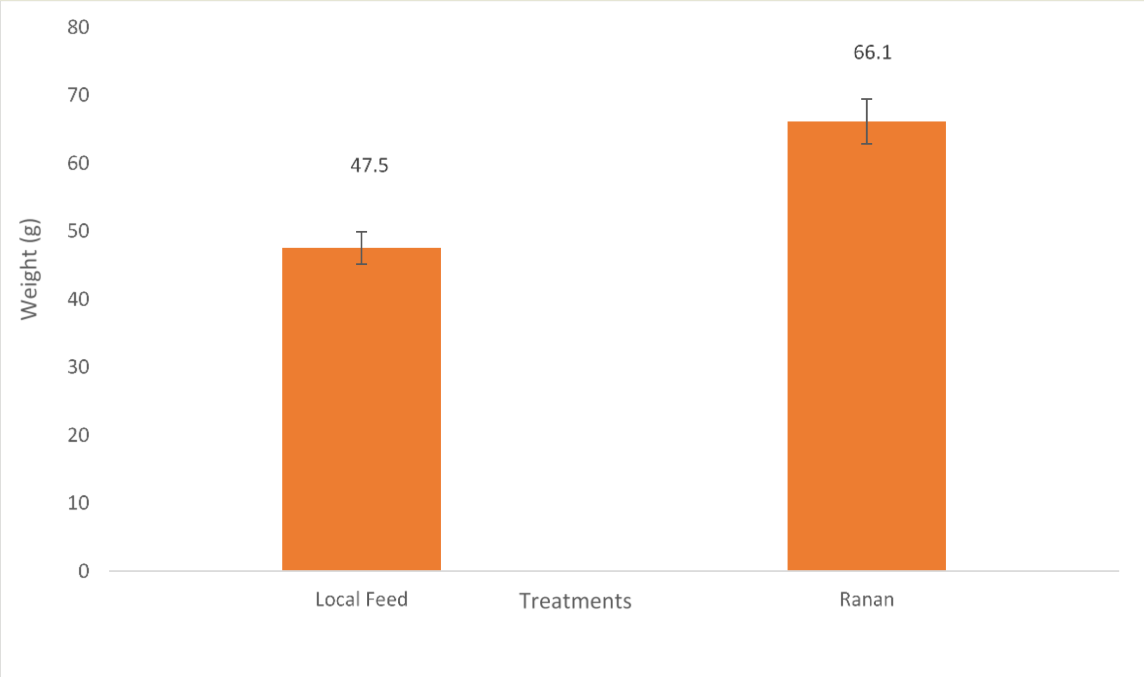

Figure 5. Effect of feed type on weight gain of *Oreochromis niloticus*

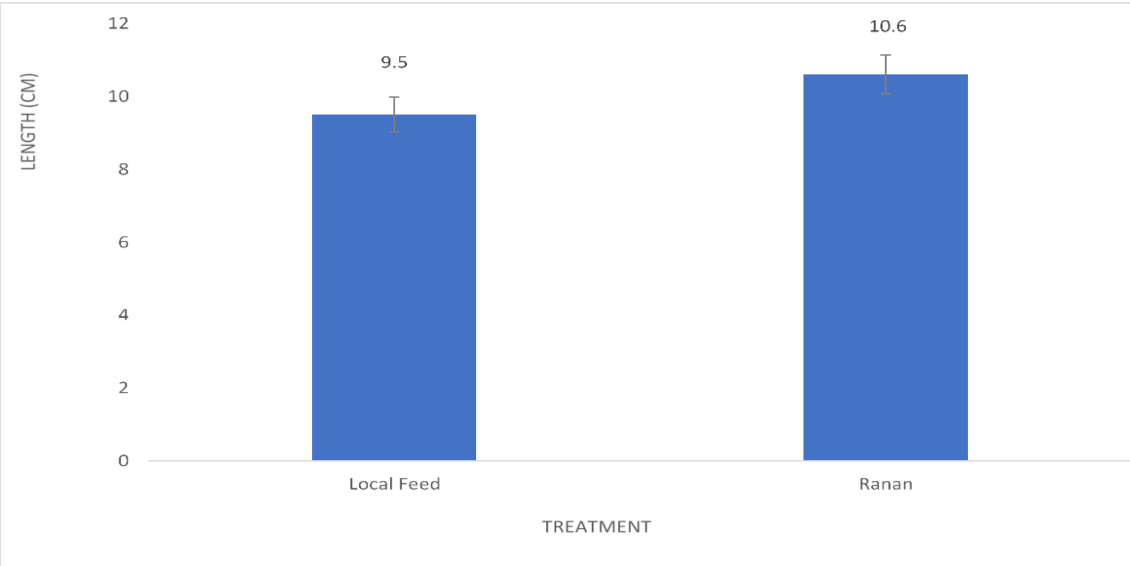

Figure 6. Effect of feed type on length of *Oreochromis niloticus*.

3.2.2 Effect of water type on growth parameters of Oreochromis niloticus

Analysis revealed that water types used for aquaculture influenced the male tilapia weight from Figure 6a. Old/reuse water triggered final weight gain by 45.9 kg whiles new water/freshwater usage produced 67.7 kg with existent weight differences at $\alpha = 5\%$. Standard weight deviations for the old water (36kg) and new water (56.2kg) respectively implied that replicate values of the former were more precise and aggregated around the average whiles those of the later were widely dispersed (Table4). Whiles the Old water registered 9.2 cm body

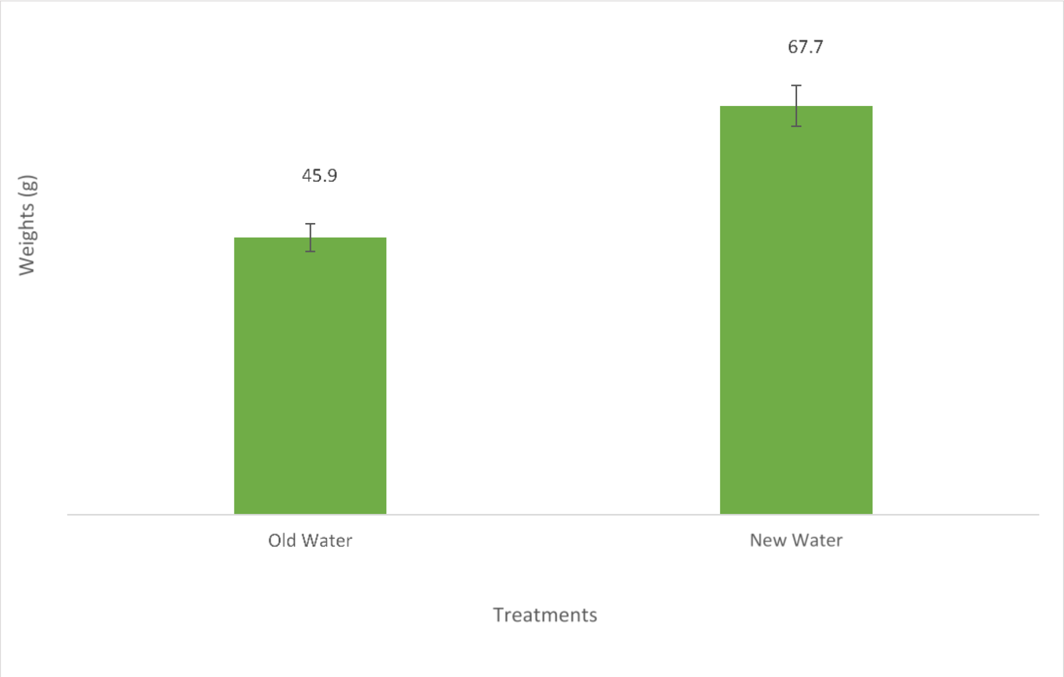

Figure 7. Effect of water type on weight of *Oreochromis niloticus*.

Table 4. Replicate data of treatment combinations on the growth performance of *O. niloticus*.

Treatments	Replicates	Weight (g)			Length (cm)		
		Standard average	**Variance**	**SD**	**Standard average**	**Variance**	**SD**
NWR	Data 1	2.4	1.9	1.4	3.9	0.6	0.8
	Data 2	27.6	136.5	11.7	9	1.6	1.3
	Data 3	90.2	663.5	25.8	12.8	1.8	1.3
	Data 4	112	291.4	17.1	13.8	6.5	2.5
	Data 5	139.3	3255.5	57.1	17.3	148.6	12.2
	Data 6	158.4	4732.1	68.8	15.8	6.9	2.6
NWL	Data 1	3.6	12.9	3.6	4.4	1.3	1.2
	Data 2	31.2	110.6	10.5	8.6	3.8	1.9
	Data 3	58	431.6	20.8	10.8	1.7	1.3
	Data 4	62.9	302.3	17.4	11	1.1	1.1
	Data 5	65.0	506.4	22.5	11.9	1.4	1.2
	Data 6	61.9	485.1	22	11.7	1.7	1.3
OWL	Data 1	2.8	1.6	1.3	4.2	0.6	0.8
	Data 2	22.2	55.9	7.5	8.2	1.1	1
	Data 3	40.2	214.0	14.6	10.1	3.5	1.9
	Data 4	55.2	207.6	14.4	9.8	216.9	14.7
	Data 5	70.4	308.8	17.6	9.9	2.0	1.4
	Data 6	96.7	2368.9	48.7	13.1	5.0	2.3
OWR	Data 1	3.0	3.5	1.9	4.2	0.6	0.8
	Data 2	21.8	53.7	7.3	8	1.2	1.1

	Data 3	48.6	513.7	22.7	10.5	2.7	1.6
	Data 4	65.4	293.1	17.1	8.7	1.5	1.2
	Data 5	86.6	1286.5	35.9	13.2	2.9	1.7
	Data 6	38.6	112.2	10.6	10.2	0.8	0.9

Length, new water picked 10.9 cm with significant differences between the water types ($p < 0.05$) (Fig. 6b and Table 3). Deviations from the overall average fish lengths were 5.2 cm and 5.4 cm in old and new water types respectively (Table 3).

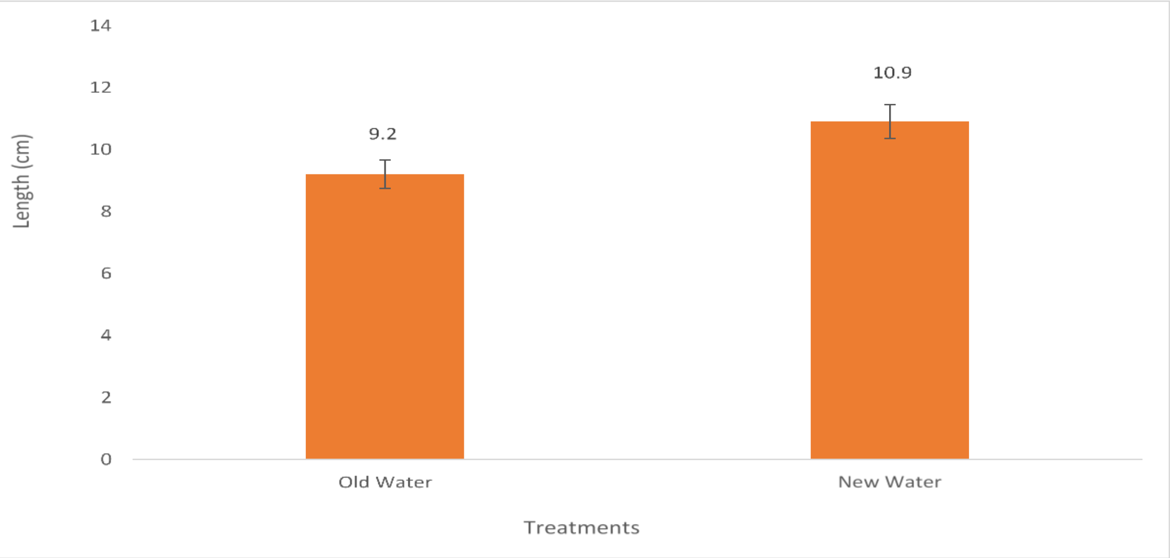

Figure 7. Effect of water type on the length of *Oreochromis niloticus.*

3.2.3. Effect of the treatment combinations on the growth performance of Oreochromis niloticus

Effects of water type and feed type combinations on *O. niloticus* mean weights and body lengths, with variances and standard deviations are presented in Table 4 and Table 5.

Table 5. Mean data for treatment combinations on the growth performance of *O. niloticus*.

Treatment	**Parameter**	**Standard average**	**Variance**	**Standard deviation**
NWR	Weight (g)	88.3	4680.3	68.4
	Length (cm)	12.1	47.3	6.9
NWL	Weight (g)	47.1	810.9	28.5
	Length (cm)	9.7	8.6	2.9
OWL	Weight (g)	47.9	1466.2	38.3
	Length (cm)	9.2	44.4	6.7
OWR	Weight (g)	44.0	1119.8	33.5
	Length (cm)	9.1	9.1	3.0

3.2.4. Effect of the treatment combinations on weight of Oreochromis niloticus

The replicate tilapia weights fluctuated between NWR and NWL and between OWR and OWL data within the same rows treatment replicates (Table 4). Tilapia weights in NWL steeply increased from 2.4g to 90.2g and gradually to 158.4g within the NWR. Fish weight gain steeply changed from 3.6g to 62.9g but subsequently declined to 61.9g within NWL. The average tilapia weight was highest (88.3g) in NWR, followed by OWL (47.9g), NWL (47.1 g) and OWR (44.0g). Fish standard body weight deviations from the means were in the order of, 28.5 g (NWL) < 33.5 g (OWR) < 38.3 g (OWL) < 68.4 g (NWR) (Table 5) respectively with significant differences between them ($p < 0.05$) (Figure 7 and Table 4).

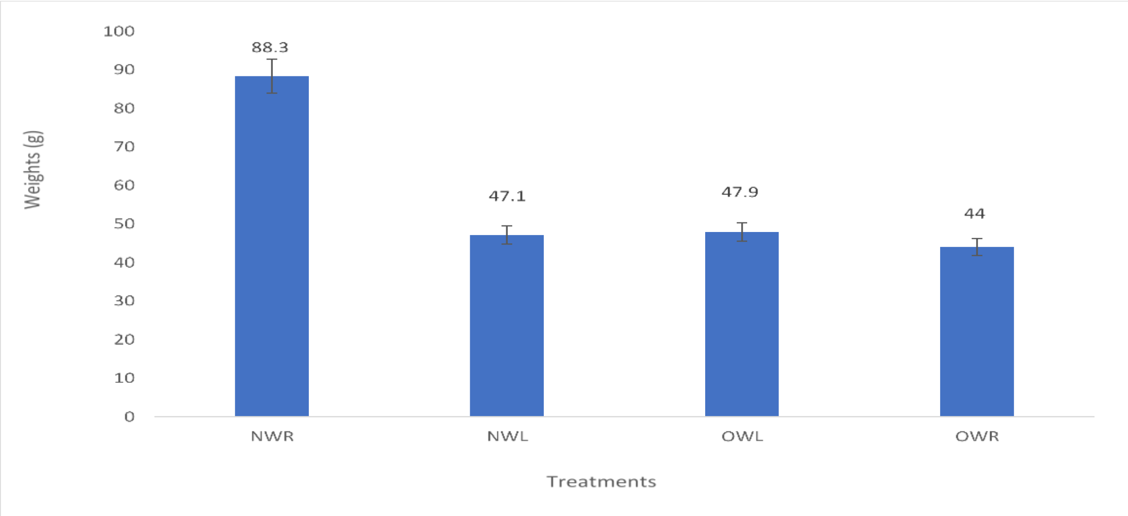

Figure 8. The effect of treatment combinations on the weight of *Oreochromis niloticus*

3.2.5 Effect of the treatment combinations on the body lengths of Oreochromis niloticus

Replicate fish body lengths data in the various treatment combinations shows similar results, except for sparing inconsistencies in discrete values within the rows (Table 4). It increased with NWL from 3.9 cm to 17.3 cm and 4.4 cm to 11.9 cm in the NWL while in the OWL body lengths of *O. niloticus* varied between 4.2 cm to 13.1 cm and 4.2 cm to 13.2. Generally, the effect of the treatment combinations on *O. niloticus* body lengths

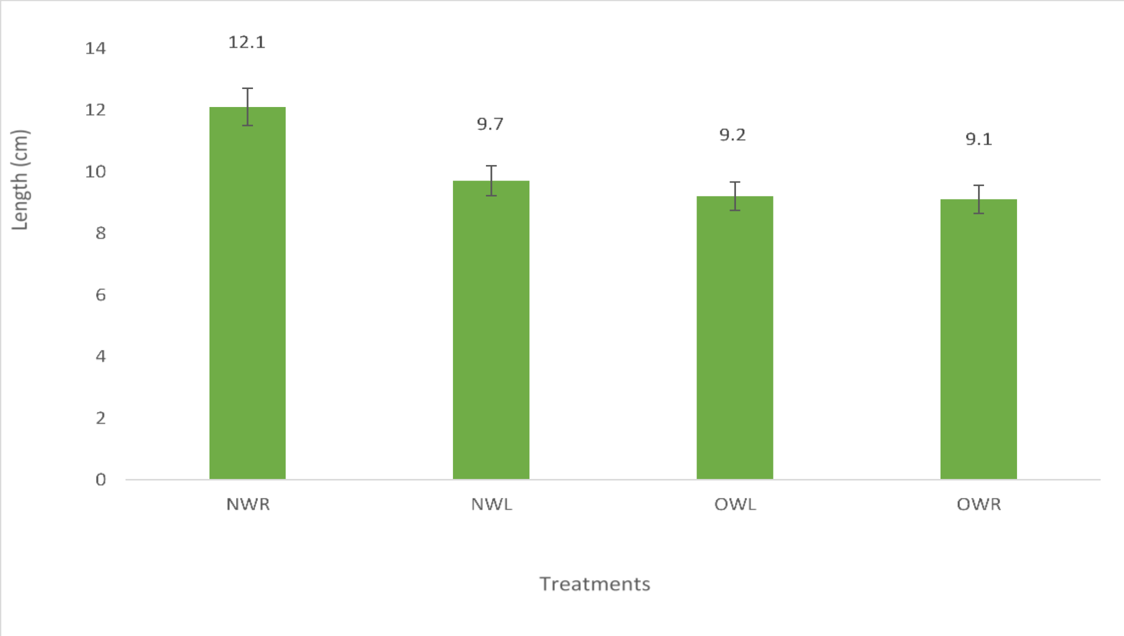

Figure 9. The effect of treatment combinations on the Length of *Oreochromis niloticus*

From Figure 8 portrayed variations in which OWR (9.1 cm) < OWL (9.2 cm) < NWL (9.7 cm) < NWR (12.1 cm) were significantly different ($p < 0.05$). Standard deviations within the average body lengths response based on the various treatment types were higher with NWR (6.9cm), than OWL (6.7cm), OWR (3.0cm) and NWL (2.9cm) respectively (Table 5).

3.3. Discussion

3.3.1. Effect of treatments on growth parameters of Oreochromis niloticus

There was a steep rise in weights of tilapia for NWR and OWL from data 1 through to data 6. NWL recorded a steep rise in tilapia weights from data 1 to data 3, then gradually to data 6. Although OWR recorded steep rise in tilapia weights from data 1 to data 5, it decreased sharply to data 6. These findings support the assertion of Wootton (1992) that the rate of growth of fish declines as it enlarges body, so that most energy is channelled into physiological functions such as respiration, excretion and digestion in support of increased muscular activity. Virtually, the effect of NWR was highest (88.3 kg) for mean tilapia weights, followed by OWL (47.9 kg), NWL (47.1 kg) and OWR (44.0 kg) respectively. Comparison of the effect of feed type on tilapia weight in new water generally confirmed the higher and significant response to growth by exotic Raanan than the local feed probably due to its sustainability (Bendiksen et al., 2011). These findings conform to the reports in Kenya that the best growth performance and feed conversion ratio occurred in fish fed with fishmeal followed by those fed a combination of rice bran and *C. nilotica*, while rice bran alone resulted in lowest fish growth performance (Mugo-Bundi et al., 2016).

Tilapia body lengths were similar to the trends in weights, except for some inconsistencies. The study proofed sharp increase in tilapia length from data 1 to data 3, where NWL and OWL rose gradually to data 5. Tilapia length decreased from data 5 to data 6 in both NWR and OWR. The mean length (12.1 cm) with NWR was the highest (9.7 cm) in NWL next by OWL (9.2 cm) and OWR (9.1cm) and only NWR was significant different from the rest (p<0.05). The entire new water performed better than the old, perhaps due to its freshness, and greenness that promote higher natural primary productivity (Chepkirui-Boit et al., 2011, Boyd, 1990). Comparison of the new waters proved significantly higher by performance of Raanan than ponds treated with local feed. Contrarily, assessment of the old waters revealed better performance of the local feed enriched ponds than comparative exotic Raanan (Raanan Fish Meal Limited 2010), though the mean difference was not significant. The study reveals the potentiality and confirms efficiency of local African feeds in optimizing best economic growth benefit

(Raanan Fish Feed West Africa Limited, 2017; Cocker, 2014; Diana et al., 1996). Similar results were recently detected from fishes fed a combination of rice bran and *C. nilotica* in Kenya and other feed resources in Norway (Ngugi et al., 2016, Ytrestøyl, 2015). The track order of changes in fish growth parameters could be the effect of increased muscular activity at maturity which halts growth and tends to compact the muscles (Duponchelle et al., 2000; Duponchelle, 1998 & Wootton, 1992).

3.3.2. Effect of Water Types on growth of fish using local feed

Higher fish weight was ascertained in ponds filled with old water and Rannan than those with new water enriched with local feed. This result confirms that of San and Preston (2003) who fertilised similar fish ponds with effluents within 30 days retention time (0.133g N/m^2/day). The fish body weights in this study were higher than previously reported data generated by Nguyen and Preston (2011). Effect of the water type on the body length of male tilapia contradicted final body weights such that for the same feed type (local feeds), the new water was higher than those in ponds filled with the old water. Notwithstanding, the final predictor of better growth performance is the mass/weight which gives an indication of the total amount of food/protein in the fish (Ngugi *et al*., 2016). Growth performance among tilapia could be influenced by several factors, such as biological and physicochemical parameters (Humbarger, 2013). Although Boyd (1998); Brogowski *et al*., (2004) and Mallya (2007) emphasised conditionally that fish growth from ponds fed with farm-made feeds was mainly a biological effect; Popma and Masser (1999) and Nguyen & Preston (2011) earlier intimated that physicochemical factors grossly influence the growth performance of tilapia in freshwater ecosystems, especially under integrated culture with the common carp (*Ciprinuscrapio*). This scientific idea directly corroborates with the reports that changing water quality, particularly under seasonal fluctuations, is recommendable and often the best practice because reintroduction of treated old waters into aquaculture ponds engenders higher fish productivity (Wootton's 1992 and Humbarger's 2013).

3.3.3. Effect of water types on growth of O. niloticus under Exotic Raanan feed

The results clarified that fish weights tented by local feed was different from the exotic Raanan types (Plates 3-12 in appendix). Contrary to the local feed, fishes cultured in the fresh water (NWR) were significantly larger and longer than the re-use water. San *et. al*., (2008) worked on tilapia cultured in reclaimed water (sewage water) and fed with water spinach and duckweed supplement, and reported 83.8g and 101g respectively. The present findings conform to what San *et al.* (2008), found to be higher than that of Anna *et al*., (2011) on growth characteristics of tilapia cultured in clear-water recirculation systems, giving rise to 83g final average weight. The daily fish weight gain directly conforms to the findings by Anna *et al*., (2011), and Nguyen and Preston (2011); nevertheless, higher than what was stated by San and Preston (2003). Increased growth performance of the new water could result from low water turbidity which enhanced light penetration for higher natural primary productivity by facultative photosynthetic algae (Bash *et. al*., 2001). The role of old water for the Raanan formulated feed (OWR) produced the lowest effect on final fish body weights and lengths; probably due to competition for feed and during reproduction in these ponds (Amisy Fish, 2017). Reproduction occurred because re-use water ponds always contain fish stocks from the previous fish culture which infests the new stock and trigger a lot of competition for food and space (Stoffels and Humphries, 2013; Amisy Fish, 2017). Ylikarjula et al. (1999), intimated that fauna species, in which both the adults and young eat virtually the same aquatic invertebrates and are not cannibalistic, become stunted when the population size reaches a particular limit. Owing to the high density of fish, the pond could not provide adequate oxygen for healthy growth (Mallya, 2007). Culturing fish in fresh water and feeding it with formulated feed gives better results (Francis *et al*., 2001). One possible reason for increased growth rate may be that in the new water, a few zooplankton and phytoplankton presence with other aquatic organisms and dissolved oxygen levels may be high since BOD in this water could be less (Amisy Fish, 2017). Enough DO will energize the fish to actively move about and feed and also carry out metabolic activities efficiently (Mallya, 2007). Besides, there may be less competition for food since many other aquatic organisms have not invaded this environment (Duodu, 2015). Nevertheless, Anna *et al.* (2011) iterated that in the absence of fresh water, re-use water could be opted when the pond is completely drained and limed to eliminate all tilapia eggs and fry.

3.3.4. Effect of feed type on growth of O. niloticus

Feed type has been reported by several investigators including Anna et al., (2011) to influence growth performance significantly. The formulated Raanan (Plates 3-12 in appendix), performed better than the local feed (which was mainly a mixture of energy sources) from this study. San *et. al.* (2008) and Nguyen (2010) reported similar trends in their findings. However, the findings contradict that of Ghosh *et al.*, (2010), who intimated that locally formulated diets with plant protein, performed better than the conventional diet enriched with animal ingredients. A similar recent study in Nigeria involving a 58-day feeding trial was conducted in concrete tanks (2m x 2m x 1.25m) of 400L capacity to determine the effects of *O. niloticus* (3.40g + 0.04) fed pelleted diet to apparent satiation at different feeding frequencies (once (FF1) at 0900hr, twice (FF2) at 0900 and 1700 h, three (FF3) at 0900,1300 and 1700 h and four times (FF4) 0900, 1200, 1500 and 1800 hs daily respectively. Fish were fed with 35% protein diet at 5% body weight. There was a significant increase between feeding frequency of three times (FF3) daily, 19.33+ 0.67 and others feeding frequencies of once (FF1) 9.33+0.33, twice (FF2)13.67+ 0.33 and four times (FF4) daily, 17.67+0.33 with respect to final mean weight (Termitope and Oluwaeum, 2013). Also Feed Conversion Ratio (FCR)of the fish fed feeding frequency of three times (FF3) daily, 13.96 +1.66, was discovered the best of the four feeding frequencies and the *O. niloticus* survival was not affected by the different frequencies within the tilapia value chains (Termitope and Oluwaeum, 2013; Rana, 2013).

3.3.5. Effect of Feed on multi-constructed fish pond water quality

Temperature of the pond measured within the range of 26.2 °C to 26.4 °C for Old Water and 26.5 °C to 26.8 °C in the New Water. From the perspective of Boyd (1990), temperatures of the different treatments were favourable for fish culture. In the new waters the temperature values were higher than the old water records and clearly demonstrated the effect of local feed ponds on temperature being much higher than in ponds treated with exotic Raanan. *p*H of the entire ponds was not significantly at variance with the exception of NWL which drew closer to acidic (6.1). Apart from NWL, the entire *p*H of the various treatment ponds was within the optimum range for tilapia culture (*p*H: 6.5 to 10) according to the prescribed standards of FAO (2000) and Anna et al., (2011). Diana *et al.* (1996) further reported that, efficient use of supplemental feed at a limiting rate along with fertilizer and natural feed did not adversely affect water quality but consequently improved fish productivity, an observation which was later confirmed by Duodu (2015). Turner & Robinson (2000) speculated that *p*H of ponds may increase above 9, especially when photosynthesis is high due to physicochemical and biological reactions resulting from the dense phytoplankton growth. Previous reports of Tunner and Robbinson (2000) were confirmed by our established maximum *p*H of 10 in the multi-constructed fish ponds at Kona-Adumase Experimental Aquaculture Centre in this study, buttressing the reports of other scientific discoveries about the significance and proven potential of controlling pH conditions to boost the primary productivity of fish ponds (Duodu, 2015).

There was a sharp decline in the DO of multi-constructed fishponds for all the treatments from Data 3 to Data 6 as opposed to the pH and temperature records within the same columns. This critical trend is suspected from the effects of incipient conditions such as fluctuating (incremental) latter day time's optimal temperatures from the early mornings recorded from data 3 to data 6. Such records were obtained between 12:00 noon and 6:00pm daytime intervals when the sun usually scorched. At such times also, much heat energy is inbuilt within the fish ponds for propelled active feeding, respiratory and masculine functions under competition with aerobic and benthic predators and parasites, thereby, increasing the net oxygen abduction or losses (Stoffels and Humphries, 2003). As fishes tend to grow bigger, they excrete more, whilst additional pond fertilization and feed treatments (Lin et al., 1999), may increase weed, zooplankton and phytoplankton development (San *et al.*,2007); posing signs of eutrophication if old water is not frequently topped or replaced with fresher (Duodu, 2015). Dissolved oxygen deficits were directly confirmed by our records from Data 3 to Data 6 of OWR and OWL treatments which significantly declined from 0.12 mg/L to non-detective (zero) respectively as opposed to its highest initial concentrations between 7.28mg/L to 7.36 mg/L in the ponds. Alternatively, higher day time temperatures caused by intense sunshine could enhance evaporation between the pond water surface and atmospheric air interfaces inducing minimal losses of dissolved oxygen in the long run (Mallya, 2007; Floyd 1997).

Initial dissolved oxygen was high, but gradually decreased in the fish ponds. In all the treatment ponds, oxygen level fell below 2 mg/l, until harvesting time fish were seldom found to be gulping for air at the surface of the water, signalling oxygen stress (Floyd, 1997). The DO levels for this study were higher 3 mg/l and 3.7 mg/l, an indication of oxygen abundance than 2.89mg/l and 2.81mg/l reported by San and Preston (2003), but were not up to the 5-15mg/l desired range (Duodu, 2015). The growth performance of the fish in this study was poor, attributable to dissolved oxygen, below 5 mg/litre, which hampered normal respiratory and growth functions (Floyd, 1997). Contrary to the assertions of Floyd (1997), Lin *et. al.* (1999) proposed that dissolved oxygen level of 2.40 - 3.52 mg/litre was good range for tilapia culture in pond, confirmed later by Duodu in 2015 and Amisy Fish in 2017.

4. Conclusion

Contextual analysis of the results and the ensuing discussion prove that the entire null hypotheses are rejected since differences existed among all the parameters under studied, even at 5% significance level. The exotic feed (Raanan), performed significantly better than the local formulated feed (which was mainly a mixture of energy sources) further confirming the findings in similar previous and recent studies. *Oreochromis niloticus* cultured in fresh water and fed with the exotic Raanan chalked better results. Nevertheless, in the absence of fresh water, old water could be used if the pond is completely drained and limed to eliminate the eggs of all tilapia and fry which may infest stocked fingerlings. From the perspective of Boyd, the temperature recorded for the different treatments were favorable for fish culture (26.2 °C to 26.4 °C for Old water and 26.5 °C to 26.8 °C in New water). Temperatures of the new waters were higher than old water records. It is clear that the effect of local feed on temperature was higher compared to ponds treated with Raanan. Apart from NWL, all the mean values recorded were within the optimum range for tilapia culture (*p*H: 6.5 to 10) according to the acceptable standards. The DO levels for this study were less than (2.89mg/l and 2.81mg/l) reported by San and Preston and not within the recommended range of 5-15mg/l for aquaculture functions.

4.1. Recommendations

4.1.1. Towards technical measures to promote aquaculture development with O. niloticus

The research proposes feasible measures for improved *O. niloticus* culture in engineered multi-constructed ponds. New/fresh water should be used for fish culture, especially tilapia because it produces better final yield (body lengths and weights). In the absence of fresh water, old water could be used on condition that the pond is completely drained and limed to eliminate the eggs of all tilapia eggs, fry and leeches, which may infest introduced fingerlings. The use of local feed could be supplemented occasionally with exotic ones like Raanan for complimentary gains in fish production. Environmental control such as frequent pond disinfection with antibiotics, changing of water especially, before fingerling stocking and after harvesting should be enforced to control likely emerging parasites, pests and infectious agents in the fish ponds.

4.1.2. Towards institutional partnership and joint studies

The Ministry of Fisheries and the Fisheries Departments of Ministry of Food and Agriculture in Ghana should harness their resources and expert potentials to provide the required technical assistance (feed trials, composition analysis, assessment of local and exotic feed conversion efficiencies, *et cetera*) in this kind of joint studies with tertiary research institutions.

4.1.3. Towards future research

Analyses of the following aspects as rejoinder to this current article reports are crucial:

1. co-evolution of antibiotic resistance genes and bacteria microbiome community structure in order to provide deeper understanding of the induced changes within the fish pond microenvironment;
2. feed conversion rates/efficiency calculations for Raanan formulated rations and local feeds;
3. sensory/proximate composition analyses of Raanan and local feeds;

4. effect of feed and antibiotics application on pond water quality and antibiotic resistance genes abundances;
5. Composition of fish pond bacteria microbiomes.

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Authors' contributions

Benjamin provided funds leadership guidance. In addition, Benjamin, Lucy and Isaac did the main research work while Elisha and Paul helped with the statistical data analyses. Richard and Gideon edited the article's main contents and Ernestina updated the references. All authors coedited the article.

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List of plates as appendixes

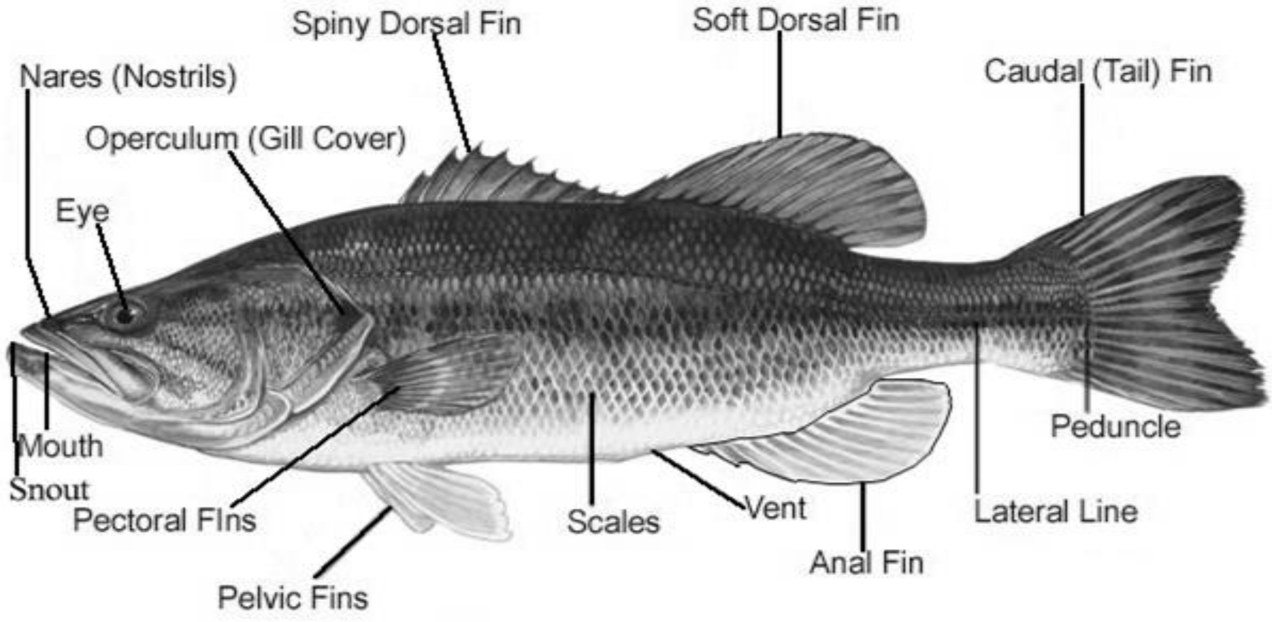

Plate 1. External Anatomy of male Nile Tilapia (Oreochromis niloticus).
Source: Kona-Odumase Aquaculture Centre's sample used for the experimental study in 2014.

Plate 2. ProDSS probes for water quality assessment.

Plate 3. Tilapia starter raanan feed TC1: Size (0.3 - 0.5mm); Protein (48%); Fat (5.0%)
(Source: Raanan Fish Meal Limited, 2010)

Plate 4. Tilapia starter raanan feed TC2: Size (0.5 - 0.8mm); Protein (48%); Fat (5.0%).
(Source: Raanan Fish Meal Limited, 2010)

Plate 5. Tilapia starter raanan feed TC3: Size (0.8 - 1.2mm); Protein (48%); Fat (5.0%).
(Source: Raanan Fish Meal Limited, 2010)

Plate 6. Tilapia starter raanan feed TC4: Size (1.2 - 1.5mm; Protein (48%); Fat (5.0%).
(Source: Raanan Fish Meal Limited, 2010)

Plate 7. Tilapia pre growth raanan feed PG (40 floating): Size (2mm); Protein (40%); Fat (7.0%).
(Source: Raanan Fish Meal Limited, 2010)

Plate 8. Tilapia supreme growth feed SG: Size (2.5mm); Protein (33%); Fat (6.0%).
(Source: Raanan Fish Meal Limited, 2010)

Plate 9. Tilapia high growth raanan feed HG: Size (3.0mm); Protein (38%); Fat (7.0%).
(Source: Raanan Fish Meal Limited, 2010)

Plate 10. Tilapia supreme growth feed SG: Size (4.0mm); Protein (33%); Fat (6.0%).
(Source: Raanan Fish Meal Limited, 2010)

Plate 11. Tilapia prime growth feed: Size (4.5mm); Protein (30%); Fat (5.0%)
(Source: Raanan Fish Meal Limited, 2010)

Plate 12. Tilapia prime growth feed: Size (6.0mm); Protein (30%); Fat (5.0%).
(Source: Raanan Fish Meal Limited, 2010)