Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

ISSN NO. 2320-5407

Article DOI:10.21474/IJAR01/7811
DOI URL: http://dx.doi.org/10.21474/IJAR01/7811

RESEARCH ARTICLE

EFFECT OF STOCKING DENSITY AND DIET ON THE PERFORMANCE OF JIPE TILAPIA (*Oreochromis jipe*) CULTURED IN HAPAS AT SAGANA, KENYA

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Manuscript Info

Manuscript History
Received: 26 September 2018
Final Accepted: 1 October 2018
Published: October 2018

Keywords:-
O. jipe, stocking density, diet, growth and survival.

Abstract

The 84 days experiment was conducted at Sagana Aquaculture Centre, Kirinyaga County, to determine the effect of stocking density and diet on the performance of Jipe tilapia (*O. jipe*) reared in hapas in an earthen pond. It involved a 3x2 factorial design (3 diets x 2 stocking densities) in 18 (1m x1m) hapas mounted in a 800 m^2 earthen pond. The stocking densities were 30 fish m^{-2} and 45 fish m^{-2} combined with 30% CP of both formulated feed (Diet 1) and Ranaan commercial feed (Diet 2) and 35% CP for Sigma commercial feed (Diet 3). Feeding was maintained at 10% of body weight (BW) in every 14 days of growth. The effects of stocking density and diet were compared on the basis of mean weight and length, weight gain percent, specific growth rate, survival, feed conversion ratio and average water quality parameters and the means of the variables were analyzed using two-way Analysis of Variance (ANOVA) at $p<0.05$ to test the effects of the two factors (stocking density and diet) on the various aspects of *O. jipe* growth and survival. Mean separation from ANOVA test was done using Tukey's HSD (Honestly significant difference) at $p<0.05$ to detail any difference among treatments. The best growth in terms of mean length and weight was achieved in diet 3 irrespective of stocking density. It recorded mean length $7.50^{a}\pm0.19$ cm and mean weight of $6.68^{a}\pm0.45$ g respectively. Survival was highest on fish fed on diet 2 ($17.00^{a}\pm1.57$) whereas stocking density had no significant effect $p<0.05$ on *O. jipe* survival. There was no significant interaction $p<0.05$ of the two factors tested on calculated growth performance parameters (mean weight, SGR, percent weight gain, percent survival and FCR) except for mean length, survival and condition factor which were significantly affected. Stocking density and diet had no significant effect at $p<0.05$ on all the water quality parameters measured. Furthermore, all the water quality parameters were within the recommended ranges for tilapia culture. The results from the present study clearly suggest that *O. jipe* should be fed on a high CP diet regardless of the stocking density in the culture systems.

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Introduction

Growth in the global supply of fish for human consumption has outpaced population growth in the past five decades thus resulting in increasing average per capita availability (FAO, 2016). Yet in the continent only Nigeria and Egypt have been dominant countries in aquaculture production surpassing over 50% of total African production of farmed fish. The situation is critical in Sub-Saharan Africa (SSA) where prevalence of chronic undernourishment appears to have risen from 20.8 to 22.7 percent between 2015 and 2016 (FAO, 2017). As yet, many countries in SSA have the potential to develop aquaculture but they continue to produce negligible quantities of fish.

Aquaculture, mainly the farming of fish, is often cited as one of the means of efficiently increasing food production hence promoting food security. A total of 842 million people in 2011-13, were estimated to be suffering from chronic hunger, regularly not getting enough food to conduct an active life (FAO, 2013). Despite overall progress, marked differences across regions persist; Sub-Saharan Africa remains the region with the highest prevalence of undernourishment (FAO, 2013). Fish provides a good source of protein and essential micronutrients and thus plays an important role in the prevention of many human diseases (Williams and Poh-Sze, 2003).

Aquaculture is one of the fastest growing food-producing sub-sectors (Subasinghe, 2003). According to Lehane (2013), it is recognized as a possible sustainable solution for food security and increased dietary nutrition in developing regions. The most important fish species used in aquaculture worldwide are carp, tilapia, salmon and catfish. Globally tilapia has become the third most important fish in aquaculture after carp and salmon (Fessehaye and Yonas, 2006). Though several species of tilapia are cultured commercially, Nile tilapia (*Oreochromis niloticus*) is the predominant cultured species worldwide (Welker and Lim, 2011).

Tilapias are considered as the best species for culture because of their high tolerance to adverse environmental conditions, their relatively fast growth and easy breeding (El-Sayed, 1999). Studies show that they are among the easiest and most profitable fish to farm due to their omnivorous diet, mode of reproduction (the fry do not pass through a planktonic phase), tolerance to high stocking density and rapid growth (sexual maturity in ponds is reached at an age of 5-6 months). These characteristics make them ideal for aquaculture.

In Kenya, freshwater aquaculture activities mainly involve the production of *O. niloticus* and African catfish (*Clarias gariepinus*) under different culture systems. However, studies done in Kenya have shown that *O. niloticus* is the most readily cultured fish with significant success. It has shown an efficient feed conversion ratio, demonstrates fast growth rates, high tolerance to low water quality, ease of spawning and resistance to diseases (Opiyo *et al*, 2014). On the contrary little is known about Jipe tilapia (*Oreochromis jipe*, Lowe, 1955), an endemic and commercially important tilapine to Lake Jipe and Pangani River in Tanzania (Bayona, 2006). There is also lack of information on its culture potential, stocking density, growth and survival in relation to diet. Therefore, the study sought to determine aquaculture potential of *O. jipe* based on stocking density and diet, reared in hapas in an earthen pond at KMFRI Sagana Aquaculture Centre.

Methodology:-

Study site

The study was carried out at KMFRI Sagana Aquaculture Centre located about 2 km Northwest of Sagana Township in Kirinyaga County and approximately 104 km Northeast of Nairobi City. It lies at latitudes $0^0$19’S and $37^0$12’E and at an altitude of 1,231 m above mean sea level. The Centre occupies an area of approximately 59.37 hectares with 109 operational ponds of which 72 (150 m^2) are research ponds and the rest used for spawning, fingerling production and grow-out production. The farm is supplied with water from River Ragati by gravity all-year round.

Research design

The 84 days experiment involved a 3x2 factorial design (3 diets x 2 stocking densities) in 18 hapas mounted in $800m^2$ earthen pond in a block design. *Oreochromis jipe* fingerlings were sourced from a designated concrete pond where the brood stock is reared within the institution. Sorting was done and fingerlings of average mean weight 1.45 g were obtained. A total of 675 fingerlings were pooled and stocked in hapas and allowed to acclimatize for 18 days. The stocking densities were 30 fish m^{-2} and 45 fish m^{-2} combined with 30% CP for both formulated diet and Ranaan commercial feed and 35% CP for Sigma commercial feed. Feeding was maintained at 10% body weight (BW) in every 14 days of growth. During the acclimatization period, mortalities as a result of stress were replaced continuously. Grading of initial length and weight of 30 fingerlings was taken at the commencement of the experiment to assist in feed calculation and subsequent growth calculations.

Sampling procedure and materials

Sampling of fish and selected physicochemical parameters was done fortnightly. The main physicochemical parameters included pH, temperature, conductivity and TDS which were measured using Hanna Multi-parameter HI 9829 Meter. Determination of ammonia, nitrites and phosphates was done using colorimetric /spectrophotometric method.

Ammonium determination

In an alkaline medium, the dissolved NH_3 reacts with hypochlorite (HClO) to form a monochlooramine. At 20°C and with nitroprussaat (Na (Fe (CN) 5NO).2H2O) as a catalyst, this reaction takes 12 hours. This will form a blue indophenol in oxidizing medium, and in the presence of a phenol. Precipitation of Ca and Mg in basic medium is avoided by complexation with sodiumcitratedihydraat. The blue indophenol complex is then read spectrophotometrically at 630nm.

Nitrite determination

The nitrite in water was quantified by diazoting with sulfanilamide and coupling with N- (1-naphtyl) ethylene-diamine to form a highly colored azo dye. The absorbance of the colored complex was measured spectrophotometrically at 543 nm.

Phosphate determination

Phosphates are analyzed by the formation of a phosphorus-molybdate complex. Water sample was allowed to react with a composite reagent containing molybdic acid, ascorbic acid, and trivalent antimony. The resulting complex heteropoly acid is reduced to give a blue solution (phosphor-molybdate complex), of which the absorption was measured spectrophotometrically at 885 nm.

Experimental commercial and local fish feed

The 3x2 factorial design *O. jipe* culture trials set in triplicates had three diets which included diet 1, an on-farm formulated diet from locally available ingredients to make 30% CP to match diet 2 a commercial diet manufactured by Ranaan. Diet 3, another commercial diet was Sigma composed of 35% CP a digression from the other two trial diets due to the manufacturers CP production array limitation. The CP for locally available ingredients for diet 1 are as indicated in table 1 below.

Table 1: Ingredients of the formulated fish feed (Diet 1)

Ingredients	**Crude Protein (CP %)**
Freshwater shrimps (*Caridina nilotica*)	63.5
Maize (*Zea mays*) Germ	12
Wheat (*Triticum aestivum*) Pollard	12
Sunflower (*Helianthus annuus*) seedcake	25.9

Experimental fish

A sample of 30 *O. jipe* fingerlings were measured for wet weight on an electronic balance (Model: EHB-3000 Cap = 3000g d=0.05 g) and total length (cm) using a measuring board to the nearest 0.1 cm. This was to determine the average wet weight and total length of the fish at the start of the experiment. The fingerlings under the various treatments were measured fortnightly to determine growth in total length and body weight. The fingerlings were then returned to the appropriate hapas after weighing. The weight measurements were used to determine the specific growth rate (SGR % day $^{-1}$), feed conversion ratio (FCR), weight gain (%) and condition factor of the fingerlings. Survival was determined by counting the remaining fish in the hapas on each sampling date and the calculation was done as follows:-

Specific growth rate (SGR) = 100 (ln W_1- ln W_0/t) where: - (ln = Natural logarithm, W_0= Initial Weight (g), W_1= Final weight (g) and t = Time (days)……………………………………………………………………………………1

$$\text{Feed conversion ratio (FCR)} = \frac{\text{Weight of dry feed given per treatment}}{\text{Wet weight gain in that treatment (g)}} \quad \ldots\ldots 2$$

$$\text{Weight gain (\%)} = \frac{\text{Final weight of fish - Initial weight of fish}}{\text{Initial weight of fish}} \times 100 \quad \ldots\ldots 3$$

The condition factor (K) value was calculated according to Offem *et al*. (2009);

Condition factor, K= W X 100/ L^3 where W is the total body weight and L is the total body length……………………………………………………………………………………..…………………………4

$$\text{Percent survival} = \frac{\text{Initial number of fingerlings in the hapa – Number of dead fingerlings}}{\text{Initial number of fingerlings in the hapas}} \times 100 \quad \ldots\ldots 5$$

Data analysis

Data analysis consists of examining, categorizing, tabulating and even recombining the evidence to address the initial prepositions of the study. Data collected was coded to enhance basic statistical analysis. Descriptive statistics including means and standard errors (SE) of the growth variables and water quality parameters were determined. Growth and survival over time was represented in graphs. The effects of stocking density and diet were compared on the basis of mean weight and length, mean weight gain (%), specific growth rate, survival and percent survival, feed conversion ratio and average water quality parameters and the means of the variables were analyzed using two-way Analysis of Variance (ANOVA) at $p<0.05$ to test the effects of the two factors (stocking density and diet). Mean separation from ANOVA test was done using Tukey's HSD (Honestly significant difference) at $p<0.05$ to detail any difference among treatments. SAS system version 8 statistical software was used for all statistical analysis.

Results:-

Effect of stocking density on growth performance parameters of fish

From the present study, fish length and weight were not significantly affected by stocking density at $p<0.05$ (Table 2). Fish from stocking density of 30 had a mean length of $7.35^a \pm 0.15$ cm whereas fish from stocking density 45 had mean length of $7.24^a \pm 0.17$ cm (Table 2). The mean length and weight were highly, positively and significantly correlated (r= 0.978, P= 0.001). Specific growth rate (SGR) was not significantly affected at $p<0.05$ by stocking density with the highest SGR reported for stocking density 45 as shown in Table 3. Stocking density did not affect percent weight gain significantly $p<0.05$ but fish reared at 30 fish m^{-2} had higher values of weight gain (591.49 to 643.22 %) compared to fish reared at 45 fish m^{-2} (522.30 to 679.31) (Table 3).

Furthermore, high stocking density resulted to higher FCR compared to low stocking density however, there was no significant effect at $p<0.05$ of stocking density on the mean FCR values. Consequently, stocking density had significant effect at $p<0.05$ on condition factor of the fish populations and ranged between $1.36^c \pm 0.02$ and $1.49^a \pm 0.02$. The lower value of $1.36^c \pm 0.02$ was recorded for fish reared in stocking density 45 while the highest value of 1.49±0.02 was recorded for fish reared in stocking density 30 (Table 3). Stocking density had no significant effect at $p<0.05$ on the percent survival of the fish with highest percent survival recorded for stocking density 30 as shown in Table 3.

Table 2:- Mean ± S.E of Body length, weight and survival rate of *O. jipe* as influenced by stocking density.

Stocking Density	Parameters			
	Length	Weight	Survival	Mortality
30	$7.35^a \pm 0.15$	$6.22^a \pm 0.34$	$14.80^a \pm 0.71$	$3.80^b \pm 0.47$
45	$7.24^a \pm 0.17$	$6.02^a \pm 0.39$	$15.13^a \pm 1.26$	$6.96^a \pm 1.33$

Means with the same superscripts are not significantly different ($p<0.05$) as determined by analysis of variance and Tukey'sHSD comparison of mean values over culture period.

Table 3:- Means ± S.E of Parameters calculated on the growth performance of *O. jipe* at different stocking densities and diets.

Stocking Density	Diet	SGR (%)	Weight Gain (%)	Survival (%)	Condition Factor (K)	FCR
30	1	$2.30^{a}\pm0.08$	$591.49^{a}\pm45.22$	$25.56^{a}\pm5.56$	$1.43^{b}\pm0.03$	$1.61^{a}\pm0.28$
	2	$2.36^{a}\pm0.16$	$643.22^{a}\pm105.6$	$28.89^{a}\pm4.44$	$1.41^{b}\pm0.01$	$1.28^{a}\pm0.05$
	3	$2.32^{a}\pm0.07$	$604.14^{a}\pm42.76$	$35.56^{a}\pm4.84$	$1.49^{a}\pm0.02$	$1.08^{a}\pm0.09$
45	1	$2.15^{a}\pm0.10$	$522.30^{a}\pm48.70$	$16.30^{a}\pm0.74$	$1.41^{b}\pm0.03$	$1.78^{a}\pm0.12$
	2	$2.24^{a}\pm0.26$	$585.29^{a}\pm152.7$	$25.93^{a}\pm8.35$	$1.42^{b}\pm0.02$	$1.21^{a}\pm0.20$
	3	$2.45^{a}\pm0.03$	$679.31^{a}\pm20.20$	$14.07^{a}\pm4.12$	$1.36^{c}\pm0.02$	$1.83^{a}\pm0.41$

Means with same letters along the column are not significantly different (P<0.05) as determined by analysis of variance and Tukey'sHSD comparison of mean values over culture period.

Effect of stocking density on survival of fish

At the end of the study period, the number of the surviving fish in both stocking densities was not significantly different. Stocking density 30 had survival of 14.80 ± 0.71^{a} compared to stocking density of 45 which had survival of 15.13 ± 1.26^{a}. However, mortality was significantly affected by stocking density whereby there was high mortalities in stocking density 45 (6.96 ± 1.33^{a}) compared to stocking density 30 (3.80 ± 0.47^{b}) as shown in Table 2. Survival was affected with time as shown in Figure 1.

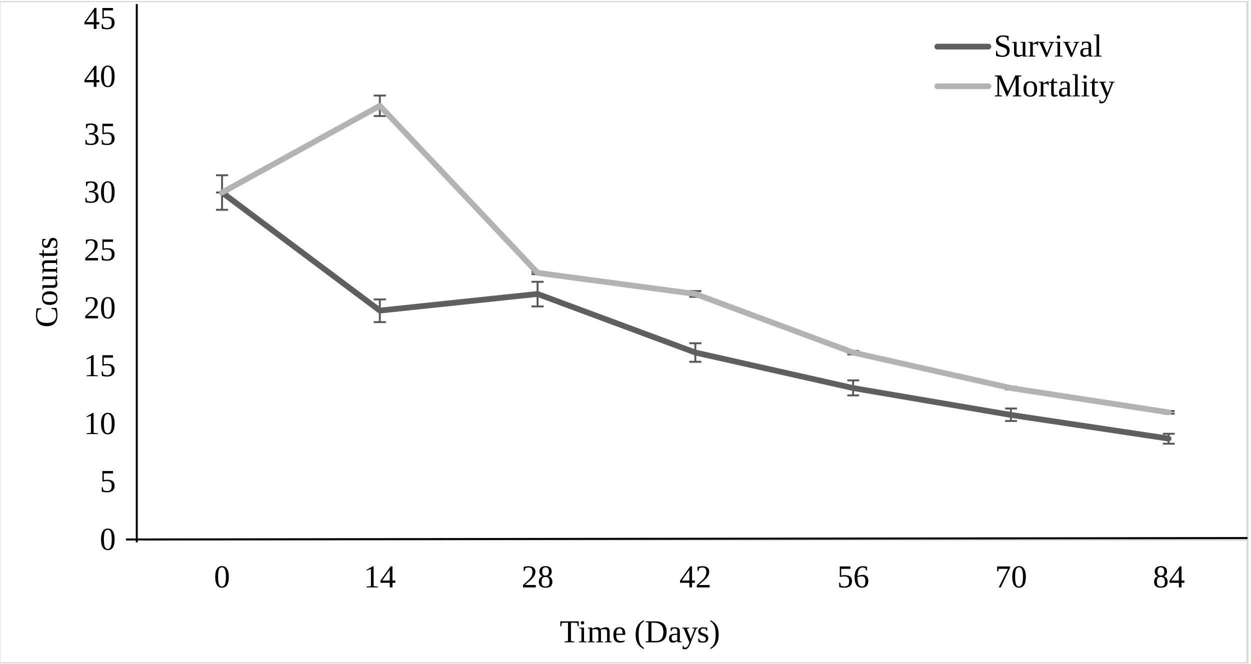

Figure 1:- Graphs showing survival and mortality against time

Effect of diet on growth performance parameters of fish

In this study, diet was found to have significant effect at p<0.001 on the mean length and weight of *O. jipe* as shown in Figures 2 and 3. Fish fed on diet 3 had significantly higher mean length of $7.50^{a}\pm0.19$ cm as compared to fish fed on diets 1 and 2 which had mean lengths of $7.17^{b}\pm0.18$ cm and $7.21^{b}\pm0.21$ cm respectively. In the 84 days of culture the fish fed on diet 3 had a significantly higher mean weight of $6.68^{a}\pm0.45$ g whereas the fish fed on diets 1 and 2 had mean weights of $5.66^{b}\pm0.38$ g and $6.02^{b}\pm0.50$ g respectively.

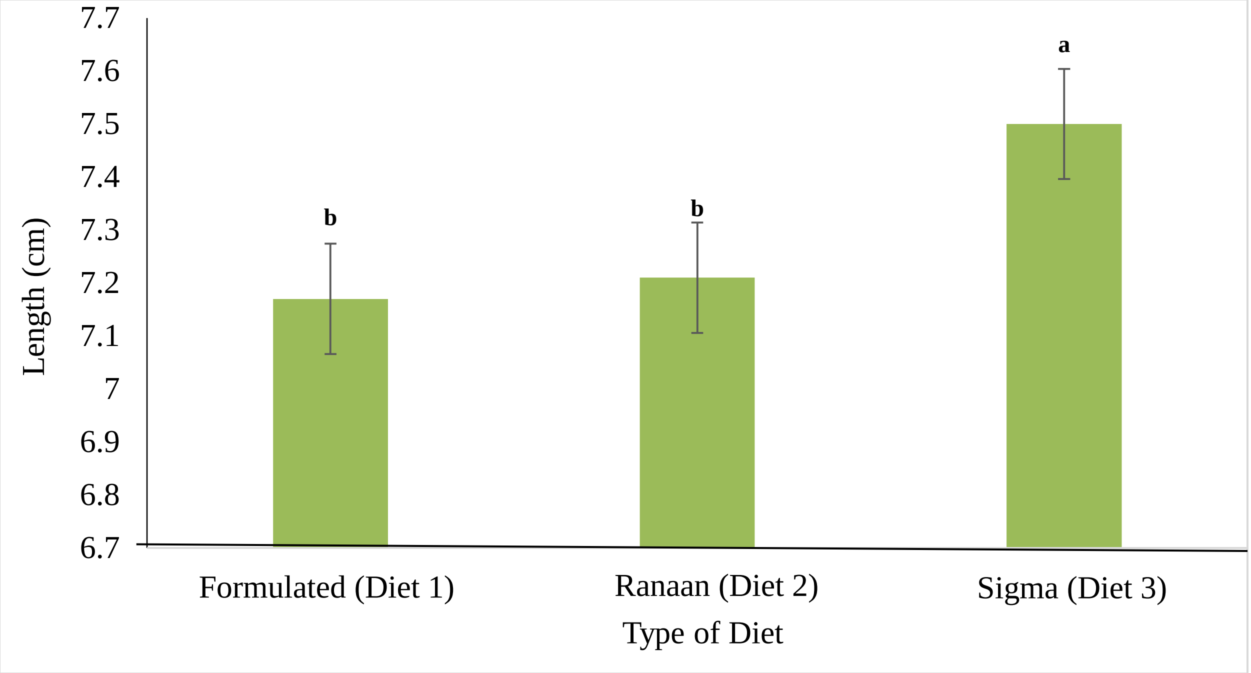

Figure 2:- Effect of diet on the length of *O. jipe*.

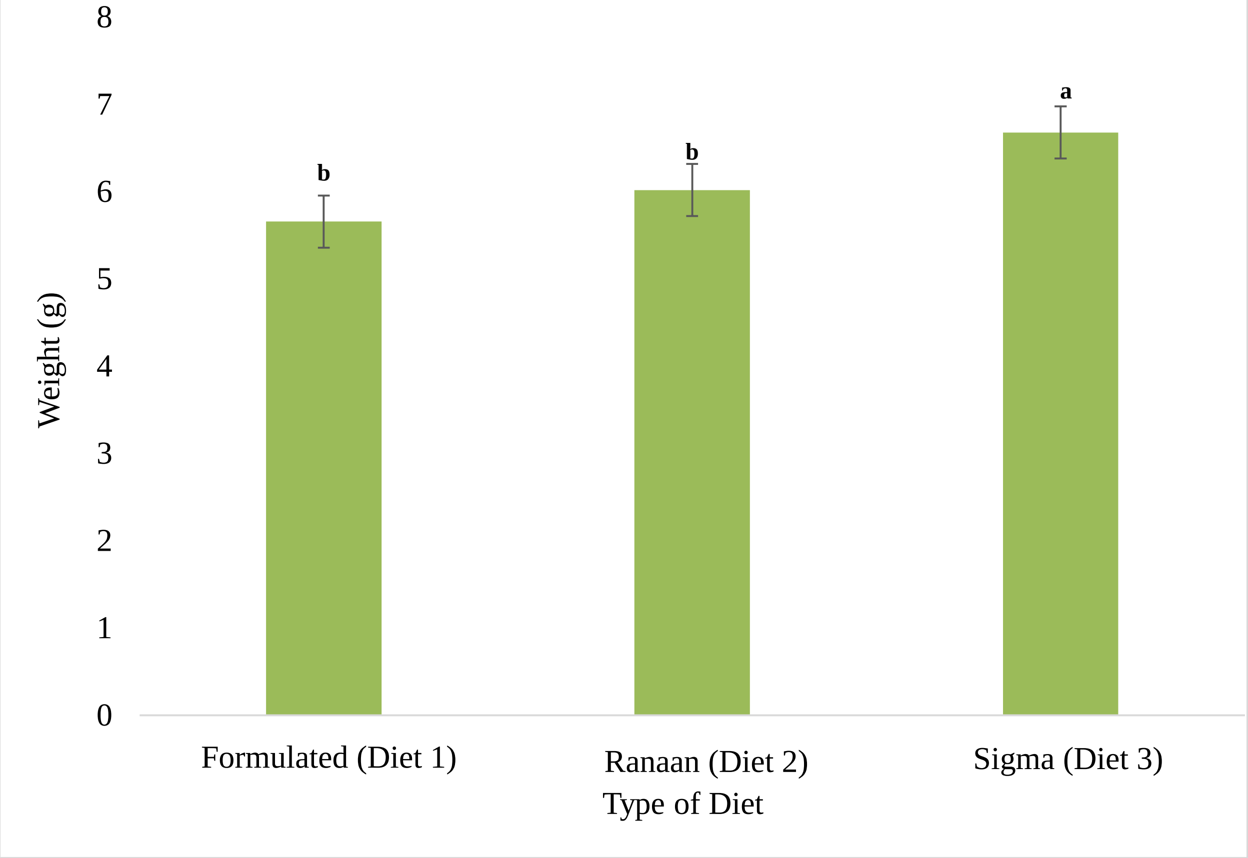

Figure 3:-Effect of diet on the weight of *O. jipe*.

Moreover, diet affected the growth of *O. jipe* with time. Both length and weight increased gradually with time regardless of the type of diet as shown in Figures 4 and 5 respectively.

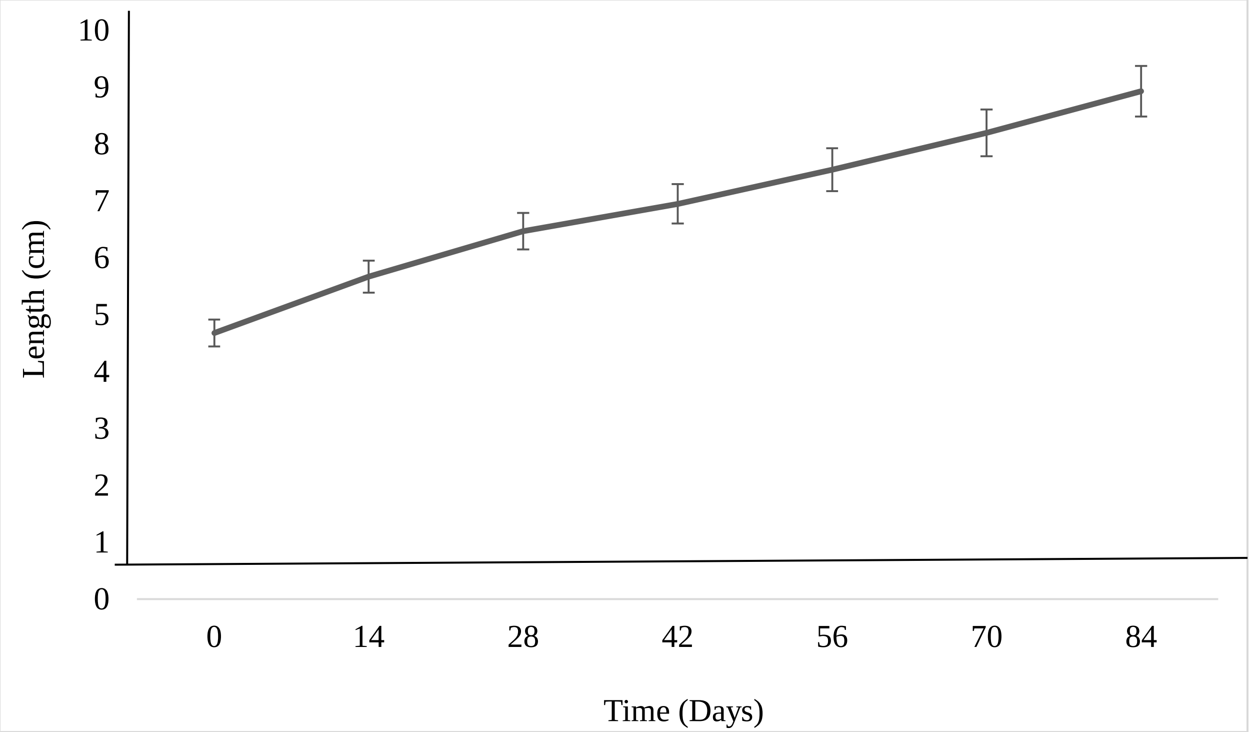

Figure 4:- Mean length (± SE) of *O. jipe* during the 84 days experiment.

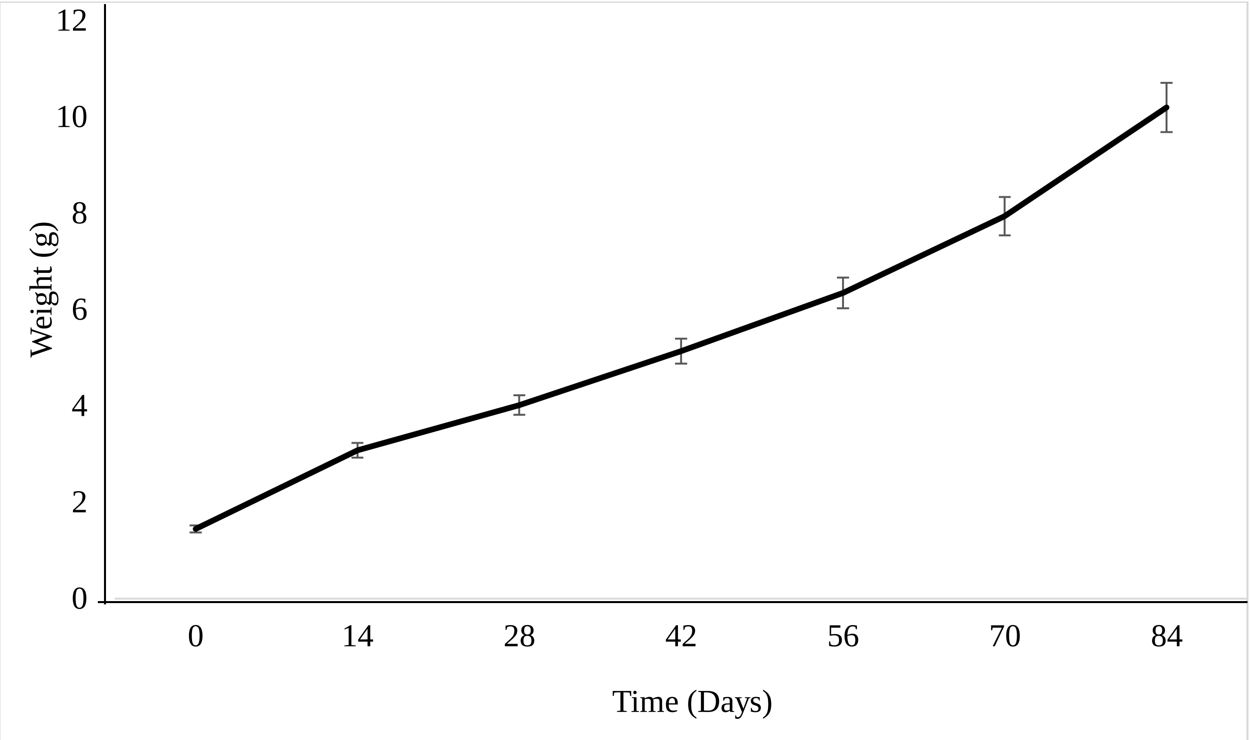

Figure 5:- Mean weight (± SE) of *O. jipe* during the 84 days experiment.

Furthermore, other growth performance parameters of *O. jipe* fed on different diets in terms of weight gain percent, specific growth rate (SGR%), percent survival, feed conversion ratio ratio(FCR) and condition factor (K) were also calculated (Table 3). Specific growth rate (SGR) was not significantly affected by the diet $p<0.05$ with the highest SGR (2.45 %) reported for diet 3 (Table 3). Diet led to increased growth rates and consequently increased growth performance. Diet also had no significant effect on percent weight gain $p<0.05$ and among the diets; diet 1 resulted to the lowest value of weight gain (522.30%) as shown in Table 3. Diet also did not significantly affect the FCR significantly $p<0.05$ with the highest FCR of 1.83 being recorded in the diet 3. Consequently, condition factor of the fish in different treatments ranged between $1.36^{c}\pm0.02$ and $1.49^{a}\pm0.02$. Both the lower value and highest values was recorded for fish fed on diet 3 in different stocking densities (Table 3). The percent survival of *O. jipe* at all the treatments was below 50 % (Table 3). Fish fed on diet 3 in stocking density 45 recorded lowest percent survivals of (14.07%) but it recorded the highest percent survival of (35.56%) in stocking density 30.The highest weight gain in diet 3 might be due to the fact that the fish received essential protein in the diet. The low weight gains in diets 1 and 2 might be due to the fact that the fish had received low protein in the feed. Diet 3 showing higher specific growth rate (SGR) than that of diets 2 and 1 has been shown in Table 3.

Effect of diet on survival of fish

From the present study, diet affected survival of *O. jipe* significantly at $p<0.05$ but not mortality. Diets 1 and 3 were not significantly different from each other with survivals of $13.56^{b}\pm1.02$ and $14.33^{b}\pm1.04$. Diet 2 was significantly higher in regard to survival $17.00^{a}\pm1.57$ compared to diets 1 and 3. On the other hand all the diets did not affect mortality significantly with diet 1 having $5.06^{a}\pm1.15$ followed by diets 3 and 2 with $5.25^{a}\pm1.25$ and $5.83^{a}\pm1.36$ respectively as shown in Figure 6 below.

Figure 6:- Graphs showing effect of diet on survival

Water quality parameters

The mean values of water physicochemical parameters during the experimental period are as shown in Tables 4 and 5. The pH values in the treatments ranged from 9.55 to 9.86 (Table 4). Stocking density had no significant effect at $p<0.05$ on the mean pH values with the highest value of 9.86 being recorded at stocking density 30 (Table 4). Diet also had no significant effect at $p<0.05$ on the pH values and no significant interaction $p<0.05$ between stocking density and diet was recorded for the pH values. Mean temperature values in all the diets were relatively equal and ranged from 25.67 to 26.27 (Table 4). Stocking density had no significant effect at $p<0.05$ on the temperature values and consequently no significant interaction $p<0.05$ was recorded between the stocking density and diet for temperature values. Mean conductivity values in all the diets were relatively equal and ranged from 53.17 to 54.83 (Table 4). Stocking density had no significant effect at $p<0.05$ on the conductivity values and consequently no significant interaction $p<0.05$ was recorded between the stocking density and diet for conductivity values. Mean TDS values in all the diets were relatively equal and ranged from 26.33 to 27.33 (Table 4). Stocking density had no significant effect at $p<0.05$ on the TDS values and consequently no significant interaction $p<0.05$ was recorded between the stocking density and diet for TDS values.

Table 4:-Mean physicochemical parameters (± S.E) monitored during the 84 days experiment.

HAPAS	STOCKING DENSITY	DIETS	PH	TEMPERATURE (°C)	CONDUCTIVITY (µS)	TDS (ppm)
1	30	3	9.70^{a}±0.42	26.13^{a}±0.56	54.67^{a}±0.99	27.00^{a}±0.52
2	30	2	9.55^{a}±0.37	26.12^{a}±0.53	54.00^{a}±0.77	26.83^{a}±0.48
3	30	1	9.69^{a}±0.28	26.05^{a}±0.54	53.83^{a}±0.87	26.83^{a}±0.48
4	30	3	9.59^{a}±0.36	25.90^{a}±0.52	54.83^{a}±1.17	27.33^{a}±0.61
5	30	2	9.57^{a}±0.37	25.90^{a}±0.56	53.67^{a}±0.76	26.83^{a}±0.40
6	30	1	9.77^{a}±0.26	26.02^{a}±0.52	54.00^{a}±0.86	26.83^{a}±0.40
7	30	3	9.76^{a}±0.27	25.95^{a}±0.54	53.83^{a}±0.79	26.67^{a}±0.33
8	30	2	9.78^{a}±0.25	25.93^{a}±0.56	53.50^{a}±0.67	26.50^{a}±0.34
9	30	1	9.86^{a}±0.24	25.88^{a}±0.59	54.17^{a}±1.01	26.83^{a}±0.48
10	45	3	9.58^{a}±0.38	25.73^{a}±0.54	54.17^{a}±0.95	26.83^{a}±0.40
11	45	2	9.56^{a}±0.38	25.67^{a}±0.53	54.17^{a}±0.79	26.67^{a}±0.33
12	45	1	9.65^{a}±0.37	25.85^{a}±0.55	53.83^{a}±1.14	26.67^{a}±0.49
13	45	3	9.63^{a}±0.33	25.82^{a}±0.57	53.83^{a}±0.57	26.83^{a}±0.40
14	45	2	9.55^{a}±0.38	25.88^{a}±0.55	53.83^{a}±0.79	26.67^{a}±0.33
15	45	1	9.56^{a}±0.28	25.95^{a}±0.54	53.67^{a}±0.67	26.67^{a}±0.33
16	45	3	9.76^{a}±0.27	25.95^{a}±0.50	53.17^{a}±0.79	26.33^{a}±0.33
17	45	2	9.55^{a}±0.34	26.08^{a}±0.55	53.50^{a}±0.56	26.50^{a}±0.22
18	45	1	9.68^{a}±0.28	26.27^{a}±0.59	53.67^{a}±0.76	26.50^{a}±0.34

Means with same letters along the column per water quality parameter were not significantly different ($p<0.05$) as determined by analysis of variance and Tukey's HSD comparison of mean values over culture period.

Table 5:-Effect of diet on the water quality parameters of the culture facilities

Diet	Ammonia (mg/L)	Nitrite (mg/L)	Phosphate (mg/L)
1	0.17^{a}±0.04	0.44^{a}±0.17	0.11^{a}±0.03
2	0.20^{a}±0.05	0.27^{a}±0.03	0.16^{a}±0.05
3	0.22^{a}±0.06	0.28^{a}±0.03	0.19^{a}±0.10

Means with same letters along the column per water quality parameter were not significantly different ($p<0.05$) as determined by analysis of variance and Tukey's HSD comparison of mean values over culture period.

Table 6:-Effect of stocking density on the water quality parameters of the culture facilities

Stocking density	Ammonia (mg/L)	Nitrite (mg/L)	Phosphate (mg/L)
30	0.19^{a}±0.04	0.27^{a}±0.03	0.13^{a}±0.04
45	0.20^{a}±0.04	0.39^{a}±0.11	0.17^{a}±0.07

Means with same letters along the column per water quality parameter were not significantly different ($p<0.05$) as determined by analysis of variance and Tukey's HSD comparison of mean values over culture period.

Table 7:-Interaction effect of stocking density and diet on the water quality parameters of the culture facilities

Diet	Stocking density	Ammonia (mg/L)	Nitrite (mg/L)	Phosphate (mg/L)
1	30	0.13^{a}±0.04	0.25^{a}±0.04	0.09^{a}±0.04
	45	0.20^{a}±0.07	0.64^{a}±0.32	0.12^{a}±0.06
2	30	0.22^{a}±0.08	0.29^{a}±0.05	0.20^{a}±0.09
	45	0.18^{a}±0.06	0.26^{a}±0.03	0.12^{a}±0.04
3	30	0.21^{a}±0.08	0.27^{a}±0.04	0.11^{a}±0.06
	45	0.23^{a}±0.09	0.28^{a}±0.04	0.27^{a}±0.19

Means with same letters along the column per water quality parameter were not significantly different (p<0.05) as determined by analysis of variance and Tukey's HSD comparison of mean values over culture period.

There was no significant difference p<0.05 in ammonia between the stocking densities with the highest ammonia value of 0.23 mg/L being recorded at stocking density 45. Diet had no significant effect p<0.05 on the ammonia values and therefore ammonia values were relatively low at all the diets in each stocking density. Consequently, there was no significant interaction p<0.05 between diet and stocking density for ammonia values. Mean values of nitrites were also low in all the treatments except for diet 1 stocking density 45 which was above recommended range of 0.5 mg/L. This could be due to dead individuals decomposing in the hapa. However, there was no significant effect p<0.05 of stocking density on nitrite values and no significant effect p<0.05 was recorded for the diets on the nitrite values and therefore, no significant interaction p<0.05 was recorded between the stocking density and diet for nitrite values. The Mean values of phosphates were also relatively low in all the treatments. There was no significant effect p<0.05 of stocking density on phosphate values and no significant effect was recorded for the diets p<0.05 on the phosphate values and therefore, no significant interaction p<0.05 was recorded between the stocking density and diet for phosphate values.

Discussion:-

The fish growth trend in this study, indicate that there was uniform growth pattern in length and weight during the culture period. This could be attributed to the fact that fingerlings were previously well acclimated to the rearing conditions. According to (Rakocy, 1989), growth performance of *O. niloticus* is dependent on water quality parameters such as temperature, pH and ammonia, food quality, energy content of the diet, its physiological status, reproductive state and stocking density. According to Jobbling and Baardvik (1994), environmental factors affecting feeding behavior or energy expenditure vary with fish stocking density. It is further documented by Boujard *et al*. (2002) that it is difficult to set food accessibility identical for each fish when density is increased, a contributing factor to fish appetite.

In the present study on *O. jipe*, stocking density did not affect the mean body weight, length, SGR, weight gain and FCR of the experimental fish. These results contradict earlier studies on *O. niloticus* (Huang and Chiu 1997; Irwin *et al*., 1999; Petit *et al*., 2001) where stocking density was noted to negatively affect the mean body weight, final mean total length, SGR and weight gain of *O. niloticus*. The relationship between stocking density and growth observed on *O. jipe* fingerlings in this study contradict findings reported on the *O. niloticus* (Yi *et al*., 1996; Huang and Chiu *et al*., 1997; El-sayed, 2002; Abou *et al*., 2007, Muangkeow *et al*., 2007; Gibtan *et al*., 2008) who observed a negative relationship between stocking density and growth on *O. niloticus*.

Studies show that reduced growth of fish at high stocking density can also be related to space limitation. The same results have been reported by (El-sayed, 2002; Yan *et al*., 2002 and Abou *et al*., 2007). This is not in agreement with the present study on *O. jipe* because almost similar growth was recorded for both stocking densities. This scenario could be as a result of reduced number of fish in all the hapas hence there was no space limitation and competition for food. In the study by Huang and Chiu (2007), they explained that tilapia is a very aggressive fish and the stocking density effect on growth performance might be expressed by their competition for territories as well as the permanent stress caused by crowding (Ellis *et al., 2002*). The results on *O. jipe* also disagree with report by Ruane *et al*. (2002) and Sahoo *et al*. (2004) that high densities result in difficulties for fish to reach the food thus insufficient acquisition of food which lead to reduced feeding rate by individual fish.

The ability of the fish to convert feed given to biomass (FCR) was not significantly affected with stocking density as reported by Osofero *et al*. (2009). This could be explained by the fact that during the study period, a lot of mortalities occurred thus striking a balance among the population in all the hapas. This could mean that the few individuals utilized the food thus bringing indifference with the *O. niloticus* authors and thereby suggesting that lower stocking density does not necessarily affect FCR. The FCR obtained in this study range between 1.08 and 1.83. The insignificant (p<0.05) differences among the diets imply that stocking densities of *O. jipe* have no apparent effect on the SGR of the fish. The results of SGR in this study are higher than those obtained on other studies. Studies by Iluyemiet *et al*. (2010) reported SGR of range 0.77 to 1.49 % and that of Attipoe *et al*. (2009) with SGR range of 0.43 to 0.53. Previous study by Osofero *et al*. (2009) on effect of stocking density on growth and survival of *O. niloticus*, reported an inverse relationship between survival rate and stocking density. This report completely agrees with the current study on *O. jipe*.

This assertion on *O. jipe* also contradicts a study by Yousif (2002) who reported that it is a generally accepted principle that increasing fish density will adversely affect fish growth. In that study, the initial fish size was homogenous and the daily supplies of food were adequate hence expecting that the fish within each population or treatment would have slightly different final body sizes. However, in this study, although the initial fish size was heterogeneous for all the treatment, the stocking density had no effect on the final size among individuals of initially non-uniform size. This also could be attributed to the fact that in both stocking densities, there were mortalities in all hapas hence striking a balance in the population present. These results on *O. jipe* is contrary to the study by Aksungur *et al*. (2007) which indicated that social interactions through competition for space and food can negatively affect fish growth. Moreover, from that study, higher stocking densities led to increased stress and that increase in energy requirements caused a reduction in growth rate and food utilization.

In the present study, 47.3% of the current study observations on survival were due to experimental factors (diet, stocking density and time) whereas 52.7% could be due to factors I couldn't account for. Survival of *O. jipe* was not density dependent and no significant differences were recorded for the two stocking densities tested. These results are consistent with the findings of Abou *et al*. (2007) and Yi *et al*. (1996); but contradicts the findings of Szkudlarek and Zakes (2007), Huang and Chiu (1997) and Ellis *et al*. (2002) who recorded a negative relationship between fish survival with stocking density.

The higher SGR values may also be due to the high amount of energy content in the feed. According to study by Ogunji *et al.* (2007), they worked on 4-5 g fingerlings and reported SGR value of 3.39 at the dietary protein content of 33.32 %. The mean feed conversion ratio (FCR) of different experimental diets ranged between 1.08 and 1.83 (Table 3). The significantly ($p<0.05$) lowest FCR 1.08 was found in diet 3 stocking density 30 while the highest 1.83 was obtained in diet 3 stocking density 45. This range would slightly agree with that reported by El-Dakar *et al*. (2008) who reported a range of 0.99 to 1.17 for Florida Red Tilapia fed on Fig jam by-product (FJB). The FCR range in this current study is slightly good because it is close to the recommended FCR of 1.5 for aquaculture (Stickney, 1979). But they are much lower compared to *O. niloticus* fed on a commercially prepared diet in a study by Siddiqui*et al*. (1991) who reported FCR values ranging from 3.7 to 4.9 and Liti*et al*. (2006) who reported FCR for *O. niloticus* and *C. gariepinus* to range between 3.40 and 4.04 respectively.

The extreme variation could be as a result of differences in the kind of species used, environmental conditions and feed sources. This notation is in agreement with Guimaraes *et al*. (2008) that efficient utilization of diets may vary within a single species because of the environmental conditions and the kind of fish used. From this study, the FCR values could be attributed to the type of fish species and the prevalent environmental conditions of the study area. In this study there was significant interaction $p<0.05$ of diet and stocking density on the condition factor (K). The mean condition factor for the *O. jipe* was between $1.36^{c}\pm0.02$ and $1.49^{a}\pm0.02$. This finding indicates that the fish were above average in terms of condition. The condition factor higher than one indicates an isometric growth and suggests good fish health condition, which is desirable in a fish farm (Ayode, 2011).

The survival rate varied from 14.07 to 35.56 in different diets (Table 3). Maximum survival was found on fish fed on diet 2. Survival rate as high as 98 % was found in *O. niloticus* reared in pond by Michael and Jian (2002). On the other hand Sumi (2011) found a survival rate of 94 % by feeding 36% protein diet based on fish meal. This is not the case with the current study on *O. jipe* where a survival rate of less than 50% was recorded. Very low survival at the start of the experiment (Figure 2) could be attributed to low water levels during the early stages hence increased stress. Furthermore, uneaten food in the hapas might have increased ammonia levels hence resulting to more mortality. However, survival still remained low even after the water levels were checked. This scenario could be as a result of the low resilience of *O. jipe* to any slight stress especially during sampling periods. This contradicts the findings of Sherif and El-Feky (2009) who reported that higher (100%) survival rates could be associated to favorable ecological conditions.

From the present study on *O. jipe*, water quality was not affected by stocking density and diet. Only in nitrite value at stocking density 45, diet 1 was there a high value of 0.64 mg/L. This could be as a result of dead individuals decomposing in the hapa or it could be as a result of increased fish biomass in the hapa. The result on nitrite contradicts study by Santhosh and Singh (2007) who recommended that nitrite concentration in water should not exceed 0.5 mg/L. However, all other concentrations were less than 0.5 mg/L which is the recommended tolerable range for survival and production of tilapia in ponds.

Conclusion:-

This study reveals that interactive effect of stocking density and diet do not considerably affect growth performance of *O. jipe* in terms of mean weight, percent weight gain, SGR and FCR. However, the two interacting factors affect mean length, survival and condition factor (K). Since there was no significant difference on mean weight and length from both stocking densities, it can be concluded that stocking density does not affect growth of *O. jipe*. However, highest stocking density registered the lowest survival and therefore imperative that the *O. jipe* survival is sensitive to stocking density. It was also demonstrated that *O. jipe* growth performance in terms of mean length and weight was highest in diet 3 (Sigma feeds) with CP content of 35%. Therefore, it can be concluded that diet 3 (35% CP) is most suitable for hapa-pond-system culture of *O. jipe* regardless of stocking density.

Acknowledgement:-

Special thanks to KMFRI fraternity for the support they accorded me during my research work.

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