



Linear Vitamin A Requirements for Maternal Health and Reproductive Performance in African Catfish (*Clarias gariepinus*)

Godswill Okure¹ , Imefon Udo^{1*}  and Ofonime Afia¹ 

¹Department of Fisheries and Aquatic Environmental Management, University of Uyo, Uyo, 520103, Akwa Ibom State, Nigeria

*Correspondence :
dorime_2004@yahoo.com

Received : 2024-10-11

Accepted : 2025-07-27

Keywords :
Growth, Fortification, Maternal,
Catfish

Abstract

A 180-day feeding experiment was conducted in three phases of sixty (60 days each, designated as F0, F1, and F2. The preliminary phase was conducted to detoxify the brood fish of cellular VA. The second and third phases were conducted to assess the first and second spawning seasons. During the preliminary phase, experimental fish were fed with the basal diet thrice a day with three percent fresh body weight to detoxify the fish of residual Vitamin A. A two-generation (F1 and F2) feeding trial evaluated the impact of graded vitamin A supplementation levels on broodstock performance. Three replicate groups of 20 fish (initial weight: 1.60 ± 0.38 kg) were fed one of five isocaloric and isonitrogenous diets, containing 0, 1666, 3332, 6664, or 13,328 IU/kg of vitamin A, at three meals per day. Growth performance, feed utilization, and Survival rate all improved with increased levels of VA and were significantly better ($P < 0.05$) in F2. Mean GSI, HSI, total fecundity, and relative fecundity. Signs of vitamin A deficiency, including growth retardation and suboptimal feed conversion, were evident in fish receiving the unsupplemented diet (0 IU kg⁻¹). Fortification of the broodstock fish diet of *C. gariepinus* and maternal age resulted in improved reproductive performance. The aquaculture industry should formulate broodstock rations with 13,328 IU kg⁻¹ diet of VA inclusion and select mature female broodstock for artificial breeding.

INTRODUCTION

Vitamin A (retinol) is a crucial dietary component for fish, supporting various physiological functions such as vision, reproductive health, embryonic development, growth, cellular differentiation, and epithelial tissue maintenance (Hernandez and Hardy, 2020). In broodfish, vitamin A supplementation enhances reproductive performance by boosting fertilization rates, increasing fecundity, supporting healthy embryo

development, and improving larval viability and quality (Bilguven, 2014). Fish rely solely on dietary sources for vitamin A, as they do not possess the necessary enzymes for its synthesis. Vitamin A is also known to be heat-labile and is easily destroyed by heat during extrusion feed production, thereby making the vitamins unavailable to fish. Recognizing that high-quality fish fry is crucial for a successful fish business, and that the health and performance of farmed fish

are largely determined by their genetic foundation, broodstock feeds must be meticulously formulated and manufactured to fulfill all essential nutrient requirements.

The African catfish (*Clarias gariepinus*) is a highly prized food fish species in Nigeria, sought after by consumers and preferred by aquaculturists. Its desirable characteristics, including rapid growth rates at high stocking densities, efficient feed conversion, superior meat quality, and favourable smoking properties, make it an ideal species for year-round production. The culture of African catfish (*C. gariepinus*) plays a vital role in Nigeria's economy, serving as a major source of food, employment, and export revenue. The economic benefits include the provision of employment opportunities for many Nigerians, contributing significantly to the country's GDP and generating revenue through exports. Nutritional benefits include a rich source of protein, which helps combat malnutrition. Environmental benefits include the utilization of unused land and water resources. Additional advantages are adaptability to various temperatures, oxygen levels, and salinity; quick maturation, making it a sustainable option in the face of climate change (Akinwole and Faturoti, 2007).

African catfish culture comprises three distinct phases: Larval Rearing (12-14 days, 0-0.5 g), Nursery (0.5-10 g), Grow-out (10-1000 g). Each phase corresponds to specific developmental stages and size classes tailored to various fish species. After the last stage, the culturist may decide to go into broodstock management for a sustainable supply of viable fish seeds. Studies by Moren *et al.* (2004) and Hu *et al.* (2006) demonstrate that finfish and crustaceans have a high demand for Vitamin A. Research by Wilson and Moreau (1996) indicates that African catfish require 1000-2000 IU/kg of vitamin A during the nursery phase (0.5-10 g). Additionally, Udo (2017) found that optimal vitamin A levels for growth performance in grow-out phase catfish (IBW 15.9 ± 0.27 g) are 1666 IU/kg, while 833 IU/kg supports efficient feed conversion,

protein efficiency, and survival. However, the VA requirement for the broodstock is yet to be determined for effective management.

This study aims to fill the knowledge gap regarding vitamin A requirements for broodstock, specifically for reproductive performance in *C. gariepinus*.

METHODOLOGY

Ethical Approval

Ethical approval was obtained by the Dean, Faculty of Agriculture, based on the recommendation of the Institutional Animal Care and Use Committee (IACUC).

Place and Time

The study was conducted between April and October 2023 at the University of Uyo's Fish Farm Hatchery Complex, Department of Fisheries and Aquatic Environmental Management, located in southeastern Nigeria (5.0408° N, 7.9198° E).

Research Materials

The following materials were utilized: fresh palm oil (PAMOL, Calabar, Nigeria); toasted soybean meal (Uyo, Nigeria); locally produced fishmeal from *Ethmalosa fimbriata* (Uyo, Nigeria); milled feed ingredients (Uyo, Nigeria); iodized salt (Dangote, Nigeria); Vitamin A supplements (Korea United Pharm. Inc., South Korea); and a digital balance (Model TD6002A, 0.01g readability, USA).

Research Design

The study was conducted in fifteen concrete tanks (rectangular) of 18.11 m with water depth and volume of 2.1 m and 14.41 m³, respectively. The tanks were arranged in triplicate and designated as A1, A2, A3, B1, B2, B3, C1, C2, C3, D1, D2, D3, and E1, E2, E3, giving a completely randomized design (CRD) of five (5) treatments and three (3) replicates. Treatment 1 (T1), 2 (T2), 3 (T3), 4 (T4), and 5 (T5) received 0, 1666 3332, 6664, and 13,328 IU Kg⁻¹Retinol and were designated as NoRE (no retinol), 1666RE, 3332RE, 6664RE, and 13328RE.

Work Procedure

The ingredients were processed at the University of Uyo's fish farm complex through the following steps: toasting soybeans until brown, removing chaff, and grinding into powder. Fishmeal, white maize, and palm kernel cake were ground into homogeneous fine particles. These were then analyzed for biochemical composition (AOAC, 1995). Nitrogen-free extract was calculated using the formula:

$$\%NFE = 100\% - (\%EE + \%CP + \%Ash + \%CF)$$

Where

NFE=nitrogen free extract

EE=ether extract

CP=crude protein

CF=crude fibre

The digestible energy content of ingredients and experimental diets was predicted from the Table ir proximate composition (Table 1) as follows:

Table 1. Biochemical composition and caloric value of the feed ingredients used in this experiment.

Ingredient	Content (%)							(Kcal kg ⁻¹ DM)			
	DM	NFE	EE	CP	CF	Ash	LS	MT	P	Ca	DE
FM	91.12	16.32	5.78	52.89	3.11	21.90	4.85	2.62	2.89	5.14	2861.00
PKC	91.6	56.60	8.90	20.40	9.0	5.70	0.75	0.94	0.60	0.30	3137.00
SBM	88.50	31.33	3.50	88.50	6.50	5.67	2.80	0.60	0.20	0.20	2230.00
WMM	88.51	76.59	3.20	7.31	2.00	0.51	0.30	0.18	0.09	0.01	3432.00

FM=fishmeal; PKC=palm kernel cake; SBM=soybean meal; WMM=white maize meal; DM=dry matter; NFE=nitrogen free extract; EE=ether extract; CP=crude protein; CF=crude fibre; LS=lysine; MT=methionine; P=phosphorus; Ca=calcium; DE=digestible energy.

DE(kcal kg⁻¹ dry matter)

$$= -236 + 48.5 \times CP - 6.7 \times CF + 37.5 \times NFE + 90.1 \times EE$$

NFE=nitrogen free extract

EE=ether extract

Where

DE=Digestible energy

CF=crude fibre

Diets were formulated on a dry matter basis by linear programming technique using Winfeed 2.8 (Table 2).

Table 2. Ingredients and nutrient compositions of the experimental diets.

Ingredient (%)	Experimental treatment				
	VAD00	VAD1666	VAD3332	VAD 6664	VAD13328
Proximate composition					
Fish oil	2.00	2.00	2.00	2.00	2.00
Fishmeal	10.0	10.0	10.0	10.0	10.0
Palm kernel cake	4.50	4.50	4.50	4.50	4.50
Sodium chloride	0.50	0.50	0.50	0.50	0.50
Soybean meal	23.0	23.0	23.0	23.0	23.0
Vitamin A (IU)	0.0	0.0	0.0	0.0	0.0
White maize meal	60.0	60.0	60.0	60.0	60.0
Nutrient composition (%)					
Ash	4.41	4.41	4.41	4.41	4.41
Calcium	0.63	0.63	0.63	0.63	0.63
Crude fibre	3.73	3.73	3.73	3.73	3.73
Crude protein	40.0	40	40	40	40
Digestible energy	3476.23	3476.23	3476.23	3476.23	3476.23
Ether extract	4.09	4.09	4.09	4.09	4.09
Methionine	1.51	1.51	1.51	1.51	1.51
NFE	67.17	67.17	67.17	67.17	67.17
Phosphorus	0.45	0.45	0.45	0.45	0.45

The ingredients were accurately measured using a Camry kitchen weighing balance and thoroughly mixed. Cassava starch (5%) was added as a binder, followed by the gradual addition of hot water, with continuous mixing to ensure uniformity. After 10 minutes, the dough was pelleted using a 6 mm die ring manual pelletizer and dried completely. A vitamin A solution (100 mg/0.25 L liquid hexane) was applied to the pellets based on treatment specifications. The diets were then air-dried for 15 minutes and sealed in black polythene bags for storage.

For this study, 20 adult female *C. gariepinus* (mean weight: 1.60 ± 0.01 kg) were collected from the University of Uyo fish farm's Hatchery Complex and distributed into five treatment groups. Additionally, 300 male *C. gariepinus* were reared in 15 separate tanks for breeding purposes. Before experimentation, the fish underwent a 7-day acclimation period with ad libitum feeding twice daily using 6 mm ECOFLOAT commercial pellets. Following a 24-hour starvation period, initial biometric parameters were measured. Feeding was done at three percent (3%) fresh body weight thrice daily at 8:00, 12:00, and 18:00 hours. Feeding for the first 60 days was done with the basal diet (control diet), which was poor in VA to reduce body VA content and to ensure that the fish were well matured. Afterward, they were fed for 60 days (1st half) and another 60 days (2nd half) with the experimental diets at the same interval as the first 60 days.

At the end of feeding trials, 150 gravid females were collected from the experimental treatments, and the whole ovaries and liver were excised, and their weights were recorded.

Growth performance was assessed using the following parameters:

$$\text{Daily Weight Gain (DWG, g)} = \frac{(\text{Final weight} - \text{Initial weight})}{\text{Number of days}}$$

$$\text{Specific Growth Rate (SGR, \%/day)} = \frac{(\ln \text{ Final body weight} - \ln \text{ Initial weight})}{\text{Number of days}} \times 100$$

$$\text{Feed Conversion Ratio (FCR)} = \frac{\text{Dry feed weight (g)}}{\text{Weight gain (g) fish harvested}}$$

$$\text{Survival Rate (SR)} = \frac{\text{initial stock}}{\text{fish harvested}} \times 100$$

Protein Efficiency Ratio (PER): ratio of weight gain to protein intake.

The reproductive and liver health of the fish were evaluated using the following indices:

$$\text{Gonadosomatic Index (GSI)} = \frac{\text{Gonad weight}}{\text{Body weight}} \times 100$$

$$\text{Hepatosomatic Index (HSI)} = \frac{\text{Liver weight}}{\text{Somatic weight}} \times 100$$

Fecundity was determined following the method described by Eyo *et al.* (2013). The collected ova were washed with distilled water, weighed to the nearest 0.01 g, and preserved according to Qadri *et al.* (2015). Subsamples were evenly distributed on a counting slide with a few drops of water, and the number of mature ova was counted. The average count of three subsamples was used as follows: Fecundity metrics were calculated as follows:

$$\text{Absolute Fecundity (AF)} = \frac{\text{Number of ova in subsample} \times \text{Total ovary weight}}{\text{Weight of subsample}}$$

$$\text{Relative Fecundity (RF)} = \frac{\text{Absolute Fecundity}}{\text{Total body weight of fish}}$$

Egg diameter measurements were taken from 30 oocytes per fish, with the mean diameter of pear-shaped eggs calculated from both long and short axes. For the breeding trial, 150 brood fish were used to select suitable male and female *C. gariepinus* donors. Selection criteria included females with fatty and tender stomachs and males with swollen urogenital papillae.

Water quality parameters were assessed using the following instruments: Ammonia: test kit, pH: Hanna pHep pocket-sized pH meter, Dissolved Oxygen (DO): DO meter, and Temperature: mercury-in-glass thermometer.

Data Analysis

Data were analyzed using ANOVA, and significant effects ($P < 0.05$) were further explored using Duncan's multiple range test,

conducted with the aid of IBM SPSS Version 21 statistical software.

RESULTS AND DISCUSSIONS

The physicochemical parameters are shown in Table 3. These values fell within the optimal range suggested for freshwater fish culture in tropical regions, as recommended by Nnanji *et al.* (2010).

Table 3. Water quality parameters (mean±SD) during the 180-day culture period.

Parameters	Experimental Treatment					Opt.
	VAD00	VAD1666	VAD3332	VAD6664	VAD13328	
NH ₃ (mg l ⁻¹)	0.02±0.01	0.03±0.11	0.03±0.13	0.03±0.01	0.02±0.01	0.02–0.05
DO (mg l ⁻¹)	5.44±0.24	5.65±1.22	5.72±1.22	5.43±1.30	5.14±2.10	≥5.00
M. Temp. (°C)	23.4±1.22	23.9±3.22	23.4±2.16	23.9±1.19	24.4±2.33	23–32
pH	7.34±1.12	7.21±2.16	7.41±2.44	7.21±2.16	7.83±1.12	6.5–9.0

NH₃ = ammonia; DO = Dissolved oxygen; M. Temperature = Morning Temperature; Opt. = Optimum.

The growth response and nutrient utilization of *C. gariepinus* fed experimental diets are presented in Table 4. Diet VAD13328 yielded the highest final mean weight, with a statistically significant difference ($P < 0.05$), and a trend of increasing weight gain with escalating inclusion levels. This was an indication of improved growth as a result of VA supplementation. The diets VAD3332 and VAD13328 yielded the highest daily weight gain (DWG), whereas the control diet (VAD00) resulted in the lowest DWG. Specific Growth Rate followed the same pattern. Significant differences ($p < 0.05$) emerged in FCR and PER among the diets. Diets VAD1666 and VAD6664 displayed higher FCR values, whereas diet 13328 RE exhibited improved feed efficiency.

Conversely, diet VAD1666 demonstrated superior PER, while diet VAD13328 showed reduced protein utilization efficiency. Diet VAD3332 exhibited a significantly higher survival rate, whereas diet VAD1666 showed a lower survival rate ($P < 0.05$). Studies by Udo *et al.* (2011) and Zhang *et al.* (2017) have shown that adequate Vitamin A supplementation can improve fish growth performance, including body weight, weight gain, and feed intake. In contrast, VA deficiency in our control group (VAD00) resulted in retarded growth, inefficient feed utilization, and morphological abnormalities. According to Yang and Kallio (2002), Vitamin A deficiency in fish can manifest as reduced weight gain, specific growth rate, and impaired feed utilization.

Table 4. Growth and feed utilization responses of *C. gariepinus* broodstock to different dietary regimens over a 6-month (180-day) experimental period.

Growth Parameter	Experimental diets (%)				
	VAD00	VAD1666	VAD3332	VAD6664	VAD13328
Growth performance					
IMW (kg)	1.58 ± 1.61 ^a	1.60 ± 0.38 ^a	1.59 ± 0.21 ^a	1.61 ± 0.22 ^a	1.60 ± 0.02 ^a
FMW (kg)	2.72 ± 0.32 ^a	3.13 ± 0.18 ^b	4.31 ± 0.24 ^d	3.40 ± 0.21 ^c	5.58 ± 0.26 ^e
DWG (kg fish ⁻¹)	0.01 ± 0.00 ^a	0.01 ± 0.00 ^a	0.02 ± 0.00 ^b	0.01 ± 0.00 ^a	0.02 ± 0.00 ^b
SGR	0.20 ± 0.00 ^a	0.37 ± 0.01 ^b	0.56 ± 0.00 ^d	0.41 ± 0.00 ^c	0.69 ± 0.02 ^e
Feed utilization					
FCR	1.82 ± 0.14 ^c	1.98 ± 0.05 ^d	1.31 ± 0.31 ^b	1.98 ± 0.05 ^d	1.28 ± 0.02 ^a
PER	1.23 ± 0.15 ^b	1.45 ± 0.261 ^d	1.24 ± 0.282 ^c	1.24 ± 0.282 ^c	1.14 ± 0.22 ^a
Survival rate	98.3 ± 5.82 ^d	94.6 ± 3.51 ^a	98.6 ± 4.43 ^e	96.8 ± 4.74 ^b	97.8 ± 4.74 ^c

^{abc} Means in the same row with different superscript letters are significantly different at P < 0.05; IMW = Initial mean weight; FMW = Final Mean Weight; DWG = Daily weight gain; SGR = Specific Growth Rate; FCR = Feed Conversion Ratio; PER = Protein Efficiency Ratio

The mean GSI for *C. gariepinus* females is presented in Table 5, while the differences between first (F1) and second (F2) spawning seasons are presented in Fig. 1. This was significantly (P<0.05) higher in diet VAD13328 and F2 (60) and significantly

lower in diet VAD1666 and F1 (60). Hussein *et al.* (2021) reported that all the doses of vitamin A did not affect the GSI of *O. Niloticus*. The disparity was because in this study, the broodstock of *C. gariepinus* was used.

Table 5. Average Reproductive Performance of Female African Catfish (*Clarias gariepinus*) Fed Diets with Different Vitamin A Levels (Sample Size: 60 per Treatment).

Reproductive parameters	Experimental Treatments (Vitamin A IU kg ⁻¹)				
	VAD00	VAD1666	VAD3332	VAD6664	VAD13328
Gonadosomatic index (%)	14.03 ± 1.56 ^d	6.08 ± 1.03 ^a	13.71 ± 2.91 ^c	9.21 ± 1.25 ^b	18.54 ± 3.12 ^e
Hepatosomatic index (%)	0.90 ± 0.21 ^c	0.53 ± 0.02 ^a	0.65 ± 0.16 ^b	1.18 ± 0.03 ^d	1.52 ± 0.05 ^e
Total fecundity	26227 ^a	35345 ^b	45500 ^c	62897 ^d	85250 ^e
Relative fecundity	9.64 ± 1.03 ^a	11.29 ± 2.02 ^c	11.25 ± 0.33 ^b	18.5 ± 3.21 ^e	15.28 ± 2.54 ^d
Egg diameter (mm)	1.65 ± 0.17 ^b	1.55 ± 0.02 ^a	2.20 ± 0.06 ^c	2.40 ± 0.13 ^d	2.50 ± 0.14 ^e

Values are mean±standard deviation. Values with the same superscript letters are not significantly different. Ns=not significant.

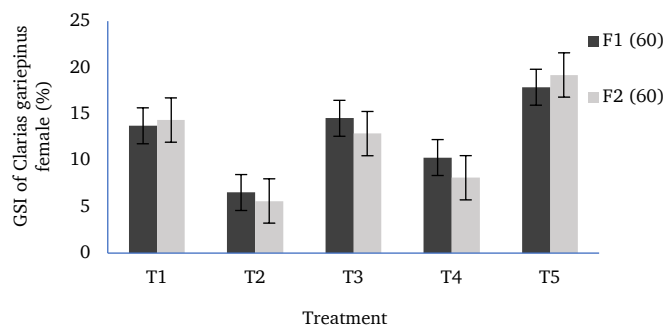


Figure 1. Mean final Gonadosomatic index (GSI) for females *Clarias gariepinus* (Error bar=SEM).

The mean final Hepatosomatic index (HSI) for *C. gariepinus* females is presented in Table 5, while the differences between the first F1 (60) and second (F2) spawning seasons are presented in Fig. 2. The mean HSI was significantly ($P<0.05$) higher in diet

VAD13328 and significantly lower in diet VAD1666. The HSI for F2 (60) was significantly ($P<0.05$) higher than F1 (60). This is in agreement with Wu *et al.* (2016), who stated that as the VA level increased, HSI increased significantly.

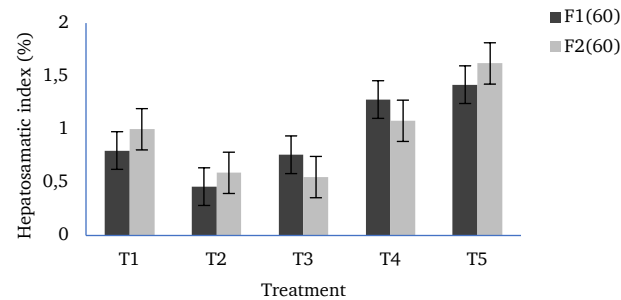


Figure 2. Hepatosomatic index (HSI) for female *Clarias gariepinus*.

The effect of Supplementation of Vitamin A on the total fecundity of African Catfish (*C. gariepinus*) Broodstock is presented in Table 5, and the F1(60) and F2 (60) are presented in Fig. 3. Total fecundity increased with an increase in concentration of Vitamin A. Each treatment mean was significantly higher ($p<0.05$) than the one before. Total fecundity in F2 (60) was

significantly higher ($p<0.05$) F1 (60). This is in agreement with Bilguven (2014), who found that fish fed an increased amount of VA had increased fecundity in rainbow trout, but disagrees with Serezli *et al.* (2010), who reported that total and relative fecundity were not affected by VA inclusion in diets either positively or negatively in salmonids.

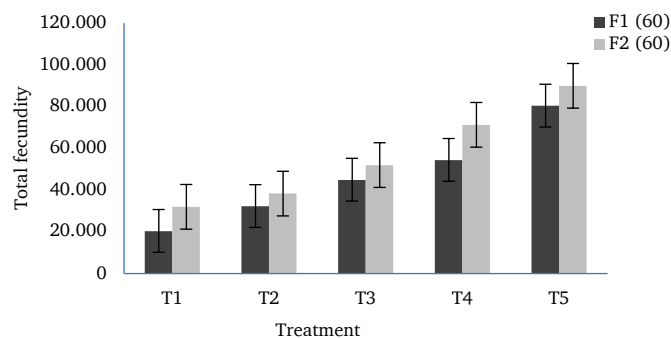


Figure 3. Total fecundity of females *Clarias gariepinus*.

The effect of Supplementation of Vitamin A on the relative fecundity of African Catfish (*C. gariepinus*) broodstock is presented in Table 5, and the difference

between F1 (60) and F2 (60) in Fig. 4. Relative fecundity increased with an increase in concentration of Vitamin A.

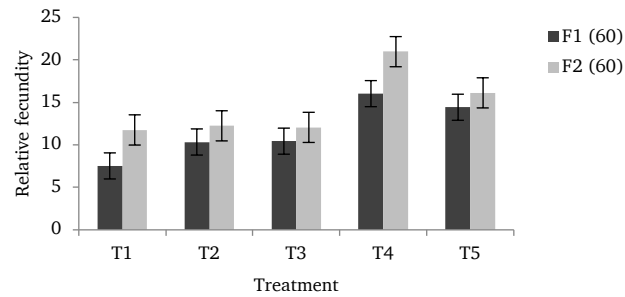


Figure 4. Relative fecundity of females *Clarias gariepinus*.

Results of Vitamin A supplementation on egg diameter of *C. gariepinus* broodstock are presented in Table 5, with graphical comparison of F1 and F2 groups (n=60) shown in Figure 5. The egg diameter was significantly larger ($p < 0.05$) in fish fed diets VAD6664 and VAD133328 compared to the other groups, with diameters ranging from 1.4 to 2.5 mm. Statistically significant

differences ($p < 0.05$) in egg diameter were observed among the treatment groups. This result contradicts Bilguven's (2014) study, which found that varying Vitamin A (VA) levels in diets had no impact on egg diameter but significantly influenced mean egg weight, with increased VA leading to differences in egg weight.

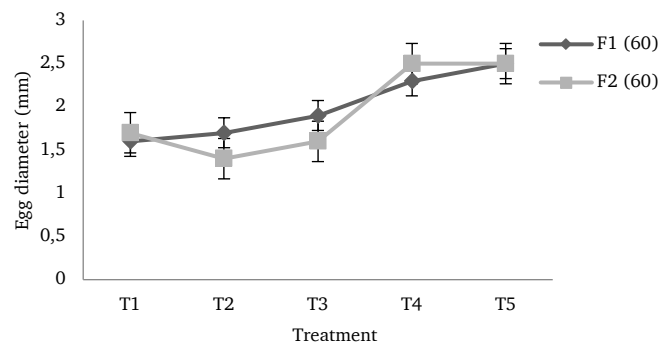


Figure 5. Mean egg diameter of *Clarias gariepinus*.

The effect of Supplementation of Vitamin A on egg fertilization of African Catfish (*C. gariepinus*) broodstock is presented in Table 5, and the difference between F1 (60) and F2 (60) in Fig. 6. The mean percentage fertilized egg was significantly higher in Treatments 4 and 5 than others. Egg fertilization rate in F2 (60)

was significantly higher ($p < 0.05$) than in F1 (60), except in T5. This study showed that increased levels of VA had a positive impact on the fertilization rate of fish. This finding agrees with Bilguven (2014). The range in this study is similar to that of red snapper (*Lutjanus campechanus*) reported by Bardon-Albaret and Saillan (2017).

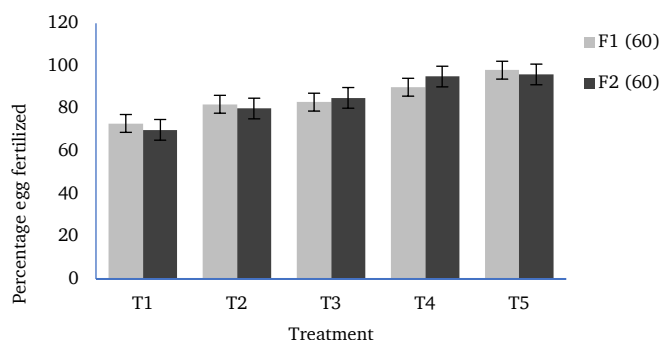


Figure 6. Mean percentage fertilized eggs of *Clarias gariepinus*.

Diets fortification with VA enhanced fry survival. The range of 65.8 to 89.5% in this study is better than 70.19 to 73% reported for Silver Carp (*Hypophthalmichthys molitrix*) in an unfortified diet. The better fry survival in the second spawning cycle agrees with findings of Umanah (2020), who reported that maternal age has a positive impact on the fry survival rate.

CONCLUSION

The recommended Vitamin A level in the maternal diet of *C. gariepinus* is 13,328 IU kg⁻¹. Inclusion at this level improved growth performance and nutrient utilization; stimulated the maturation of the ovary, optimized GSI and HSI, had a positive effect on fecundity, fertility embryo development by improving egg morphology and hatching rates. It also improved the percentage of live larvae after yolk reabsorption. Lack of VA in the diet seems to prolong the spawning period and cause deformity of the embryo. The requirement for vitamin A during reproduction is much higher than that required for juveniles, but deficiency or excess amounts of this vitamin could also be detrimental to the reproduction process. From the foregoing, fortification of the broodstock fish diet of *C. gariepinus* has resulted in positive growth and reproduction parameters. A vitamin A dosage of 13,328 IU kg⁻¹ diet is recommended for the broodstock diet of this species.

CONFLICT OF INTEREST

No conflict of interest among all authors upon writing and publishing the manuscript.

AUTHOR CONTRIBUTION

Godswill Okure conceived the work, produced the experimental design, and executed the work. Imefon Udo supervised the work and developed the manuscript, while Ofonime Afia assisted in biochemical and data analyses. All signed the manuscript.

ACKNOWLEDGMENTS

All staff of the Department of Fisheries and Aquatic Environmental Management are acknowledged.

REFERENCES

- Akinwale, A.O. and Fatoruti, E.O., 2007. Biological Performance of African catfish (*Clarias gariepinus*) cultured in recirculating system in Ibadan. *Aquacultural Engineering*, 36(1), pp.18–23.
<https://doi.org/10.1016/j.aquaeng.2006.05.001>
- AOAC, 1995 Official Methods of Analysis. 16th Edn Association of Official Analytical Chemists Washington DC USA.
- Bardon-Albaret, A. and Saillan, E., 2017. Egg quality traits and predictors of embryo and fry viability in redsnapper *Lutjanus campechanus*. *Aquaculture Reports*, 7, pp.48–56.
<https://doi.org/10.1016/j.aqrep.2017.05.004>

- Bilguven, M., 2014. The effects of vitamin A and E supplementation into the female broodstock diets of Rainbow Trout (*Oncorhynchus mykiss*, W.) on the fecundity and egg quality parameters. *Journal of Animal and Veterinary Advances*, 13(19), pp.1120–1125.
<https://doi.org/10.36478/javaa.2014.1120.1125>
- Eyo, V.O., Ekanem, A.P., Eni, G. and Edet, A.P., 2013. Relationship between fecundity and biometric indices of the silver catfish *Chrysichthys nigrodigitatus* (Lacepede) in the Cross River estuary, Nigeria. *Croatian Journal of Fisheries*, 71(3), pp.131–135. <https://hrcak.srce.hr/108852>
- Hernandez, L.H. and Hardy, R.W., 2020. Vitamin A functions and requirements in fish. *Aquaculture Research*, 51(8), pp.3061–3071.
<https://doi.org/10.1111/are.14667>
- Hu, C.J., Chen, S.M., Pan, C.H. and Huang, C.H., 2006. Effects of dietary vitamin A or β -carotene concentrations on growth of juvenile hybrid tilapia (*Oreochromis niloticus* x *O. aureus*). *Aquaculture*, 253(1-4), pp.602–607.
<https://doi.org/10.1016/j.aquaculture.2005.09.003>
- Hussein, S.Y. Metwally, M.A. and Asmaa, A.M., 2021. Effect of Vitamin A and D3 Supplementation on the Growth Performance of Nile Tilapia (*Oreochromis niloticus*). *Assiut Veterinary Medical Journal*, 67(169), pp.152–164.
<https://dx.doi.org/10.21608/avmj.2021.188845>
- Moren, M., Opstad, I., Bemtssen, M.H.G., Zambonino Infante, J.L. and Hamre, K., 2004. An optimum level of vitamin A supplements for Atlantic halibut (*Hippoglossus hippoglossus* L.) juveniles. *Aquaculture*, 235(1-4), pp.587–599.
<https://doi.org/10.1016/j.aquaculture.2004.01.030>
- Nnanji, J.C., Uzairu, A., Harrison, G.F.S. and Balarabe, M.L., 2010. Effect of pollution on the physico-chemical parameters of water and sediment of river Galma, Zaria, Nigeria. *Libyan Agriculture Research Center Journal International*, 1(2), pp.115–122.
<https://www.researchgate.net/publication/235914633>
- Qadri, S., Shah, T.H., Balkhi, M.H., Bhat, B.A., Bhat, F.A., Najjar, A.M., Asmi, O.A., Farooq, I. and Alia, S., 2015. Absolute and Relative Fecundity of Snow Trout, *Schizothorax curvifrons* Heckel, 1838 in River Jhelum (Jammu & Kashmir). *SKUAST Journal of Research*, 17(1), pp.54–57.
<https://indianjournals.com/article/skuastjr-17-1-009>
- Serezli, R., Güzel, Ş. and Kocabaş, M., 2010. Fecundity and egg size of three salmonids species (*Onchorhynchus mykiss*, *Salmo labrax*, *Salvelinus fontinalis*) cultured at the same farm condition in North-Eastern Turkey. *Journal of Animal and Veterinary Advances*, 9(3), pp.576–580.
<https://doi.org/10.3923/javaa.2010.576.580>
- Udo, I.U., 2017. Effects of dietary vitamin A level on growth, feed utilization and survival of juvenile North African catfish (*Clarias gariepinus*). *Livestock Research for Rural Development*, 29(2), 22.
[http://www.lrrd.cipav.org.co/lrrd29/2/udo29022.htm#Livestock%20Research%20for%20Rural%20Development%2029%20\(2\)%202017](http://www.lrrd.cipav.org.co/lrrd29/2/udo29022.htm#Livestock%20Research%20for%20Rural%20Development%2029%20(2)%202017)
- Udo, I.U., Ndome, C.B., Ekanem, S.B. and Asuquo, P.E., 2011. Application of linear programming technique in least-cost ration formulation for African catfish (*Clarias gariepinus*) in semi-intensive culture system in Nigeria. *Journal of Fisheries and Aquatic Science*, 6(4), pp.429–437.
<https://doi.org/10.3923/jfas.2011.429.437>
- Umanah, S.I., 2020. Maternal Age Influence on Fry Survival, Growth and Size Variation in *Clarias gariepinus*. *Asian Journal of Animal Sciences*, 14(4),

pp.145-152.

<https://doi.org/10.3923/ajas.2020.145.152>

- Wilson, R.P. and Moreau, Y., 1996. Nutritional requirements of catfishes (Siluroidei). *Aquatic Living Resources*, 9, pp.103-111. <https://doi.org/10.1051/alr:1996045>
- Wu, F., Zhu, W., Liu, M., Chen, C., Chen, J. and Tan, Q., 2016. Effects of Dietary Vitamin A on Growth Performance, Blood Biochemical Indices and Body Composition of Juvenile Grass Carp (*Ctenopharyngodon idellus*). *Turkish Journal of Fisheries and Aquatic Sciences*, 16(2), pp.339–345. https://doi.org/10.4194/1303-2712-v16_2_14
- Yang, B. and Kallio, H., 2002. Composition and physiological effects of sea buckthorn (*Hippophaë*) lipids. *Trends in Food Science & Technology*, 13(5), pp.160-167. [https://doi.org/10.1016/S0924-2244\(02\)00136-X](https://doi.org/10.1016/S0924-2244(02)00136-X)
- Zhang, L., Feng, L., Jiang, W.D., Liu, Y., Wu, P., Kuang, S.Y., Tang, L., Tang, W.N., Zhang, Y.A. and Zhou, X.Q., 2017. Vitamin A deficiency suppresses fish immune function with differences in different intestinal segments: the role of transcriptional factor *NF-κB* and *p38 mitogen-activated protein kinase* signaling pathways. *British Journal of Nutrition*, 117(1), pp.67–82. <https://doi.org/10.1017/S0007114516003342>