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Improving the Reproductive Performance of *Oreochromis Niloticus* (Linnaeus, 1758) Broodstock Using Local Ingredients from the Agro-ecological Zones of Côte d'Ivoire

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Abstract This study was carried out with the aim of reducing the cost of aquaculture feeds in Côte d'Ivoire. Therefore, three (3) fish feeds for the reproduction stage in the three main agro-ecological zones of the country were formulated (SG1, SG2 and G). Male and female *Oreochromis niloticus* broodstock with mean initial masses of 62.63 ± 1.23 g and 53.88 ± 4.54 g respectively were distributed in nine 9 m^3 floating cages at a density (1 ind/m^2) of one male for every three females. The different batches of fish were fed at 3-2.5% of biomass with feed containing 35% protein. Feed was distributed twice a day at 9 am and 5 pm for two months. At the end of the rearing period, all the fish were weighed individually and samples were dissected, the gonads removed and weighed. A sample of the ovaries was taken so that the oocytes could be counted under an electron microscope. In hapas, after two months of rearing, the condition indices for the males were 1.20 ± 0.00, 1.42 ± 0.10 and 1.63 ± 0.06. Gonadal weight ranged from 1.26 ± 0.08 to 1.53 ± 0.9 g. In females, absolute fecundity ranged from 572 ± 51 to 644 ± 44 oocytes/female. Oocyte diameter ranged from 3.02 ± 0.07 to 3.28 ± 0.02 mm. Relative fertility values ranged from 7683.2 ± 756.91 to 8257.28 ± 455.6.

Keywords: *agro-ecological zones, tilapia, reproduction, growth, Côte d'Ivoire*

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1. Introduction

Oreochromis niloticus is the most widely farmed species in fish farms in Côte d'Ivoire. However, one of the obstacles to the expansion of tilapia farming in Côte d'Ivoire is the lack of sufficient quantities of high-quality fingerlings [1]. Furthermore, another significant limiting factor is the high cost of commercial aquaculture feed [2]. This is the main expense in fish production and can account for over 60% of production costs in semi-intensive systems [3]. The high price of feed limits fish farmers' ability to feed fish properly, particularly broodstock. This situation can negatively affect reproductive performance and the availability of fry. To address this, improving broodstock management through feed control is an essential tool [4]. In fish farming, broodstock feeding is the most critical element of sustainable aquaculture production, as it provides the nutrients necessary for gonadal development, egg yield and fry quality [5,6]. Furthermore, to ensure the sustainable growth and expansion of tilapia farming, effective measures such as improved nutrition and feeding, with a particular focus on broodstock, are essential for producing large, high-quality eggs [7,8]. Indeed, the importance of protein content on gonadal maturation and reproductive success has been highlighted by several authors [9,10]. The nutritional requirements for optimal reproductive performance in tilapia broodstock have already been reported by several authors [11,12,13]. One potential solution is for fish farmers to produce their own feed using cheaper ingredients available in the agro-ecological zones (Guinean, Sudano-Guinean 1 and 2) of Côte d'Ivoire. The aim of this study is to formulate low-cost, isoproteic diets containing 35% protein, adapted to the local agro-ecological conditions of Côte d'Ivoire, using available raw materials in order to improve the reproductive success of *O. niloticus* broodstock.

2. Materials and Methods

2.1. Materials

2.1.1. Choice of Experimental Site and Study Framework

The experimental site was the Green fish farm, located in southern Côte d'Ivoire, in the Agboville department, specifically within the sub-prefecture of Azaguié. The fishpond's water supply was provided by a dam fed by a stream. The pond selected for the experiment was previously drained, cleaned, and then refilled. Its water supply was provided by gravity from the dam. Furthermore, protective devices were installed at the entry and exit points to prevent the intrusion of unwanted species and to avoid any escape of the farmed fish.

2.1.2. Fish Farm Equipment

Three (3) hapas were installed in triplicate in the same pond, in accordance with the method described in [14], as follows: each 9 m³ net (length × width × height; 4 m × 3 m × 0.75 m) was secured to four (4) stakes. The depth of the hapas in the water was 0.6 m. The ropes were attached 20 cm above the bottom of the pond and the upper ropes 70 cm above the water level. These hapas were arranged in three rows across the full width of the pond. They were made from mosquito nets, sewn together with rope to form rectangular enclosures. These stakes were placed in the pond filled with water. As for the pond, it was supplied with water by gravity from the dam. Protective barriers were installed at the entrance and exit of the pond to prevent, on the one hand, the intrusion of unwanted fish and, on the other hand, the loss of experimental fish. Landing nets, buckets, barrels, sieves, rulers and various scales were used to measure and weigh the fish during the control fishing. A CAMRY scale with a capacity of 5 kg was used to weigh the daily rations, and an EKS scale with a capacity of 5 kg and an accuracy of 1 g was used to determine the weight of the experimental fish.

2.1.3. Biological Material

The biological material consisted of formulated feed from three agro-ecological zones. These were the Sudano-Guinean zone 1 (south-central), the Sudano-Guinean zone 2 (central and eastern) and the Guinean zone (southern and western) of Côte d'Ivoire, as well as Nile tilapia (*Oreochromis niloticus)* at the reproductive stage. Broodstock of the Bouaké strain of *O. niloticus* were purchased from a fish farm to establish the various experimental groups.

2.1.4. Feed Formulation

Using the Excel linear programming method, three feed formulas were developed at 35% protein, with ash (4-8%), carbohydrate (25-40%), fibre (< 10%) and energy (18-25 kJ/g) contents within the ranges recommended for rearing *Oreochromis niloticus* broodstock [11,12,13]. Fishmeal with 55% protein, cotton and soya cake and wheat bran available locally in the fish farming agro-ecological zones were used for the formulation. The different feed formulations are presented in Table 1.

Table 1. Formulation (kg/100 kg) and Costs of Feed Produced for Rearing *O.niloticus* Broodstock by Agro-Ecological Zones (SG1= Sudano-Guinean zone 1; SG2= Sudano-Guinean zone 2 and G=Guinean)

Raw materials	Food composition (%)		
	SG1	SG2	G
Fish meal 55	20	15	25
Cottonseed oil cake	20	20	20
White rice bran	15	-	-
Wheat bran	10	15	15
Cashewnut oil cake	-	20	20
Soybean meal	35	30	20
Cost (FCFA/kg)	345	340	345

1 FCFA= 0,0015 EURO based on october 2025 exchange data

2.2. Methods

2.2.1. Proximate Composition Analysis of Feeds and Fish

Proximate composition of fish and feeds was determined according to [15] and [16]. Dry matter (DM) was determined after drying the samples in an oven (80°C) until a constant mass. Crude protein was measured using Kjeldhal method (N% × 6.25), Ash was measured by incineration at 550°C in a muffle furnace for 24 hours, and crude fat was determined using Soxhlet extraction with hexane as solvent. The gross energy content of feeds and fish samples were calculated based on energy equivalents of crude protein, crude fat, and total carbohydrates; 23.7, 39.5, and 17.2 kJ/g, respectively [11]. The mineral contents of the samples were determined by atomic absorption spectrophotometer. All analyses were made in triplicate for each sample.

2.2.2. Rearing of Broodstock

Male and female broodstock of *Oreochromis niloticus* had average initial weights of 62.63 ± 1.23 g and 53.88 ± 4.54 g, respectively. The males had a higher average weight than the females in order to minimise aggression during reproductive interactions. These broodstock were distributed across nine 9 m³ floating cages at a stocking density (1 ind./m²) of one male to three females. This experimental phase took place from 12 September to 12 November. The fish were fed isoproteic experimental diets (SG1, SG2 and G) containing 35% protein respectively in the different cages. The daily ration was divided into two meals, at 9 am and 5 pm, from September to November. The different groups of fish were fed at a rate of 3% of biomass per day at the start of the experiments, then adjusted to 2.5% based on samples taken during control catches. At the end of the rearing period, all fish were weighed individually and samples were dissected; the gonads were removed and weighed (Figure 1). Ovarian samples were taken and the oocytes were counted using an electron microscope.

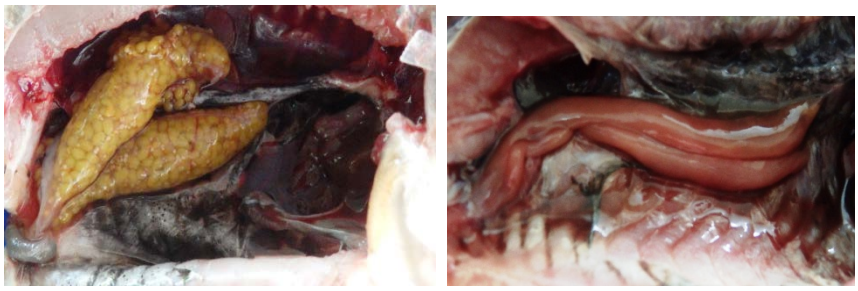


Figure 1. Female and male gonads of *Oreochromis niloticus*

2.2.3. Reproductive Parameter Measurements

The condition factor K, gonado-somatic indices, absolute and relative fecundities were calculated for males and/or females according to the following formulae:

$$condition\ factor\ K = \frac{fish\ mass}{(fish\ length)^3} \quad (1)$$

$$Male\ gonado-somatic\ index(GSI) = \left(\frac{male\ gonad\ mass}{male\ broodstock\ mass}\right)\times 100 \quad (2)$$

$$Female\ gonado-somatic\ index(GSI) = \left(\frac{ovary\ mass}{female\ broodstock\ mass}\right)\times 100 \quad (3)$$

$$Absolute\ fecundity = number\ of\ oocytes\ per\ female \quad (4)$$

$$Relative\ fecundity = \frac{number\ of\ oocytes}{female\ mass(kg)} \quad (5)$$

2.2.4. Statistical Analysis

Statistical analysis of data collected was performed on STATISTICA 7.1 software. Data were expressed as means ± standard deviation. One-way ANOVA analysis of variance was used to compare the values. Then, Duncan multiple range tests were used to compare differences among means. Differences were considered significant at $p < 0.05$.

3. Results

3.1. Biochemical and Chemical Composition of Formulated Feeds

Table 2 presents the biochemical and mineral compositions of the three experimental diets (SG1, SG2, and G). The analysis reveals several significant differences likely to influence the zootechnical performance and physiology of the fish. In general, the diets have similar protein content (~35%), but differ in their energy and mineral composition. Diet SG1 is richer in carbohydrates and ash, but it has the best protein/energy ratio. Conversely, diets SG2 and G are richer in lipids. They are therefore more energy-dense, with higher gross energy but a lower protein/energy ratio. In terms of minerals, diet SG1 is distinguished by high levels of phosphorus, magnesium, and potassium, while diet G is richer in calcium and sodium.

Table 2. Biochemical and Chemical Composition of Formulated Feeds (SG1= Sudano-Guinean zone 1; SG2= Sudano-Guinean zone 2 and G=Guinean)

Parameter	Fish feeds		
	SG1	SG2	G
Biochemical composition			
Moisture (%)	8,50 ± 0,18^c	7,90 ± 0,08^b	7,30 ± 0,11^a
Crude protein (%)	35,38 ± 0,02^a	35,22 ± 0,04^a	35,13 ± 0,02^a
Crude fiber (%)	4,30 ±0,04^a	5,45 ±0,04^b	5,80 ± 0,04^c
Crude lipid (%)	5,38 ± 0,05^a	10,87 ± 0,02^b	11,66 ± 0,05^c
Ash (%)	8,17 ± 0,02^c	5,74 ± 0,05^a	6,28 ± 0,02^b
Carbohydrate (%)	38,27 ± 0,02^c	34,83 ± 0,4^b	33,84 ± 0,02^a
Gross energy (kJ/g)	17,83 ± 0,03^a	19,57 ± 0,04^b	19,75 ± 0,04^b
Protein/energy (mg/kJ)	19,84 ± 0,05^b	18,00 ± 0,82^a	17,79 ± 0,02^a
Chemical composition			
Calcium (mg/g)	5,80	5,20	6,44
Phosphorus (mg/g)	6,37	6,04	5,34
Magnesium (mg/g)	4,70	3,36	4,14
Manganese (mg/g)	0,17	0,19	0,04
Potassium (mg/g)	21,33	13,83	17,43
Sodium (mg/g)	3,92	2,99	4,82
Iron (mg/g)	1,03	1,28	1,01

Values bearing the same alphabetical letters on the same line are not significantly different at the threshold of α = 0.05

3.2. Water Quality Parameter

The nine cages were placed in the same pond to ensure that the experiment was conducted under identical conditions. To this end, the temperature was around 30.58 ± 0.89°C. The average pH was estimated at 9.22 ± 1.08. The dissolved oxygen level recorded in the rearing pond was 7.96 ± 0.61 mg/L. As for the average conductivity, its value was 15.67 ± 3.58 µS/cm (Table 3).

Table 3. Water Quality Parameter

Pond water parameters	Temperature (°C)	pH	Dissolved oxygen (mg/L)	Conductivity (µS/cm)
	30,58±0,89	9,22±1,08	7,96±0,61	15,67±3,58

3.3. Reproduction Parameters of *Oreochromis niloticus* at the End of Rearing

The Table 4 shows the effect of three experimental

diets (SG1, SG2 and G) on various reproductive parameters in males and females. The results are expressed as mean ± standard deviation, and different letters indicate the presence of significant differences ($p < 0.05$) between treatments.In males, the eviscerated carcass weight varied significantly between treatments. Fish fed diet SG1 (131.43 ± 3.17 g) and SG2 (127.64 ± 2.92 g) had significantly higher values than those fed diet G (119.14 ± 2.8 g). The condition factor (K) also showed significant variation between treatments. The values increased from SG1 (1.20 ± 0) to G (1.63 ± 0.06). Regarding gonadal mass, males fed SG1 (1.53 ± 0.9 g) had a significantly higher gonadal mass than those receiving SG2 (1.31 ± 0.01 g) and G (1.26 ± 0.08 g). By contrast, the gonadosomatic index (GSI) remained unchanged (0.01 ± 0) across the three treatments. In females, the eviscerated carcass weight varied significantly between treatment groups. Fish fed SG1 (82.41 ± 0.83 g) had the highest values, followed by SG2 (76.41 ± 1.49 g) and G (69.35 ± 3.32 g). The condition factor (K) showed a gradual and significant increase across the treatments, with the highest values observed in fish fed G (2.81 ± 0.05), followed by SG2 (2.38 ± 0.03) and SG1 (2.17 ± 0.03). Ovarian mass was significantly higher in females fed SG1 (3.49 ± 0.25 g) compared with the SG2 (2.69 ± 0.23 g) and G (2.48 ± 0.25 g) treatments. In contrast, the gonadosomatic index showed no significant difference between the treatments (0.03–0.04). Similarly, absolute fertility, relative fertility and oocyte diameter showed no significant differences between the diets ($p > 0.05$).

Table 4. Reproductive Parameters of *O. niloticus* Broodstock as a Function of Formulated Feeds across Agro-Ecological zones (SG1= Sudano-Guinean zone 1; SG2= Sudano-Guinean zone 2 and G=Guinean)

Reproduction Parameters	Fish feeds		
	SG1	SG2	G
Male			
Gutted carcass (g)	131,43±3,17^{b}	127,64±2,92^{b}	119,14±2,8^{a}
Condition factor K	1,20±0^{a}	1,42±0,1^{ab}	1,63±0,06^{b}
Gonad mass (g)	1,53±0,9^{b}	1,31±0,01^{a}	1,26±0,08^{a}
Gonosomatic index	0,01±0^{a}	0,01±0^{a}	0,01±0^{a}
Female			
Gutted carcass (g)	82,41±0,83^{c}	76,41±1,49^{b}	69,35±3,32^{a}
Condition factor K	2,17±0,03^{a}	2,38±0,03^{b}	2,81±0,05^{c}
Ovary mass (g)	3,49±0,25^{b}	2,69±0,23^{a}	2,48±0,25^{a}
Gonosomatic index	0,04±0^{a}	0,03±0^{a}	0,04±0^{a}
Absolute fertility (oocytes/female)	644,5±44,07^{a}	589,5±57,71^{a}	572,03±50,9^{a}
Relative fertility (oocytes/kg female)	7818,7±455,6^{a}	7683,2±756,9^{a}	8257,28±368,4^{a}
Oocyte diameter (mm)	3,28±0,02^{a}	3,02±0,07^{a}	3,02±0,07^{a}

Values bearing the same alphabetical letters on the same line are not significantly different at the threshold of $\alpha = 0.05$

4. Discussion

The biochemical composition of experimental feeds is a key factor in zootechnical performance and the metabolic utilisation of nutrients in fish. In the present study, the crude protein, fibre, energy, ash and carbohydrate contents of the three formulated feeds fall within the range generally recommended for the feeding of broodstock [11,12,13]. The fat contents in diets SG2 (10.87%) and G (11.66 %) exceed the standards recommended by these same authors. However, [17] suggests fat levels in tilapia feed of between 5 % and 12 %. With regard to mineral composition, the variations observed between the diets likely reflect differences in the raw materials used.

The physicochemical parameters of the water play a decisive role in the growth, survival and productivity of fish reared in ponds, particularly in tilapia such as *Oreochromis niloticus*. The average water temperature was 30.58 ± 0.89°C, which generally corresponds to the favourable range for tilapia farming. Indeed, the optimum temperature for the growth of this species is generally between 26 and 30°C, with a wider tolerance extending up to approximately 32°C [17,18,19]. The average pH observed in the pond was 9.22 ± 1.08, indicating an alkaline environment. For tilapia, the optimal pH is generally between 6.5 and 8.5, although this species is relatively tolerant to pH variations [17]. An increase in pH in fish ponds may be linked to high photosynthetic activity of phytoplankton, which consumes carbon dioxide dissolved in the water. Values slightly above the optimal range may nevertheless be observed in highly productive systems without necessarily causing severe stress in tilapia, a species renowned for its high environmental tolerance. Although the pH value recorded is slightly high (pH above 9) in this pond, this is not a cause for concern as *Oreochromis niloticus* can survive successfully and tolerate a pH range of 4 to 11 [20]. The recorded dissolved oxygen concentration (7.96 ± 0.61 mg/L) is favourable for fish production. Indeed, studies indicate that tilapia generally require a minimum dissolved oxygen concentration of around 5 mg/L [21]. High concentrations of dissolved oxygen in the water are often associated with high photosynthetic activity and good water circulation in the ponds. The electrical conductivity measured in this study (15.67 ± 3.58 µS/cm) indicates a low concentration of dissolved mineral salts in the water. This value is below the lethal range, which is between 3.8 and 10 µS/cm [22].

With regard to males, the results show that eviscerated weight is significantly higher in fish fed diets SG1 and SG2 compared to diet G. This suggests that diets SG1 and SG2 provide better energy and protein utilisation, promoting somatic growth. However, the condition factor (K) is higher with the G diet, indicating a greater accumulation of body reserves despite a lower weight. Gonadal mass was significantly higher in the SG1 group (1.53 g), indicating a more efficient allocation of nutrients to reproduction. However, the gonadosomatic index (GSI) remained low and was identical across treatments (0.01). Indeed, in *O. niloticus*, a gonadosomatic index value between 0.05 and 0.15 is said to characterise very different stages of ovarian maturation, such as a gonad at the start of maturation or a post-spawning gonad (after the release of male or female gametes) [23]. In females, eviscerated weight follows the same trend as in males (SG1 > SG2 > G), indicating better growth with the SG1 diet. In contrast, the condition factor (K) increases significantly from SG1 to G, reflecting increased lipid

accumulation, which is often associated with preparation for reproduction or energy storage. Ovarian mass is significantly higher under SG1, confirming that this diet promotes gonadal maturation. However, as in males, the IGS remains low (0.03-0.04) and does not differ significantly from the other treatments. This suggests that the females are also in the post-laying phase, with their ovaries in the process of recovery. Furthermore, the results obtained were higher than the values for the gonadosomatic index of mature females (2.6 %), relative fertility (3,720 oocytes/kg of female body weight) and oocyte diameters (2.17 and 2.55 mm) reported by [24] and [25] for the same species in a farming environment. Similarly, the absolute fertility values (572 to 644 oocytes/female) were higher than those reported by [26], which ranged from 348 to 467 oocytes/female for females weighing 64.5 to 80.95 g fed a diet containing 38 % protein. These results showed that the values for ovarian mass and gonadosomatic indices in females were higher than those for testicular mass and gonadosomatic indices in males. These findings are consistent with the work [27]. According to this author, in the African intertropical zone, the testes of *O. niloticus* always weigh less than the ovaries.

5. Conclusion

This study highlights the influence of diets on the zootechnical and reproductive performance of breeding stock. The results show that the experimental diets, particularly diet SG1, significantly improve eviscerated weight and gonadal mass in both males and females, reflecting a more efficient allocation of nutrients towards the growth and development of the gonads. However, the absence of significant variation in the gonadosomatic index (GSI), absolute and relative fertility, and oocyte diameter between treatments suggests that the various diets tested generally meet the essential nutritional requirements for reproduction. These feeds should therefore be made available to Ivorian fish farmers to contribute to the mass production of high-quality fry on Ivorian farms.

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References

[1] MIRAH, Ministère des ressources animales et halieutiques. Plan stratégique de développement de l'élevage, de la pêche et de l'aquaculture en Côte d'Ivoire (PSDEPA 2014-2020), 2014,102 p.

[2] Kimou, B.N, Etude descriptive et analytique de l'alimentation des poissons d'elevage en Côte d'Ivoire. Thèse de Doctorat, Université Félix HOUPHOUËT- BOIGNY, Côte d'Ivoire, 2017, 175 p.

[3] Kaleem, O and Sabi A.-F.B.S., 2021. Overview of aquaculture systems in Egypt and Nigeria, prospects, potentials, and constraints. *Aquaculture and Fisheries* 6. 535-547. 2021.

[4] Bhujel, R.C., Little, D.C. and Hossain, A, Reproductive performance and the growth of pre-stunted and normal Nile tilapia (Oreochromis niloticus) broodfish at varying feeding rates, *Aquaculture* 273: 71-79.2007.

[5] Lupatsch, I., Deshev, R. and Magen, I, Energy and protein demand for optimal egg production including maintenance requirements of female tilapia Oreochromis niloticus, *Aquaculture Research* 41: 763-769. 2010.

[6] Engdaw, F and Geremew, A, Broodstock nutrition in Nile tilapia and its implications on reproductive efficiency. *Frontiers in Aquaculture*.3:1281640. 2024.

[7] Mabroke, R. S., Tahoun, A. M., Suloma, A., and El-Haroun, E. R, Evaluation of meat and bone meal and mono-sodium phosphate as supplemental dietary phosphorus sources for broodstock Nile tilapia (Oreochromis niloticus) under the conditions of Hapa-in-pond system. *Turkish Journal of Fisheries and Aquatic Sciences* 13, 11-18. 2013.

[8] Sousa, S.M.N., Freccia, A., Santos, L.D., Meurer, F., Tessaro, L., and Bombardelli, R.A, Growth of Nile tilapia post-larvae from broodstock fed diet with different levels of digestible protein and digestible energy. *Revista Brasileira de Zootecnia* 42, 535-540. 2013.

[9] Coward, K. and Bromage, N.R, Spawning frequency, fecundity, egg size and ovarian histology in groups of Tilapia zillii maintained upon two distinct food ration sizes from first feeding to sexual maturity. *Aquatic Living Resources* 12: 11-22.1999.

[10] Tsadik, G.G and Bart, A.N, Effects of feeding, stocking density and water-flow rate on fecundity, spawning frequency and egg quality of Nile tilapia, Oreochromis niloticus (L.). *Aquaculture* 272: 380-388. 2007.

[11] Guillaume, J., Kaushik, S., Bergot, P. and Metailler, R, Nutrition et alimentationon des poissons et crustacés. Eds. INRA, Paris,2009, 485p.

[12] El-sayed, A.-F.M., Mansour, C.R. and Ezzat, A.A, Effects of dietary protein level on spawning performance of Nile tilapia (Oreochromis niloticus) broodstock reared at different water salinities. *Aquaculture* 220: 619-632. 2003.

[13] LAZARD, J, Aquaculture et espèces introduites: Exemple de la domestication ex situ des tilapias. *Cahiers Agricultures* 16 (2): 123–124. 2007.

[14] Sarr, S.M., Thiam, A., Faye, E.H., Sene, M. and Ndiaye, M, Production d'alevins de Tilapia (Oreochromis niloticus) avec 3 aliments à base de sous-produits agro-industriels au Nord du Sénégal. *International Journal of Biological and Chemistry Sciences*, 9 (5): 2598 -2606. 2015.

[15] AOAC, Official methods of analysis, 16th edition. AOAC, Arlington, Virginia, USA, 1995, 1094 p.

[16] AOAC, Metals and others elements. Association of Analytical Chemist. Arlington, Virginia, USA, 2003, 1425 p.

[17] Suresh, V. Tilapias. In: Lucas, J.S. and Southgate, P.C., (Eds.) Aquaculture: farming of aquatic animals and plants, United Kingdom: *Blackwell publishing*, 276 - 294. 2003.

[18] Hussain, M. G, Farming of Tilapia: breeding plans, mass seed production and aquaculture techniques, Habiba Akter Hussain, 55 Kristawpur, Mymensingh 2200 Bangladesh, 2004, 149 p.

[19] Shahabuddin, A., Oo, M., Yi, Y., Thakur, D., Bart, A. and Diana J, Study about the effect of rice straw mat on water quality parameters, plankton production and mitigation of clay turbidity in earthen fish ponds. *World Journal of Fish and Marine Sciences*, 4 (6): 577-585. 2012.

[20] El-Sayed, A.-F.M. 2006. Tilapia Culture. Wallingford. CABI Publishing. 274 pp.

[21] Makori, A.J., Abuom, P.O. and Kapiyo, R., Effects of water physico-chemical parameters on tilapia (Oreochromis niloticus) growth in earthen ponds in Teso North Sub-County, Busia County. *Fisheries and Aquatic Sciences*, 20: 20 - 30. 2017.

[22] Stone, N. Shelton, J.L. Haggard, B.E. and Thomforde, H.K, Interpretation of Water Analysis Reports for Fish Culture. Southern Regional Aquaculture Center (SRAC) Publication N°. 4606. 2013, 12 p.

[23] Legendre M. and Ecoutin J.-M., Suitability of brackish water tilapia species from the Ivory Coast for lagoon aquaculture. I-Reproduction. *Aquatic Living Resources* 2 (2): 71-79. 1989.

[24] Albaret J.J, Reproduction et fécondité des poissons d'eau douce de Côte d'Ivoire. *Revue d' Hydrobiologie Tropicale* 15(4): 347-371. 1982.

[25] De Oliveira, M.M. Ribeiroa, T. Orlandoa, T.M. De Oliveira D, G.S, Drumond, M.M, De Freitas, R.T.F. & Rosa P. V, Effects crude protein levels on female Nile tilapia (Oreochromis niloticus) reproductive performance parameters. *Animal Reproduction Sciences*, 150 (1-2): 62-69. 2014.

[26] Orlando, T.M. Oliveira, M.M. Paulino, R.R. Costa, A.C. Allaman, I.B. and Rosa, P.V, Reproductive performance of female Nile tilapia (*Oreochromis niloticus*) fed diets with different digestible energy levels. *Revista Brasileira de Zootecnia* 46 (1): 1-7. 2017.

[27] Paugy, D, Reproductive strategies of fishes in a tropical temporary stream of the Upper Senegal basin: Baoulé River in Mali. *Aquatic Living Resources* 15: 25-35. 2002.



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