Comparative study of spawn performance of three wild populations of Oreochromis niloticus (Linnaeus, 1758) from Mono basin in Benin

by Jana Publication & Research

Submission date: 17-May-2025 12:44PM (UTC+0700)
Submission ID: 2664979740
File name: IJAR-51629.docx (180.33K)
Word count: 4707
Character count: 25738

Comparative study of spawn performance of three wild populations of *Oreochromis niloticus* (Linnaeus, 1758) from Mono basin in Benin

Abstract

This study aims to assess the spawn performance of three populations of *O. niloticus* collected in Sohoumè, Nangbéto and Togbadji stations of Mono basin. By population, wild spawners were collected and distributed separately in two tanks, one containing ten females and the other five males. The male was brought into the females' tank. At each spawning, the eggs were collected, measured and the laying female was tagged and returned to the tank. For the three populations, the average total weight of eggs, average absolute fecundity, average relative fecundity, and average gonado-somatic index per population ranged respectively from 8.6 ± 3 to 9.6 ± 1.7 g ; 1304 ± 323.1 to 1402 ± 371.4 eggs; 4.7 ± 1.6 to 6.4 ± 1.2 eggs / g of female and 3 ± 1.2 to 4.4 ± 1.8% without significant differences. Diameter of the eggs varied significantly ($P < 0.01$) from 1.9 ± 0.2 to 2.2 ± 0.4 mm between the three populations with the population of Togbadji which thus, displays the best performance of spawning.

Key words: Nil tilapia, Reproduction, populations

1- Introduction

Tilapia is the fourth largest aquatic species in the world after herbivore carp, silver carp, common carp, with a production of 4.2 million tonnes or 8% of the total raised aquaculture species (FAO 2018). This rapid growth in global tilapia production is due in part to the intensification of breeding systems which has led to a critical need for large quantities of fry for the stocking of fattening systems. Also, it is increasingly important to produce high-quality fry because of the low fertility of the broodstock (Mires, 1982; El-Sayed & Kawanna, 2008; Fagbemi et al., 2021).

Among tilapias, *Oreochromis niloticus* is the main species produced due to, among other characteristics, the ease with which they can be bred in captivity and the wide range of water conditions in which they can be bred (Biswas et al., 2005). Tilapia is popular because of its rapid growth, rusticness, high quality meat and market acceptance, as well as its early sexual maturity (Botaro et al., 2007). Thus, as there is an increasing demand for tilapia, it becomes essential that breeding operations meet the market demand. Optimizing the efficiency of fry production systems is of paramount importance if the production has to be maximized and maintained (Coward & Bromage, 1999). The productivity of broodstock is clearly the most important constraint on commercial tilapia production. A better understanding of the factors regulating the broodstock productivity (Coward & Bromage, 1999. Fagbemi et al., 2021) and a better choice of the strains to be used for fry production are therefore of great importance for the further development of tilapiaculture. Tilapias of the genus *Oreochromis* are female oral incubators and provide parental care given the relatively small number of eggs at each spawning (Mires, 1982; El-Sayed & Kawanna, 2008a; Fagbemi et al., 2021). The problem of mass production of tilapia eggs is still exacerbated because of the low degree of breeding females synchronization and the reduction of spawning over time (Mires, 1982. El-Sayed & Kawanna, 2008a). However, many factors can affect nesting performance of Nil tilapia, such as strain, age, crossbreeding, parental care, broodstock nutrition and photoperiod (Smitherman *et al.* 1988; Izquierdo *et al.* 2001; Biswas et al., 2005 Osure & Phelps 2006; Almeida *et al.* 2013). Also, different strains of this species may possess genetic, physiological, behavioral and/or other traits that foster significant changes in life cycle characteristics such as growth rate and fertility (Khater, 1986; Smitherman et al., 1988; Tave et al., 1990). Thus, the present work aims to study the spawning performance of three wild populations of *Nil tilapia* spawners from the Mono basin in order to identify the one with the best spawn performances.

2- Material and method

The broodstock were collected from Togbadji, Sohoumè and in Nangbeto dam lakes (Figure 1). These stations were chosen based of the presence of the species in the environment (Ahouansou Montcho, 2003; Lederoun et al., 2018.). It should be noted that apart from Nangbéto (NGT) station located in the dam of Mono river, Sohoumé (SH) and Togbadji (TG) stations are water bodies depending on Mono river and are supplied by it during floods.

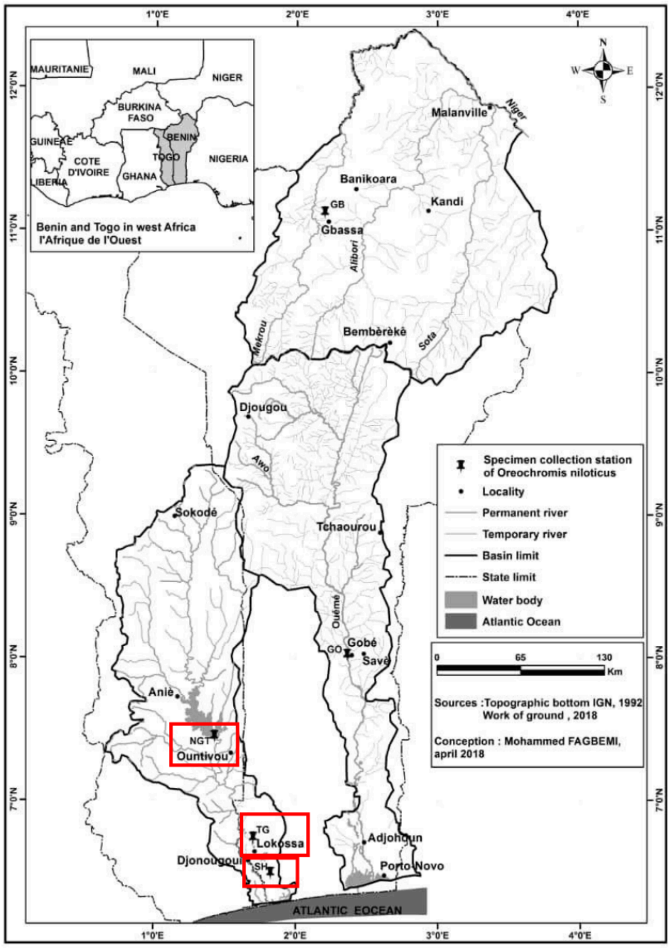


Figure 1: Broodstock collection area

Experimental setup

By population, ten females and five males were selected based on whether the females were bearing oocytes and the males were giving sperm. The different broodstocks were separated by sex and stored in different fiberglass tanks of 1.9 m^3 to avoid breeding. The different batches thus constituted were fed daily at 5% of the biomass of each tank with Biomar commercial feed (Protein 35%, Lipid 6%) for one week before the beginning of the tests. The feeding rate was maintained during the study. The water parameters were measured every morning before feeding during the study. Fish (222.9 ± 65.2 - 296 ± 38.6 g for females and 324 ± 72.2 – 334.9 ± 102.7 g) were maintained under 12L;12D photoperiod during this study at 28.9 ±0.03°C.

Eggs harvesting and counting

After a week's feeding of the different batches, a male was selected and introduced into the batch of females to induce egg-laying. Regular monitoring was then carried out twice a day to observe any reproduction and identify the egg incubating female. When spawning occurred and the female was identified, the eggs were harvested. The female was marked with a pit-tag and returned to the tank. The collected eggs were weighed and photographed. In this way, data such as laying dates, number of clutches per female during the test period, clutch weight and female weight at each clutch harvest were collected. The gonado-somatic index (GSI) was calculated per population according to the following formula:

GSI = Spawn weight (g)/ weight of females at each spawn harvest (g) x 100.

Statistical analysis

Based on the pictures, Image J 1.45S software was used to count all clutches and measure their diameter for a sample of 100 eggs per clutch. Data were presented as means with standard deviations. Parameters such as egg weight, gonado-somatic index (GSI), egg diameter and absolute fecundity were determined and analyzed using Statview 5.0.1.0 software. Data were tested for normality. If the data were normal, they were subjected to a one-factor analysis of variance (ANOVA 1), if not, the Kruskal-Wallis test and the Man Whitney test were used to determine the difference between the different populations taken in pairs. The differences observed were defined as statistically significant at the 5% threshold.

3- Results

At the end of the study, water parameters were on mean 28.9 ± 0.03°C for temperature, 6.4 ± 0.08 mg/L for dissolved oxygen and 6.6 ± 0.1 for pH. The recorded parameters did not vary between the different populations tested ($P > 0.05$).

Table 1: Spawning parameters by female and population, **TW** : Sum of total weights of females at each spawning / Number of spawns, **NS :** Number of spawns, **TIS** : Time interval between two spawns, **TWE** : Total weight of eggs collected in a female, **TEL** : cumulative total of eggs laid per female, **AF** : absolute fecundity per female , **RF** : Relative fecundity, **EW** : egg weight , **GSI** : gonado-somatic index, **DE** : diameter of the eggs

Population/ Femelle		TW (g)	NS	TIS(Day)	TWE (g)	TEL	AF	RF (eggs/g of female)	EW (g)	GSI (%)	DE (mm)
Nangbeto	**N1**	217.7	3	19	26.1	3400	1133	5.2	0.008	4	1.9±0.2
	N2	262.5	2	35	22.2	2545	1273	4.8	0.009	4.2	1.9±0.1
	N3	304.6	2	14	23.9	3981	1991	6.5	0.006	3.9	1.8±0.2
	N4	195.4	1	-	7	1337	-	6.8	0.005	3.6	1.8±0.2
	N5	197	1	-	8.8	994	-	5	0.009	4.5	2.4±0.2
	N6	251.6	1	-	9.2	1150	-	4.6	0.008	3.7	1.8±0.2
	N7	258.8	1	-	10.3	1247	-	4.8	0.008	4	1.8±0.2
Sohoume	**S1**	208.5	3	23	22.8	3125	1042	5	0.007	3.6	2±0.3
	S2	237.6	4	15	35.4	4943	1236	5.2	0.007	3.7	2±0.2
	S3	153	**2**	14	17.3	2289	1145	7.5	0.008	5.7	2±0.3
	S4	301.2	1	-	7.9	1907	-	6.3	0.004	2.6	1.6±0.1
	S5	316.9	1	-	8.3	1920	-	6.1	0.004	2.6	1.8±0.1
	S6	172.6	1	-	9.5	1120	-	6.5	0.008	5.5	2.4±0.1
	S7	170.7	1	-	12.5	1441	-	8.4	0.009	7.3	2.3±0.2
Togbadji	**T1**	234.6	**1**	-	8.7	1394	-	5.9	0.006	3.7	3±0.2
	T2	294	**2**	14	10.4	1146	573	1.9	0.009	1.8	2.2±0.3
	T3	271.9	1	-	13.5	1804	-	6.6	0.007	5	1.9±0.2
	T4	352.7	1	-	7.2	1912	-	5.4	0.004	2	2.5±0.2
	T5	289.3	1	-	6.5	1557	-	5.4	0.004	2.2	1.7±0.2
	T6	296.5	1	-	7.3	968	-	3.3	0.008	2.5	2.1±0.2
	T7	332.7	1	-	12	1502	-	4.5	0.008	3.6	2.1±0.2

Average weights of females and spawnings

By population, spawnings were collected from seven females with the ones that had between two to four spawns during the study period. The average weight of all females harvested per population ranged from 222.9 ± 65.2 g to 296 ± 38.6 g while the average weight of spawnings collected per population ranged from 8.6 ± 3 g to 9.6 ± 1.7 g with the Nangbeto population showing the best average spawning weight (Table 2). The median values of spawning weights of the three populations were not significantly different (*p = 0.256*).

Table 2: Spawning parameters by population, **WF** : Average weight of females per population; **TWE** : average total weight of the eggs; **AF** : average absolute fecundity per population, **RF** : Average relative fecundity; **GSI** : average gonado-somatic index per population; **DE** : diameter average of the eggs per population.

Populations	WF (g)	TWE (g)	AF	RF (eggs/g of female)	GSI(%)	DE (mm)
Nangbeto	241.1±39.8	9.6±1,7^{a}	1304±323.1^{a}	5.4±0.9^{a}	4±0.3^{a}	1.9±0.2^{a}
Sohoume	222.9±65.2	9.1±1.6^{a}	1402±371.4^{a}	6.4±1.2^{a}	4.4±1.8^{a}	2±0.3^{b}
Togbadji	296±38.6	8.6±3^{a}	1387±470.8^{a}	4.7±1.6^{a}	3±1.2^{a}	2.2±0.4^{c}

In a column, values with the same letters are not significantly different

Eggs' diameters

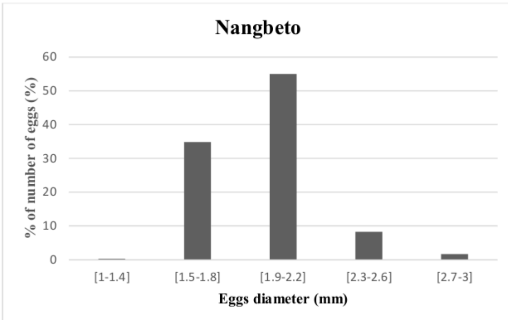
Egg diameters ranged from 1.9 ± 0.2 mm to 2.2 ± 0.4 mm (Table 2) for the Nangbeto and Togbadji populations respectively. Figure 2 shows the frequency distributions of egg diameters for the different populations. It should be noted that for all populations, eggs measuring between 1.9 and 2.2 mm in diameter dominate at 39.3%; 45.5% and 55%; respectively for Sohoumè; Togbadji and Nangbéto, while eggs with diameters ranging from 1-1.4 mm; 2.8-3 mm and 3.1-3.4 mm are poorly represented in clutches for the same populations (Figure 2). It should also be noted that the Sohoumè and Togbadji populations have the highest rates of eggs with a larger diameter, at 28.8% and 24.9% respectively (for 2.3-2.6 mm). Togbadji population had 9.5% of eggs with diameters of 2.7-3 mm, and was the only population to have eggs with diameters of 3.1-3.4 mm, with 6.25% of eggs. The median egg diameter values of the three populations are significantly different from each other (*P < 0.01*). Analysis of figure 2 and table 2 shows that the Togbadji population generally has larger eggs than the other two populations in the same basin.

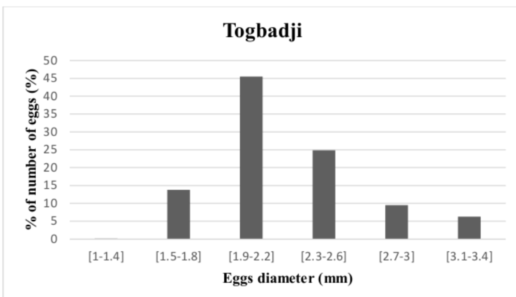
Absolute and relative fecundity

Mean absolute fecundity (AF) varied (P = 0.88) from 1304 ± 323.1 to 1402 ± 371.4 for the Nangbeto and Sohoumè populations respectively. However, the Sohoumè population showed the highest mean absolute fecundity (1402 ± 371.4 eggs) with a mean egg size of 2 ± 0.3 mm, compared with the Nangbeto and Togbadji populations whose mean absolute fecundities were 1304 ± 323.1 and 1387 ± 470.8 eggs respectively (Table 2). Similarly, for all populations, relative fecundity varies from 4.7 ± 1.6 eggs/g to 6.4 ± 1.2 eggs/g. The Sohoumè population had the highest relative fertility, although there was no significant difference (*P = 0.064*) between the mean relative fertilities of the three populations. It should be noted that during the study period, the average duration between two clutches of eggs varied from 14 to 35 days (Table 1), taking into account females with more than one clutch per population.

Gonado-somatic index (GSI)

Overall, the gonadosomatic index of the different populations varied (*P = 0.0805*) from 3 ± 1.2% to 4.4 ± 1.8% (Table 2) for Togbadji and Sohoume respectively.





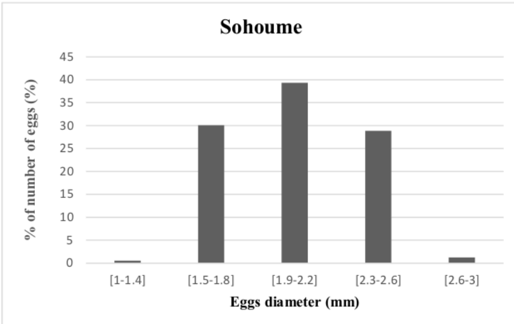


Figure 2: Frequencies distributions of eggs per population

4- Discussion

In aquaculture, the choice of a successful strain for the development of the sector takes into account the study of several parameters including the ability of that strain to produce in quantity good quality eggs allowing to obtain viable fry. Thus, the current breeding problems related to the low fecundity and asynchronous spawning can be partially mitigated by selecting and using broodstock with optimal reproductive characteristics such as total fecundity, egg size and eggs weight ratio to body weight (Macintosh & Little, 1995).

The present study shows that for all the populations considered, the diameter of the eggs varied significantly from one population to another. Togbadji population has the largest eggs with an average diameter of 2.2 ± 0.4 mm and remains the only population of the batch with 6.25% of eggs ranging in diameter from 3.1 mm to 3.4 mm. The average egg diameters obtained in this study are similar to those obtained by Wing Keong & Wang (2011) and Carvalho et al. (2018) that fed the broodstock with food containing 35% protein and 18% gross energy and various doses of phosphorus. But they remain inferior to those obtained by de Oliveira et al. (2014) who fed spawners with foods with protein levels ranging from 32% to 40%. Indeed, the protein content of the broodstock's feed determines the size and quality of eggs obtained during production (El-Sayed & Kawanna, 2008a; Gunasekera et al., 1995; Sotolu, 2010) and can therefore be explained in diets with an approximate level of 38% protein by an increased deposit of proteins and/or lipids, key nutrients that make up the yolk (Chong *et al.,* 2004). Also, the egg size of the Togbadji population also remains a considerable advantage, since egg size is a function of yolk content, which could be a determining factor in the hatching rate of eggs from this population. This may well explain the results obtained by Fagbemi et al. (2021), who reported a better hatching rate of 88.9 ± 9.1 compared with other populations. Thus, the protein and lipid content (35% and 6%) of the feed used for the broodstock could explain the relatively small size of the eggs obtained. Also, it should be noted that in Togbadji population in which we have large eggs, the females have had an average weight greater than the average weight of the females of the other two populations, suggesting a relationship between the egg size and female weight (Rana, 1988; Trewavas, 1983). Also this performance displayed by Togbadji the population could also be explained by the origin and the genetic characteristics related to this population since it has been reported that the reproduction performance of tilapia could vary from one strain to another (Smitherman et al. 1988; Izquierdo et al., 2001; Biswas et al., 2005 Osure & Phelps 2006; Almeida et al., 2013).

For females having laid more than once during the study period, there is significant variability in the cumulative absolute fecundity between the three populations considered with a benefit for the population of Sohoumè (Table 1). Also, these values remain better than those obtained by de Oliveira et al. (2014) and those reported by Carvalho et al. (2018) (454 to 6679 eggs per female) after 26 weeks of testing. Considering the average absolute fecundity per population (Table 2), it remains better than the one obtained by Siraj et al. (1983), Siddiqui et al., (1998), and Bombardelli et al. (2017).

The mean relative fecundity obtained per population (Table 2) is similar to each other with the population of Sohoumè which has the highest relative fecundity. This result could be linked to the genetic characteristics inherent to this population, since although the females had a lower mean weight than the other populations, this population had the highest mean absolute fecundity and mean gonado-somatic index (1402 ± 371.4 eggs and 4.4 ± 1.8 respectively). The relative fecundity obtained remains better than the one reported by de Oliveira et al. (2014) and it ranged from 3.33 to 4.7 eggs/g of the female, by Bombardelli et al. (2017), Osure & Phelps (2006) on different strains of *O. niloticus*. However, these values remain low compared to those obtained by Siddiqui et al. (1998) and Smitherman et al. (1988) who reported relative fecundity of 11.13; 10.56 and 11.96 eggs / g of the female for strains from Egypt, Ghana and Ivory Coast. The variability observed for the mean absolute fecundity and mean relative fecundity between the three populations could be explained by the origin, genetic characteristics, differences between the weights and probable age of the different exploited females since it is reported that relative fecundity in *O. niloticus* decreases with an increase in the weight and age of the female (Rana, 1988; Rana, 1986; Ridha & Cruz, 1989; Siraj et al., 1983), which is supported by the results obtained in the present study (Table 2). Indeed, the age and reproductive history of the different specimens tested is unknown and could be one of the factors influencing these results. Regarding the average length between two spawns, it varies on average for all populations from 14 to 35 days and remains higher than the one reported by Wing Keong & Wang (2011) and Siddiqui et al. (1998) which ranged from 18.6 to 20.8 days for different diets and from 15.8 to 17.1 days respectively. However, it remains better than the one reported by Carvalho et al. (2018) which ranged from 28.53 to 61.12 days. It should be noted that spawning frequency may be influenced by parameters such as the social interactions, environmental factors, collecting eggs from the mouth of female, density, sex ratio, protein level of the food, specimen strain and age (Cissé, 1988; Eguia, 1996; Gunasekera et al., 1996a, 1996b, 1997; Hughes & Behrends, 1983; Jalabert & Zohar, 1982; Ridha et al., 1998; Siddiqui et al., 1997; Siraj et al., 1983). Also, overall fecundity and number of spawns per female could be improved by improving the sex ratio which here was 1:10 in favor of females, which considerably limits the reproduction performance of the single male and reduces the possibility of seeing all females reproduce during the trial period. Only 28.6% to 42.9% of the reproducing females had more than one spawning during the test period.

The average gonado-somatic index of the three populations is similar to the population of Sohoumè which has the highest index. The mean GSI values obtained per population in this study are in the range of values obtained for *O. niloticus* fed with different diets and are still better than those reported by de Oliveira et al. 2014. However, these values remain lower than those reported by Bombardelli et al. (2017) and by Peters & others (1983) which varied respectively from 3.61% to 5.44% and from 4.6% to 10.2%.

Generally, it should be noted that for all three populations except the egg diameter that varies significantly, all other spawning performance parameters considered by this study are similar. Compared with other studies that show overall better performance (Bombardelli et al., 2017; de Oliveira et al., 2014; Peters & others, 1983; Siddiqui et al., 1998; Smitherman et al., 1988). These weak parameters are due to the sex ratio,the protein and energy content of the food used. Indeed, several studies (El-Sayed & Kawanna 2008a; El-Sayed et al., 2003; Gunasekera et al., 1995, 1996a; Lupatsch et al., 2010; de Oliveira et al., 2014; Sotolu, 2010) reported that feeding females with feeds with protein levels ranging from 30% to 40% would increase the reproductive performance of females.

5- Conclusion

Multiple studies have shown the need to ensure the selection of exploited broodstock to respond appropriately to the ever-increasing needs of good quality fry. Based on the results obtained, the present study shows that, although the population of Sohoumè has displayed the highest values for parameters such as the absolute, relative fecundity and GSI, Togbadji population remains the one with an egg diameter that varies significantly compared to the other populations tested. Thus, The Togbadji population has a good spawning performance and could be interesting for the development of a strain for aquaculture.

References

Ahouansou Montcho, S. 2003. “Etude de l’écologie et de La Production Halieutique Du Lac Toho Au Bénin.” Mémoire de DESS, Faculté des Sciences Agronomiques, Université d’Abomey-Calavi, Bénin 88.

Almeida, Diones Bender et al. 2013. “Reproductive Performance in Female Strains of Nile Tilapia, Oreochromis niloticus.” Aquaculture international 21(6): 1291–1300.

Biswas, Amal K. et al. 2005. “Control of Reproduction in Nile Tilapia Oreochromis niloticus (L.) by Photoperiod Manipulation.” Aquaculture 243(1–4): 229–39. https://doi.org/10.1016/j.aquaculture.2004.10.008

Bombardelli, Robie Allan et al. 2017. “Growth and Reproduction of Female Nile Tilapia Fed Diets Containing Different Levels of Protein and Energy.” Aquaculture 479(July): 817–23. http://dx.doi.org/10.1016/j.aquaculture.2017.07.031.

Botaro, Daniele et al. 2007. “Redução Da Prote{\'\i}na Da Dieta Com Base No Conceito de Proteina Ideal Para Tilápias-Do-Nilo (Oreochromis niloticus) Criadas Em Tanques-Rede.” Revista Brasileira de Zootecnia: 517–25. https://doi.org/10.1590/S1516-35982007000300001

Carvalho, Pedro Luiz Pucci Figueiredo et al. 2018. “Available Phosphorus as a Reproductive Performance Enhancer for Female Nile Tilapia.” Aquaculture 486(September 2017): 202–9. https://doi.org/10.1016/j.aquaculture.2017.12.023.

Chong, Alexander S C, Saraitul Dahlianis Ishak, Zulfaizuddin Osman, and Roshada Hashim. 2004. “Effect of Dietary Protein Level on the Reproductive Performance of Female Swordtails Xiphophorus helleri (Poeciliidae).” Aquaculture 234(1–4): 381–92. https://doi.org/10.1016/j.aquaculture.2003.12.003

Cissé, A. 1988. “Effects of Varying Protein Levels on Spawning Frequency and Growth of Sarotherodon Melanotheron.” In The Second International Symposium on Tilapia in Aquaculture, RSV Pullin, T. Bhukasawan, K. Tonguthai and JL Maclean (Eds), , 329–33.

Coward, K, and N R Bromage. 1999. “Spawning Periodicity, Fecundity and Egg Size in Laboratory-Held Stocks of a Substrate-Spawning Tilapiine, Tilapia Zillii (Gervais).” Aquaculture 171(3–4): 251–67. https://doi.org/10.1016/S0044-8486(98)00498-0

Eguia, Maria Rowena R. 1996. “Reproductive Performance of Four Red Tilapia Strains in Different Seed Production Systems.” The Israeli Journal of Aquaculture-Bamidgeh 48(1): 10–18. https://www.cabidigitallibrary.org/doi/full/10.5555/19960104651

El-Sayed, Abdel-Fattah M, and Mamdouh Kawanna. 2008a. “Effects of Dietary Protein and Energy Levels on Spawning Performance of Nile Tilapia (Oreochromis niloticus) Broodstock in a Recycling System.” Aquaculture 280(1–4): 179–84. https://doi.org/10.1016/j.aquaculture.2008.04.030

El-Sayed, Abdel-Fattah M Kawanna, Mamdouh. 2008b. “Optimum Water Temperature Boosts the Growth Performance of Nile Tilapia (Oreochromis niloticus) Fry Reared in a Recycling System.” Aquaculture Research 39(6): 670–72. https://doi: 10.1111/j.1365-2109.2008.01915.x

El-Sayed, Abdel-Fattah M, Cathrine R Mansour, and Altaf A Ezzat. 2003. “Effects of Dietary Protein Level on Spawning Performance of Nile Tilapia (Oreochromis niloticus) Broodstock Reared at Different Water Salinities.” Aquaculture 220(1–4): 619–32. https://doi.org/10.1016/S0044-8486(02)00221-1

Fagbemi, M. N. A., R. Oloukoule, D. S. I. B. Lederoun, C. Laleye, P. A. Melard, and C. Rougeot. 2021. “Comparative study of the breeding performances of five populations of Nile tilapia (Oreochromis niloticus) (F1) in an experimental ongrowing system in Benin (West Africa).” Journal of Applied Aquaculture 35 (1):83–99. https://doi: 10.1080/10454438.2021.1939223 .

FAO. 2018. Licence: CC BY-NC-SA 3.0 IGO La Situation Mondiale Des Pêches et de l’aquaculture 2018. Atteindre Les Objectifs de Développement Durable.

Gunasekera, Rasanthi M, K F Shim, and T J Lam. 1995. “Effect of Dietary Protein Level on Puberty, Oocyte Growth and Egg Chemical Composition in the Tilapia, Oreochromis niloticus (L.).” Aquaculture 134(1–2): 169–83. https://doi.org/10.1016/0044-8486(95)00028-Z

Gunasekera, Rasanthi M Shim, K F Lam, T J. 1996a. “Effect of Dietary Protein Level on Spawning Performance and Amino Acid Composition of Eggs of Nile Tilapia, Oreochromis niloticus.” Aquaculture 146(1–2): 121–34. https://doi.org/10.1016/S0044-8486(96)01365-8

Gunasekera, Rasanthi M Shim, K F Lam, T J. 1996b. “Influence of Protein Content of Broodstock Diets on Larval Quality and Performance in Nile Tilapia, Oreochromis niloticus (L.).” Aquaculture 146(3–4): 245–59. https://doi.org/10.1016/S0044-8486(96)01380-4

Gunasekera, Rasanthi M Shim, K F Lam, T J. 1997. “Influence of Dietary Protein Content on the Distribution of Amino Acids in Oocytes, Serum and Muscle of Nile Tilapia, Oreochromis niloticus (L.).” Aquaculture 152(1–4): 205–21. https://doi.org/10.1016/S0044-8486(96)01526-8

Hughes, D G, and L L Behrends. 1983. “Mass Production of Tilapia Nilotica Seed in Suspended Net Enclosures.” In Tilapia Aquaculture. Proceedings of the International Symposium on Tilapia Aquaculture, Israel Tel Aviv University, Nazareth, , 394–401.

Izquierdo, M S, H Fernandez-Palacios, and A G J Tacon. 2001. “Effect of Broodstock Nutrition on Reproductive Performance of Fish.” Aquaculture 197(1–4): 25–42. https://doi.org/10.1016/S0044-8486(01)00581-6

Jalabert, B, and Y Zohar. 1982. “Reproductive Physiology in Cichlid Fishes, with Particular Reference to Tilapia and Sarotherodon (Tropical and Sub-Tropical).” In International Conference on the Biology and Culture of Tilapias. Bellagio (Italy). 2-5 Sep 1980.,. https://hal.science/hal-01600571v1

Kather, A, A E. 1986. Identification and comparison of three Tilapia nilotica strains for selected aquacultural traits (cold tolerance, reproductive performance, weight gains, growth, color)

Lederoun, Djiman, Jos Snoeks, Philippe Lalèyè, Pierre Vandewalle and Emmanuel Vreven. 2018. “An Updated Checklist of the Ichthyofauna of the Mono River Basin (Benin and Togo: West Africa).” Ichthyological Exploration of Freshwaters 28(2): 135–56. https://hdl.handle.net/2268/222376

Lupatsch, Ingrid, Raviv Deshev, and Igal Magen. 2010. “Energy and Protein Demands for Optimal Egg Production Including Maintenance Requirements of Female Tilapia *Oreochromis niloticus*.” Aquaculture Research 41(5): 763–69. https://doi.org/10.1111/j.1365-2109.2009.02229.x

Macintosh, D J, and D C Little. 1995. “Nile Tilapia (*Oreochromis niloticus*).” Broodstock management and egg and larval quality 277.

Mires, D. 1982. “A Study of the Problems of the Mass Production of Hybrid Tilapia Fry.” In International Conference on the Biology and Culture of Tilapias, Bellagio (Italy), 2-5 Sep 1980,.

Ng, Wing Keong, and Yan Wang. 2011. “Inclusion of Crude Palm Oil in the Broodstock Diets of Female Nile Tilapia, Oreochromis niloticus, Resulted in Enhanced Reproductive Performance Compared to Broodfish Fed Diets with Added Fish Oil or Linseed Oil.” Aquaculture 314(1–4): 122–31. https://doi.org/10.1016/j.aquaculture.2011.01.034.

de Oliveira, Marinez Moraes et al. 2014. “Effects Crude Protein Levels on Female Nile Tilapia (Oreochromis niloticus) Reproductive Performance Parameters.” Animal reproduction science 150(1–2): 62–69. https://doi.org/10.1016/j.anireprosci.2014.08.006

Osure, George O., and Ronald P. Phelps. 2006. “Evaluation of Reproductive Performance and Early Growth of Four Strains of Nile Tilapia (*Oreochromis niloticus*, L) with Different Histories of Domestication.” Aquaculture 253(1–4): 485–94. https://doi.org/10.1016/j.aquaculture.2005.09.019Get rights and content

Peters, Hans M, and others. 1983. “Fecundity, Egg Weight and Oocyte Development in Tilapias (Cichlidae, Teleostei).” *The WorldFish Center Working Papers*.

Rana, K J. 1986. “An Evaluation of Two Types of Containers for the Artificial Incubation of Oreochromis Eggs.” *Aquaculture Research* 17(2): 139–45. https://doi.org/10.1111/j.1365-2109.1986.tb00095.x

Rana, Krishen. 1988. “Reproductive Biology and the Hatchery Rearing of Tilapia Eggs and Fry.” In *Recent Advances in Aquaculture*, Springer, 343–406.

Ridha, M, and E M Cruz. 1989. “Effect of Age on the Fecundity of the Tilapia *Oreochromis spilurus*.” *Asian Fisheries Science* 2: 239–47.

Ridha, M T, E M Cruz, A A Al-Ameeri, and A A Al-Ahmed. 1998. “Effects of Controlling Temperature and Light Duration on Seed Production in Tilapia, *Oreochromis spilurus* (Günther).” *Aquaculture Research* 29(6): 403–10. https://doi.org/10.1046/j.1365-2109.1998.00216.x

Siddiqui, A. Q., Y. S. Al-Hafedh, and S. A. Ali. 1998. “Effect of Dietary Protein Level on the Reproductive Performance of Nile Tilapia, *Oreochromis niloticus* (L.).” *Aquaculture Research* 29(5): 349–58. https://doi.org/10.1046/j.1365-2109.1998.00206.x

Siddiqui, A Q, A H Al-Harbi, and Y S Al-Hafedh. 1997. “Effects of Food Supply on Size at First Maturity, Fecundity and Growth of Hybrid Tilapia, *Oreochromis niloticus* (L.)/ *Oreochromis aureus* (Steindachner), in Outdoor Concrete Tanks in Saudi Arabia.” *Aquaculture Research* 28(5): 341–49. https://doi.org/10.1046/j.1365-2109.1997.t01-1-00864.x

Siraj, S S, R Oneal Smitherman, S Castillo-Galluser, and R A Dunham. 1983. “Reproductive Traits for Three Year Classes of Tilapia Nilotica and Maternal Effects on Their Progeny.” In *Proceedings of the Symposium on Tilapia in Aquaculture, Tel Aviv University, Nazereth, Isreal*, , 210–18.

Smitherman, R O, A A Khater, N I Cassell, and R A Dunham. 1988. “Reproductive Performance of Three Strains of *Oreochromis niloticus*.” *Aquaculture* 70(1–2): 29–37. https://doi.org/10.1016/0044-8486(88)90004-X

Sotolu, A O. 2010. “Effects of Varying Dietary Protein Levels on the Breeding Performance of *Clarias gariepinus* Broodstocks and Fry Growth Rate.” *Blood* 18(21.2): 22–26.

Tave, Douglas, R Oneal Smitherman, V Jayaprakas, and Daryl L Kuhlers. 1990. “Estimates of Additive Genetic Effects, Maternal Genetic Effects, Individual Heterosis, Maternal Heterosis, and Egg Cytoplasmic Effects for Growth in Tilapia Nilotica.” *Journal of the World Aquaculture Society* 21(4): 263–70. https://doi.org/10.1111/j.1749-7345.1990.tb00538.x

Trewavas, Ethelwynn. 1983. *Tilapiine Fishes of the Genera Sarotherodon, Oreochromis and Danakilia*. British Museum (Natural History).

Comparative study of spawn performance of three wild populations of Oreochromis niloticus (Linnaeus, 1758) from Mono basin in Benin

ORIGINALITY REPORT

19%	15%	15%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	orbi.uliege.be Internet Source	4%
2	eprints.usm.my Internet Source	1%
3	dspace.stir.ac.uk Internet Source	1%
4	docksci.com Internet Source	1%
5	Mohammed N. A. Fagbemi, Razzak Oloukoule, Djiman Lederoun, Imaculé S. Baglo et al. " Comparative study of the breeding performances of five populations of Nile tilapia ( ) (F1) in an experimental ongrowing system in Benin (West Africa) ", Journal of Applied Aquaculture, 2021 Publication	1%
6	Amal K. Biswas, Tetsuro Morita, Goro Yoshizaki, Masashi Maita, Toshio Takeuchi. "Control of reproduction in Nile tilapia Oreochromis niloticus (L.) by photoperiod manipulation", Aquaculture, 2005 Publication	1%
7	Submitted to Lilongwe University of Agriculture and Natural Resources Student Paper	1%
8	www.researchgate.net Internet Source	1%
9	core.ac.uk Internet Source	<1%
	www.fisheriesjournal.com	

10	Internet Source	<1%
11	pdacrsp.oregonstate.edu Internet Source	<1%
12	moam.info Internet Source	<1%
13	Mohamed Said. "Reproductive Performance and Early Growth of Three Strains of Nile Tilapia (Oreochromis niloticus) in Egypt: Abbassa, Kafr El Sheikh, and Manzala", Journal of Animal, Poultry & Fish Production, 2016 Publication	<1%
14	Robie Allan Bombardelli, Juliano Kelvin dos Santos Henriques, Marta Margarete Cestari, Antônio Ernesto Meister Luz Marques et al. "Improved sperm DNA integrity and altered fat metabolism and intestinal morphology in Nile tilapia (Oreochromis niloticus) males fed rations with purified nucleotide", Aquaculture, 2022 Publication	<1%
15	horizon.documentation.ird.fr Internet Source	<1%
16	pure.unamur.be Internet Source	<1%
17	Getinet G. Tsadik, Amrit N. Bart. "Effects of feeding, stocking density and water-flow rate on fecundity, spawning frequency and egg quality of Nile tilapia, Oreochromis niloticus (L.)", Aquaculture, 2007 Publication	<1%
18	epdf.pub Internet Source	<1%
19	www.pesca.sp.gov.br Internet Source	<1%
20	ALINIYA, Masoumeh, KHARA, Hossein, NOVEIRI, Shahrouz Baradaran and DADRAS,	<1%

Hadiseh. "Influence of age of common carp (Cyprinus carpio) broodstock on reproductive traits and fertilization", TÜBİTAK, 2013.
Publication

21	crsps.net Internet Source	<1 %
22	repo.bunghatta.ac.id Internet Source	<1 %
23	unsworks.unsw.edu.au Internet Source	<1 %
24	www.nativefishlab.net Internet Source	<1 %
25	www.scielo.br Internet Source	<1 %
26	Getinet G Tsadik. "Characterization and comparison of variations in reproductive performance of Chitralada strain Nile tilapia, Oreochromis niloticus (L.)", Aquaculture Research, 7/2007 Publication	<1 %
27	Hamzah, Azhar, Nguyen Hong Nguyen, Wagdy Mekkawy, Hooi Ling Khaw, Hoong Yip Yee, Khairul Rizal Abu Bakar, Raul W. Ponzoni, and Siti Azizah Mohd Nor. "Genetic parameters and correlated responses in female reproductive traits in the GIFT strain", Aquaculture Research, 2014. Publication	<1 %
28	Marcio Douglas Goes, Andresa Carla Feihrmann, Karen Izabela Freire Silva Carvalho, Leonardo Aluisio Baumgartner et al. "Diets with soybean oil and l-carnitine alter lipid metabolism and improve the growth and reproduction of Rhamdia quelen females", Aquaculture, 2023 Publication	<1 %
29	Zhanyang Tang, Yi Zhou, Jun Xiao, Huan Zhong, Weiwei Miao, Zhongbao Guo, Xu Zhang, Lei Zhou, Yongju Luo. "Transcriptome	<1 %

Analysis of Ovary Development in Nile Tilapia Under Different Photoperiod Regimes", Frontiers in Genetics, 2019
Publication

30	arccjournals.com Internet Source	<1%
31	coek.info Internet Source	<1%
32	docplayer.fr Internet Source	<1%
33	erepository.uonbi.ac.ke Internet Source	<1%
34	hal.archives-ouvertes.fr Internet Source	<1%
35	maxwellsci.com Internet Source	<1%
36	open.library.ubc.ca Internet Source	<1%
37	repositorio.ufsc.br Internet Source	<1%
38	scholar.sun.ac.za Internet Source	<1%
39	www.scielo.org.mx Internet Source	<1%
40	Kpoumie Nsangou Amidou, Tonfack Achile Peguy, Efole Ewoukem Thomas, Djikengoue Kameni Patricia Linda et al. "Reproductive Parameters of Three Populations of Oreochromis Niloticus (Linnaeus, 1758) in the Sudano-Guinean Altitude Zone of Cameroon", International Journal of Aquaculture Research and Development, 2020 Publication	<1%
41	Mohammed Nambyl A. Fagbémi, Lise-Marie Pigneur, Adrien André, Nathalie Smitz et al. "Genetic structure of wild and farmed Nile tilapia (Oreochromis niloticus) populations in	<1%

Benin based on genome wide SNP technology", Aquaculture, 2021
Publication

42	Abdel-Fattah M. El-Sayed. "Reproduction and seed production", Elsevier BV, 2020 Publication	<1%
43	Fangning Xu, Chang Xu, Shusheng Xiao, Maixin Lu, Samwel M. Limbu, Xiaodan Wang, Zhenyu Du, Jian G. Qin, Liqiao Chen. " Effects of α-lipoic acid on growth performance, body composition, antioxidant profile and lipid metabolism of the GIFT tilapia ( ) fed high-fat diets ", Aquaculture Nutrition, 2019 Publication	<1%
44	Marinez Moraes de Oliveira, Tainá Ribeiro, Tamira Maria Orlando, Dênio Garcia Silva de Oliveira et al. "Effects crude protein levels on female Nile tilapia (Oreochromis niloticus) reproductive performance parameters", Animal Reproduction Science, 2014 Publication	<1%
45	Wing-Keong Ng, Yan Wang. "Inclusion of crude palm oil in the broodstock diets of female Nile tilapia, Oreochromis niloticus, resulted in enhanced reproductive performance compared to broodfish fed diets with added fish oil or linseed oil", Aquaculture, 2011 Publication	<1%
46	techagro.org Internet Source	<1%

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		