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Effect of different rates of maggot protein in feed on the growth and cost of production of tilapia *Oreochromis niloticus* (Brazilian strain) at larval stage

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Abstract

The present study was conducted to evaluate the effects of a variation in the ratio of maggot proteins and vegetable proteins in the feed on the growth and production cost of tilapia *Oreochromis niloticus* at the larval stage. The average weight for fish was 19 ± 1 mg. In total, four experimental diets containing 40% crude protein (maggot and vegetal protein) were formulated. The diets were designed D0 (diet containing 0% maggot protein), D1 (diet containing 10% maggot protein), D2 (diet containing 20% protein maggot) and D3 (diet containing 30% maggot protein). The fish were fed four times daily to duplicate groups at 30-20% body weight for consecutive 30 days. After these days, fish fed with D3 had the highest ($p \le 0.05$) mean daily gain (ADG) (11.6 ± 0.82 mg.day^{-1}) compare to those obtained by fish fed D2 (8.38±0.25 mg.day^{-1}) and D1 (8.6±0.46 mg.day^{-1}). During the breeding period, fish fed with D0 had the lowest ADG ($p \le 0.05$) (3.26±0.83 mg.day^{-1}) compared to other feed. The specific growth rate (SGR), feed conversion ratio (FCR), survival rate (SR), and the production cost of 1 kg of fish (PC) were evaluated. In conclusion, the results of this study show that the 30% incorporation rate of maggot protein (D3) in diet improves growth in this species and reduce the cost of 1 kg of fish produced.

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Introduction

Aquaculture has become an essential component of the global supply of animal protein, providing almost half of the fish for human consumption (Fao, 2020). Average global consumption would increase from 14 to 25 kg per capita by 2030 (Fao, 2022). In Ivory Coast, fish remains the main source of animal protein with human consumption between 15 and 16 kg/inhabitant/year (Comhafat, 2014). However, national production is low, despite the immense natural potential that Ivory Coast has to develop fish farming (Fao, 2015). Despite the efforts made by the Ivorian State, the share of fish farming in national fish production is only around 2.4% due to the high cost of feed, the availability of fry to seed the water body and the absence of qualified labor.

According to some authors (Bamba, 2007; Adeyemi *et al.*, 2020) the major constraint to the emergence of fish farming is the high cost of fish meal-based diet to feed the fish.

In recent years, research has been directed towards alternative sources of proteins, in particular agricultural by-products which are not directly usable for human consumption (Hardy, 2010**;** Bosanza *et al.*, 2017; Bamba *et al.*, 2017). However, their use as the only source of protein in fish feed leads to a reduction in growth due to their deficiency in certain micronutrients, notably lysine and methionine, but also the presence of anti-nutritional factors and high levels of fiber (Medale and Kaushik, 2009; Medale *et al.*, 2013). Furthermore, other agricultural by-products directly used by human consumption have been used in fish feed to partially or completely replace fish meal (Miegoue *et al.*, 2018; Adekambi *et al.*, 2024**)**. However, their influence on zootechnical parameters without fish meal remains to be examined and especially their availability.

Recent work has shown that a feed based on maggot meal gives better results in terms of growth compared to that based on fish meal and the incorporation rates of the two flours being the same. In addition, feed made from maggot meal was cheaper, with a production cost reduced by around 30% compared to feed made from fish meal (Gbai *et al.*, 2019), hence the interest in conducting research with a view to completely replacing fish meal with maggot meal. Furthermore, the effectiveness of a given protein source in promoting fish growth depends on its digestibility coefficient (Köprücü and Özdemir, 2005**)**. In general, plant proteins are less digestible than animal proteins. However, in tilapia, the importance of the animal protein/plant protein ratio on growth varies between authors. For Hastings (1973), in a 30% protein diet, animal proteins are not essential in intensive pond farming, while Sitasit and Sitasit (1977) obtain the opposite results. Melard and Philippart (1981) also report that with foods with a low protein content (23-26%), the conversion rates of the food are all the lower as the proportion of animal proteins compared to vegetable proteins is higher. In other tilapia species such as *Oreochromis aureus* and *Oreochromis mossambicus*, the incorporation of animal proteins greatly increases digestion and growth performance (Davis and Stickney, 1978). Appler and Jauncey (1983), however, showed that replacing animal proteins with algae (*Cladophora glomerata*) led to a reduction in growth.

The objective of this work is therefore to evaluate the effects of a variation in the ratio of maggot proteins/vegetable proteins in the feed on the growth and production cost of Brazilian source tilapia *Oreochromis niloticus* at the larval phase.

Materials and methods

Experimental diets

Proportion (%) of ingredients used in the composition of experimental diets is shown in Table 1. Four isoproteic practical diets (40% crude protein content) were formulated with 100% vegetal protein, 10% maggot protein, 20% maggot protein and 30% maggot protein. The proximate composition and cost of formulate diets are shown in Table 2. Maggots were produced from blowflies (Calliphoridae), kept in captivity in dome nets following the description of Mpoame *et al.* (2004). A solar dryer made of a Chinese bamboo device covered with a transparent plastic sheet was used for drying the maggots. The four formulated diets were designated as D0 (diet containing 100% vegetal protein), D1 (diet containing 10% maggot protein and 90% vegetal protein), D2 (diet containing 20% maggot protein and 80% vegetal protein) and D3 (diet containing 30% maggot protein and 70% maggot protein vegetal). All diets were prepared according to the method of Bamba *et al.* (2014).

Table 1. Proportion (%) of ingredients used in formulated diets

Ingredients (%)	Diets			
	D0	D1	D2	D3
Soybean meal	68.5	60.00	51.50	43.00
Copra meal	6.50	6.00	5.50	5.50
Cotton meal	15.00	15.00	15.00	15.00
Low rice flour	2.50	2.50	3.00	3.50
Wheat bran	6.00	6.50	6.500	6.00
Maggot meal	0.00	8.50	17.00	25.50
Palm oil	0.75	0.75	0.75	0.75
Seashell flour	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25
Premix[1]	0.25	0.25	0.25	0.25
Total	100	100	100	100

D0 = diet with 100% vegetable protein, D1 = diet with 10% maggot protein and 90% vegetable protein, D2 = diet with 20% maggot protein and 80% vegetable protein and D3 = diet with 30% maggot protein and 70% vegetable protein

[1]Composition for 2.5 kg of premix; Vitamins A=10 000 000 UI; Vitamins D3 = 2 000 000 UI; Vitamins E= 6 000 mg; Vitamins K3= 1500 mg; Vitamins B1=500 mg; Vitamins B2=1500 mg; Vitamins B6 = 800 mg; Vitamins B12 = 5 mg; Vitamins B9 = 1500 mg; Vitamins B3 = 8000 mg; Vitamins C = 10 000 mg; Choline Chloride = 100 000 mg; Manganese = 60 000 mg; Cobalt = 100 mg; Zinc = 40000 mg; Selenium = 100 mg; Iodine = 500 g; Copper = 3000 mg; Iron = 40 000 mg; Antioxidant = 30000 mg.

Table 2. Proximate composition (%Dry matter) and cost of experimental diets

Component	Diets			
	D0	D1	D2	D3
Moisture	8.67±0.06	8.72±0.07	8.63±0.08	8.79±0.07
Crude protein	39.65 ± 0.12	39.53 ± 0.18	39.55± 0.16	39.59± 0.20
Crude lipid	2.94 ±0.11	3.41±0.08	3.18±0.09	3.10± 0.07
Ash	6.42 ± 0.09	5.83 ± 0.10	5.22 ± 0.08	5.16 ±0.09
Crud fiber	7.22 ±0.11	6.87 ± 0.10	6.53± 0.09	6.78 ±0.10
NFE	35.1 ±0.09	35.64 ±0.11	36.89 ±0.10	36.58±0.12
GE (kJ.g^{-1})	1598.32± 0.08	1623.22±0.12	1636.22±0.09	1628.66±0.13
CF (FCFA. Kg^{-1})	305.57	284.37	262.92	218.47

Nitrogen free extract (NFE) = 100 – (%Moisture + %Protein+ %Ash +%Lipid + %Fiber), GE= Gross Energy = 22.2 × %Protein + 38.9 × %Lipid + 17. 2 × %Nitrogen free extract (Luquet and Moreau, 1992), CF = Cost of 1 kg of feed, Price in CFA pound: 100 CFA= 0.18 $ based on 2021 exchange prices in Ivory Coast.

Experimental condition and fish feeding

The nutrition trial was carried out at the Nangui Abrogoua University aquaculture station (5°21 N and 4°01 W), Ivory Coast. A total of 3200 of *Oreochromis niloticus* larvae were produced by placing 120 mature female and 60 mature male fish together in eight spawning concrete tank for 21 days. The 3200 fish averaging 19 ±1 mg were randomly distributed in eight concrete tanks. The stocking density used was 444 larvae per m^3 in the concrete tank (1.5 m × 1 m × 0.6 m). The feeding experiment was for 30 days. Two concrete tanks were then randomly assigned to each of four experimental diets. Fish were fed the experimental diets four times daily (08:00, 11:00;

14:00 and 17:00 hour) at 30% of wet body weight/day at the beginning and 20% of wet body weight/day at the end of the feeding trial for 2 weeks. At 2 weeks intervals, 25% of the fish population in each concrete tank were randomly sampled, batch weighed. The average weight of the fish sampled in each concrete tank was determined and the amount of feed provided to the fish was adjusted accordingly. Wet weight was measured on an electronic digital balance SARTORIUS L 6200 S (accuracy of ± 0.001 mg). At the end of the feeding period, all experimental concrete tank were emptied and fish counted to determine fish survival.

Water quality parameters

Water quality parameters were monitored during rearing period. Water temperature, dissolved oxygen, and pH were measured daily 08:00 hour using YSI 6920 V2 by the method of Golterman *et al.* (1978). The mean data of physicochemical parameters of water measured in the hapas were showed in Table 3.

Analytical methods

The feed ingredients, experimental diets and fish samples were analyzed according to AOAC (1990) for dry matter, crude protein, crude lipid, crude fiber, nitrogen free extract (NFE) and ash. The gross energy contents of the diets and fish samples were calculated using factors of 22.22, 38.9 and 17.2 $kJ.g^{-1}$ of protein, lipid and nitrogen free extract respectively (Luquet and Moreau, 1992).

Measurement of growth performance, feeds utilization parameters and economic values

Weight Gain (WG) = final fish weight (g) – initial fish weight (g).

Average daily Gain (ADG) = Gain (g) / time (days).

Feed conversion ratio (FCR) = Feed intake (g) / Weight Gain (g).

Protein efficiency ratio (PER) = Weight gain (g) / Protein intake (g).

Survival Ratio (SR %) = (Final fish / initial fish) × 100.

Specific Growth Rate (SGR %) = [(LnFW-LnIW) × 100] / time (days).

Where FW is the final weight of fish, IW is the initial weight of fish and Ln is natural log.

Feed Used (FU) (kg) = Daily ration (kg) × rearing time (days).

Cost of Feed Used (CFU) (F.CFA) = Feed Used (kg) × CF (F.CFA).

Where CF is the cost of 1 kg of feed.

Production Cost (PC) (F.CFA)/kg fish produced = Cost of Feed Used / Weight Gain (kg).

Reduction Rate (RR. CF) of kg of tested feed compared to control feed (%) = [(Cost of 1 kg control feed – Cost of 1 kg tested feed) ×100] / Cost of 1 kg control feed.

Reduction rate (RR. PC) of feed cost to produce 1 kg of fish (%) = [(feed cost to produce 1 kg control fish – feed cost to produce 1 kg tested fish) × 100] / feed cost to produce 1 k g control fish.

Statistical analysis

Results were presented as mean ± SD (standard deviation) for three or two replicates. The statistical analyses were carried out using one-way analysis of variance (ANOVA). The Tukey's multiple range test and Duncan's multiple-range test were used to compare differences among treatment means. Treatment effects were considered significant at $P \leq 0.05$. The analyses were performed using Statistica 7.1 software.

Results

Physicochemical parameters of water

The averages of the physicochemical parameters of the tank water recorded during larval rearing are presented in Table 3. The water temperature ranged from 26.25 ± 0.51 (D2) to 26.45 ± 0.74°C (D0), pH from 7.32 ± 0.47 (D2) to 7.35 ± 0.48 (D3). Dissolved oxygen from 8.50 ± 2.61 (D2) to 9.05 ± 2.96 $mg.L^{-1}$ (D0). Therefore, there were no significant differences ($p > 0.05$) in the water quality parameters among the treatment during rearing.

Nutrient profile of protein ingredients

The proximate compositions of maggot meal, soybean meal, cotton meal, copra meal, Low rice flour and wheat bran meal used as the major protein ingredients in this study were presented in Table 4. The crude protein content was found to be highest for maggot meal followed by soybean meal and cotton meal respectively. On the other hand, crude lipid was recorded to be highest for maggot meal followed by copra meal and soybean meal respectively.

Table 3. Physicochemical parameters of water

Parameters	Diets			
	D0	D1	D2	D3
O_2 (mg/l)	9.05 ± 2.96	8.68 ± 2.57	8.50 ± 2.61	8.55 ± 2.87
T (°C)	26.45 ± 0.74	26.41 ± 0.65	26.25 ± 0.51	26.32 ± 0.72
pH	7.30 ± 0.48	7.35 ± 0.48	7.32 ± 0.47	7.35 ± 0.48

Each value is the mean ± Standard deviation. Means with the same letters in the same row are not significantly different (P>0.05). ANOVA and HSD Tukey's multiple test. D0 = diet with 100% vegetable protein, D1 = diet with 10% maggot protein and 90% vegetable protein, D2 = diet with 20% maggot protein and 80% vegetable protein and D3 = diet with 30% maggot protein and 70% vegetable protein

Table 4. Analyzed nutrient composition (% Dry Matter) of protein ingredients

Component	Ingredients					
	MM	LR	SM	CM	COM	WB
M (%)	8.57	9.78	10.76	7.89	8.24	11.78
Ash (%)	5.20	8.00	6.00	5.00	6.00	7.36
CP (%)	47.26	10.00	46.00	40.00	20.00	14.33
CL (%)	27.03	3.20	18.00	4.00	9.00	3.73
Fiber (%)	2.00	16.00	4.00	14.00	19.00	18.67
NFE (%)	9.94	53.02	15.24	29.11	37.76	44.13

Values are average from duplicate groups of samples.

MM= Maggot meal, LR= Low rice flour, SM= Soybean meal, CM= Cotton meal, COM= Copra meal, WB= Wheat bran, M = Moisture, CP = Crude protein, CL = Crude lipid, NFE = Nitrogen free extract. Nitrogen free extract (NFE) =100 – (%Moisture + %Protein+ %Ash +%Lipid + %Fiber) (Luquet and Moreau, 1992)

Table 5. Growth performance, survival rate, feed conversion ratio and protein efficiency ratio

Parameters	Diets			
	D0	D1	D2	D3
SR (%)	98.85 ± 0.07	98.65 0 ± 0.21	98.35 ± 0.21	98.13 ± 0.17
IW (mg)	19 ± 10	19 ± 10	19 ± 10	19 ± 10
FW (mg)	116.92 ± 25.12^a	277.08 ± 13.86^b	270.40 ± 7.54^b	366.95 ± 24.65^c
WG (mg)	97.92 ± 25.12^a	258.08 ± 13.86^b	251.40 ± 7.54^b	347.95 ± 24.65^c
ADG (mg.days^{-1})	3.26 ± 0.83^a	8.6 0± 0.46^b	8.38 ± 0.25^b	11.6 ± 0.82^c
SGR (%.days^{-1})	5.97 ± 0.72^a	8.92 ± 0.16^b	8.82 ± 0.90^b	9.84 ± 0.22^c
FCR	1.54 ± 0.20^a	0.95 ± 0.11^b	0.93 ± 0.01^b	0.80 ± 0.10^c
PER	1.20 ± 0.28^a	2.15 ± 0.07^b	2.1 ± 0.001^b	2.65 ± 0.49^c

Each value is the mean ± Standard deviation. Means has the different letters in the same row are significantly different at p ≤ 0.05. ANOVA and Tukey's multiple tests

Growth performance and feed utilization

At the larval stage, significant effects (p≤ 0.05) of the different ratio of maggot proteins and vegetable proteins on the growth performance of *Oreochromis niloticus* were observed (Table 5). Use the 30% maggot protein in fish feed gave higher (p ≤ 0.05) final weight (FW) followed by fish fed with diet contained 20% maggot protein and 10 % maggot protein. *Oreochromis niloticus* larval fed with diet contained 100% vegetal protein got the lowest FW compared to other diet. Survival rate (SR), were similar (p> 0.05) for all diets.

Cost-benefit analysis

The data on the kilogram costs of the feeds used, and the rates of reduction of these costs were evaluated (Table 6). The analysis of financial profitability shows that, the use 30 % of maggot protein in the diet of *Oreochromis niloticus* resulted in a decrease the cost of 1 kg of feed (cost/kg of feed) by 28.50% compared to D0. In addition, the use of 30 % of maggot meal protein in diet to fed fish also helped reduce the production cost of 1kg of fish by 70.74 % compared to D0.

Table 6. Cost-benefit analysis

Parameters	Diets			
	D0	D1	D2	D3
CF (FCFA/Kg)	305.57	284.37	262.92	218.47
QFU (g)	516.90	217.20	207.03	235.65
CFU (FCFA)	157.94	61.76	54.43	51.48
PC (FCFA/Kg)	644.65	282.51	256.74	188.57
RR. CF/D0 (%)	--	6.93	13.95	28.50
RR. PC/D0 (%)	--	56.17	60.17	70.74

CF= Cost of 1 kg of feed, QFU= Quantity of feed used, CFU= cost of feed used, PC= production cost of 1 kg of fish, RR. CF/D0 = Reduction Rate of CF compared to D0, RR. PC/D0= Reduction Rate of PC compared to D0, -- = Absents values.

Discussion

The average values of the physicochemical parameters of the water recorded during the breeding period are similar from one pond to another. According to Balarin and Haller (1982), the optimal temperature for the growth and survival of tilapia is between 25°C and 30°C, the pH must be between 5 and 11 (Billard and Marcel, 1980; Konan *et al*., 2017). For dissolved oxygen, it was 9.05, 8.68, 8.50 and 8.55 $mg.L^{-1}$ respectively for D0, D1, D2 and D3. According to Lequenne (1984), tilapia is not very demanding in dissolved oxygen. They can survive at an oxygen concentration of 1.2 mgL^{-1} (Coche ,1978). These dissolved oxygen values were also within the limits indicated by Effendi (2016) and Kunindar *et al.* (2018) for the good survival and growth of fish. The values recorded in this study for these parameters make it possible to say that the waters of the experimental ponds were of good quality for the growth and survival of fish. The maggot meal used in this study presented excellent nutritional quality. The protein rate of 47.26±0.1% obtained in the present study is higher than that of Gbai *et al.* (2019) (40.7%) obtained in a previous study. This rate in our work could be explained by the nature of the production substrate (only fish gills), while the previous author used a mixture of pig slurry and fish gills. Indeed, according to Bouafou *et al.* (2007), the biochemical composition of maggots depends on their stage of larval development but also on the drying time. Fat and ash rates were similar to those obtained by Gbai *et al.* (2019). Lipids were 28.5% compared to 27.09±0.05% in the present study, and ash was 5.20±0.03% in the present study compared to 7.90% in Gbai *et al.* (2019)**.**

Survival rates were greater than 98%. This result shows that the test diets were not toxic to the fish. After 30 days of rearing the larvae, the results obtained show that the larvae fed with feeds formulated with maggot meal (D1, D2 and D3) elicited higher growth performances (FW, ADG and SGR) than those with the D0 diet. The slowdown in larval growth observed with the D0 diet could be explained by the low uptake of the D0 by the fish as shown by Medale *et al.* (2013) and Francis. (2001). Indeed, according to these authors, materials of plant origin contain anti-nutritional factors such as tannins which reduce the consumption of the feed. On the other hand, the better growth recorded in fish fed with diets D1 and D2 and D3 would certainly be linked to the effective use of these diets. But even more, the D3 diet would be more digestible than these two other feeds (D1 and D2).

It contributed to a good start to growth. The low value of the consumption index (0.80 compared to 1.54 for D0) justifies the good quality of this feed which would be more digestible and easily assimilated by the fish than the Do. For Sklan *et al.* (2004) and Köprücü and Ozdemir (2005), the performance of a compound feed depends closely on the variability of the coefficient of digestibility, adsorption and the availability of the nutrients which constitute it. The economic evaluation of formulated diets shows a reduction in the cost per kilogram of diet formulated with 10, 20 and 30% of maggot meal compared to diet formulated with 100% plant protein. In the same order, production costs per kilogram of fish were reduced with diets containing maggot meal, compared to that of diets formulated with 100% plant protein. The reduction in these costs can be explained on the one hand by the efficiency of the feed, and on the other hand by the lower cost of the maggot flour produced. In fact, the production of maggot meal is less expensive, thus leading to a reduction in the cost per kilogram of formulated diet and the cost per kilogram of fish produced.

Conclusion

The results obtained during this study highlighted the benefit of incorporating less expensive maggot meal into the diet of tilapia in the larval phase, replacing fish meal. Furthermore, the use of maggot flour at a protein level of 30% contributed to a strong start to the growth of the larvae. At the end of this work, it appears appropriate to continue research on other aspects of feeding in order to have a high-performance and less expensive feed for the rearing of *O. niloticus* in the larval phase. This will include work on different protein levels (30%, 35%, and 40%) and on the frequency of food distribution on the growth and production cost of the species.

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References

Adekambi DA, Adechola PPK, Ifagbemi BC, Abdel-Fadel A, Martinus JRN, Anita RL. 2024. Formulating efficient and affordable feeds for *Clarias gariepinus* (Burchell, 1822) based on locally available ingredients in Benin, West Africa. International Journal of Fisheries and Aquaculture **16**(1), 1-12.

Adeyemi AD, Kayode APP, Chabi IB, Odouaro OBO, Nout MJR, Linnemann AR. 2020. Screening local feed ingredients of Benin, West Africa, for fish feed formulation. Aquaculture Reports **17**, 100386. https://doi.org/10.1016/j.aqrep.2020.100386.

AOAC. 1990. Association of official optimal aquaculture chemists. Official methods of analysis. 15th ed. Benjamin Franklin Station, Washington D.C., USA.

Appler HN, Jauncey K. 1983. The utilization of a filamentous green alga (*Cladophora glomerata* (L) Kutzin) as a protein source in pelleted feeds for *Sarotherodon niloticus* fingerlings. Aquaculture **30**, 21-30.

Balarin JD, Haller RD. 1982. The intensive culture of tilapia in tanks, raceways and cages. In: Muir JF, Roberts RJ (Eds.), Recent Advances in Aquaculture Vol. 1. Croom Helm, London, 265-356.

Bamba Y, Ouattara N, Soro Y, Ouattara A, Yao K, Gourène G. 2014. Evaluation of production efficiency of Nile tilapia (*Oreochromis niloticus* L.) fed diets containing crop residues in combination with cocoa bean shell and coconut oil cake in Côte d'Ivoire. Livestock Research for Rural Development **26**(189).

Bamba Y, Ouattara S, Ouattara N, Doumbia L, Ouattara A, Da Costa KS, Gourene G. 2017. Incorporation du coprah et des cuticules de cacao et d'arachide dans l'aliment du tilapia du Nil (*Oreochromis niloticus*, Linné, 1758) élevé en étang : Effet sur la croissance et la composition biochimique. Agronomie Africaine **29**(2), 1-14.

Bamba Y. 2007. Production en étang du tilapia *Oreochromis niloticus* (Linné, 1758) nourris avec des sous-produits agricoles sans adjonction de farine de poisson. Thèse de Doctorat, Université d'Abobo-Adjamé, Abidjan, 155p.

Billard R, Marcel J. 1980. Quelques techniques de production de poissons d'étangs. Pisciculture France **59**, 9-16 et 41-49.

Bosanza JBZ, Mongeke MM, Bobuya PN, Bedi BN, Mukendi B, Manzongo DB, Djoza DR, Ngbolua KN. 2017. Effect of nourishment and fertilization on the growing of *Oreochromis niloticus* (Linnaeus, 1758) (Cichlidae), bred in semi-drained ponds in the Sud Ubangi (Democratic Republic of the Congo). International Journal of Innovation and Scientific Research **33**(1), 162-176.

Bouafou K, Kouame K, Offoumou A. 2007. Bilan azoté chez le rat en croissance de la farine d'asticots séchés. Tropicultura **25**(2), 70-74.

Coche AG. 1978. Revue des pratiques d'élevage de poissons en cages dans les eaux continentales. Aquaculture **13**, 157-189.

Comhafat. 2014. Rapport n°7 de la revue de l'industrie des pêches et de l'aquaculture dans la zone de la COMHAFAT, 100p.

Davis AT, Stickney RR. 1978. Growth responses of *Tilapia aurea* to dietary protein quality and quantity. Transaction of American Fisheries Society **107**, 479.

Effendi H. 2016. River water quality preliminary rapid assessment using pollution index. Proceedings of Environmental Science **33**, 562-567.

FAO. 2015. Engrais et fertilisant: Système d'information sur les ressources alimentaires et d'engrais en aquaculture. Rome, Italy, 15p.

FAO. 2020. The State of World Fisheries and Aquaculture, 7p.

FAO. 2022. Autosuffisance de la Côte d'Ivoire en tilapia. FAO: programme FISH4ACP, 22p.

Francis G, Makkar HPS, Becher K. 2001. Antinutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish. Aquaculture **199**, 197-227.

Gbai M, N'golo O, Bamba Y, Mamadou O, Ouattara A, Yao K. 2019. Substitution of the fishmeal by maggot meal in the feed of Nile tilapia *Oreochromis niloticus* at different stages of growth. International Journal of Fisheries and Aquaculture Research **5**(1), 1-16.

Golterman HL, Clymo RS, Ohnstad MAM. 1978. Methods of physical and chemical analysis of fresh water. Oxford, UK: Blackwell Scientific.

Guillaume J, Kaushik S, Bergot P, Metailler R. 1999. Nutrition et alimentation des poissons et crustacés. INRA, Paris, France, 489p.

Hardy RW. 2010. Utilization of plant proteins in fish diets: Effects of global demand and supplies of fishmeal. Aquaculture Research **41**, 770-776.

Hastings WH. 1973. Regional project on research and fisheries development (Cameroon-Central African Republic - Gabon - Congo People's Rep.). Experience related to diet preparation of fish feed and their feeding. Report prepared for the regional project. FAO Project Report, FAO-FI-DP/RAF-66/054/10, 24p.

Konan SK, Ouattara N, Yao LA, Gourène Adepo B. 2017. Hybridization of *Oreochromis niloticus* (Linnaeus, 1758) with *Tilapia guineensis* (Bleeker, 1862) and *Sarotherodon melanotheron* (Rüppell, 1852) in ponds at Layo Aquaculture Station (Côte d'Ivoire). International Journal of Biology and Chemical Sciences **11**(6), 2901-2913. DOI: 10.4314/ijbcs.v11i6.27.

Köprücü K, Özdemir Y. 2005. Apparent digestibility of selected feed ingredients for Nile tilapia (*Oreochromis niloticus*). Aquaculture 308-316.

Kunindar S, Efendi E, Supono S. 2018. Utilization of tofu and tapioca industrial liquid waste for Nile tilapia (*Oreochromis niloticus*) culture within different biofloc systems. e-Jurnal Rekayasa dan Teknologi Budidaya Perairan **7**(1), 763-774. DOI: 10.23960/jrtbp.v7i1.p763-774.

Lequenne P. 1984. Les fermes marines. Éd. Charley Yves Chandroreille, 126p.

Luquet P, Moreau Y. 1992. Energy-protein management by some warm water fin fishes. In: Advances in Tropical Aquaculture, Actes du Colloque n°9, AQUACOP, Tahiti, 129-162.

Medale F, Boucher R, Dupont-Nivet M, Quillet E, Aubin J, Panserat S. 2013. Les aliments à base de végétaux pour les animaux d'élevage. INRA Prod. Anim. **26**, 303-316.

Medale F, Kaushik S. 2009. Les sources protéiques dans les aliments pour les poissons d'élevage. Cahiers Agricultures **18**, 103-111.

Melard CH, Philippart JC. 1981. La production de tilapia de consommation dans les rejets industriels d'eau chaude en Belgique. Cahiers d'Ethologie Appliquée, collection Enquêtes et dossiers **2**, vol. 1, suppl. 2, Institut de Zoologie de l'Université de Liège, 122p.

Miegoue E, Zebaze PDT, Tendonkeng F, Lemoufouet J, Njoh NE, Nganyo RK, Pamo ET. 2018. Effect of replacement of fishmeal with lima bean meal on the zootechnical performances of African catfish (*Clarias gariepinus*) in the Batié Subdivision, West Region of Cameroon. International Journal of Aquaculture Research and Development **1**(1). DOI: 10.14302/issn.2691-6622.ijar-18-2463.

Mpoame M, Téguia A, Nguemfo EL. 2004. Essai comparé de production d'asticots dans les fientes de poule et dans la bouse de vache. Tropicultura **22**(2), 84-87.

Sitasit D, Sitasit V. 1977. Comparison of the production of *Tilapia nilotica* (Linn.) fed with protein from different sources. In: Indo-Pacific Fisheries Council, Proc. 17th session, Colombo, Sri Lanka, 27 Oct.-5 Nov. 1976: Section 3-Symp. On Dev. And Util. Of Inld. Fish. Res. FAO Regional Office for Asia and the Far East, Bangkok, Thailand, 400-403.

Sklan D, Uni Z, Amit-Romach E. 2004. Microflora ecology of the chicken intestine using 16S ribosomal DNA primers. Poultry Science **83**(7), 1093-1098.