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EVALUATION OF THE ZOOTECHNICAL PERFORMANCE OF *OREOCHROMIS NILOTICUS* FED LOCAL BY-PRODUCTS ENRICHED WITH PROBIOTICS

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ABSTRACT

This study aimed to evaluate the zootechnical performance of *Oreochromis niloticus* fed a formulated diet based on agricultural by-products and supplemented with probiotics. Three different treatments were administered to the fish: an industrial feed treatment (control), a formulated feed supplemented with probiotics (AAP), and a formulated feed without probiotics (ASP). Growth performance and welfare indicators were assessed. The results showed no significant differences among treatments for growth parameters, with mean daily weight gains of 61.24 ± 2.22 g (control), 62.1 g (AAP), and 69.51 ± 2.83 g (ASP). In contrast, among the welfare indicators, only the gonadosomatic index showed a significant difference among treatments. The highest value was recorded in fish receiving the probiotic-supplemented diet (1.12 ± 0.19%). These findings confirm the potential of agricultural by-products as cost-effective substitutes for industrial feeds, thereby helping to secure aquaculture feed supply. Combined with the use of probiotics, this approach effectively supports the physiological health of fish.

Keywords: *Oreochromis niloticus*, Zootechnical Performance, Probiotics, Growth, Welfare.

1 INTRODUCTION

Oreochromis niloticus is currently recognized as one of the major species in African aquaculture (Toko et al., 2010). This position can be attributed to its good zootechnical performance, highly adaptable feeding habits, and strong market demand (Lazard, 2009 ; Amoussou et al., 2017). However, aquaculture faces major challenges, particularly antimicrobial resistance associated with the excessive use of antibiotics, as well as the high cost and scarcity of nutritional inputs

(Tanon et al., 2026). This situation directly threatens the viability of aquaculture operations, leading to substantial economic losses or even production shutdowns. In this context, the use of probiotics in combination with agricultural by-products represents a sustainable alternative. Consequently, the incorporation of plant residues has been the subject of numerous studies, including those by Brou et al. (2020), which have highlighted the formulation of feeds based on combinations of several locally available products, with the aim of reducing costs while maintaining nutritional stability. However, these raw materials present nutritional constraints, particularly low protein content and reduced digestibility under certain conditions (FAO, 2014). To enhance their nutritional value, fermentation may be considered, together with fishmeal supplementation to compensate for protein deficiencies (Médale et al., 2013). Therefore, the incorporation of formulated feeds based on fermented agricultural by-products and enriched with probiotics is emerging as a promising alternative. The present study falls within this context and aims to evaluate the effects of such a formulation on the zootechnical performance of *Oreochromis niloticus*.

2 MATERIALS AND METHODS

2.1 Biological material

The experiments were conducted on juvenile tilapia (*Oreochromis niloticus*) obtained from the National Center for Agronomic Research in Bouaké (Côte d'Ivoire). The agricultural by-products used included banana peels, dried peanut shells, mango kernels, and sweet potato leaves. Saccharomyces cerevisiae and Bacillus amyloliquefaciens were used as probiotic strains.

2.2 Methods

2.2.1 Formulation of a feed based on agricultural by-products

The feed formulation based on agricultural by-products relied on linear programming, a mathematical method used to achieve a fixed protein content of 35% in each feed mixture. Incorporation of the probiotic strains into the feed first involved inoculating the two probiotic strains, Bacillus amyloliquefaciens and Saccharomyces cerevisiae, in BHI broth and Sabouraud medium, respectively. After growth, each microbial suspension was centrifuged at 3,000 rpm for 10 minutes. The recovered pellet was resuspended in saline solution at 9/1000. The probiotics were directly incorporated (Angoua et al., 2025) into the formulated feed at a concentration of 10^8 CFU/mL. The formulated feed was then processed into homogeneous pellets. The feed was subsequently dried at room temperature for 4–5 hours under a laminar-flow hood, with stirring every hour (Castex, 2009; Chemlal-Kherraz, 2013).

2.2.2 Experimental design

The experimental setup consisted of aquaria with a capacity of 300 L each (150 × 50 × 40 cm), operated in an open-flow system. Each treatment consisted of three aquaria containing thirty juveniles each and began after a period of acclimation of the fish to the experimental conditions. The fish were then fed different diets corresponding to the respective treatments: commercial industrial feed used as the control, formulated feed supplemented with probiotics, and formulated feed without probiotics. The experiment lasted seven weeks.

2.2.3 Zootechnical Analysis

2.2.2.1 Assessment of Growth Performance

At the end of the experiment, fish growth and welfare parameters were assessed. The growth indices considered included weight gain, total length, daily weight gain, and specific growth rate (Thabet, 2017).

The body weight gain (BWG) of the fish was determined by individual weigh-ins conducted on an electronic scale at the beginning and end of the experiment.

GMC = mf – mi   Where: mf = final weight; mi = initial weight

Linear growth of the fish was monitored using an ichtyometer throughout the various treatment periods.

To assess the daily growth of the fish, daily weight gain was calculated based on weigh-ins conducted at the beginning and end of the experiment. This was determined using the following equation: ADWG = fw – bw /ΔT   Where: ADWG: average daily weight gain; fw: final weight; bw: initial weight; and ΔT: time interval in days

The specific growth rate measures the daily weight gain of a fish, expressed as a percentage of its live biomass. Calculated by dividing the difference between the natural logarithms of the final and initial masses by the duration of the experiment (in days), it is determined using the following formula: TCS = (ln mf – ln mi) /ΔT × 100   Where: TCS:

specific growth rate; ln mf: natural logarithm of final mass; ln mi: natural logarithm of initial mass; ΔT: change in time per day

2.2.2.2 Evaluation of Welfare Measures

The hepato-somatic index (HSI) is the ratio of liver mass to body mass (Bougis 1952).

IHS = (liver mass (g)) / (total fish mass (g)) * 100

The gonado-somatic index (GSI) is the ratio of gonadal weight to body weight (Kime, 1999).

IGS = (gonad mass (g)) / (total fish mass) * 100

The Fulton constant (K), or Fulton condition index, was calculated based on the fish's size and length parameters (Smolders et al., 2005).

K = (mass of the fish (g)) / ((length of the fish (cm))^3) * 100

The survival rate (Rukera et al., 2005) was calculated based on the ratio of the total number of fish at the end of the experiment to the number of fish at the start of the rearing period, using the following formula:

TS = (Final number of fish) / (Initial number of fish) * 100

2.3 2.2.4. Statistical analysis

The data obtained were analyzed using Statistica software, version 7.1 (StatSoft France, 2005).

Means and standard deviations were calculated. The non-parametric Kruskal–Wallis test, including multiple comparisons at the 5% significance level, was used to compare the treatments based on fish growth and welfare parameters.

3 RESULTS AND DISCUSSION

Statistical analysis of the data obtained for fish growth parameters did not differentiate the three dietary treatments (Table 1). Final fish weight was statistically similar, with values ranging from 61.24 ± 2.22 g (ASP), 62.1 ± 1.54 g (AAP), to 69.51 ± 2.83 g (control). Our results are broadly similar to those reported by Lazard (2009a). The similarity in weight among treatments indicates that feeds formulated from agricultural by-products may contain nutritional components comparable to those of industrial feeds. Likewise, the statistically similar mean daily weight gain (0.57 ± 0.03 g (control), 0.517 ± 0.06 g (ASP), and 0.71 ± 0.07 g (AAP)) across all treatments shows that the formulated feeds provide nutritional inputs comparable to the control, thereby supporting adequate daily growth. This is consistent with Gabriel et al. (2007), who reported that daily fish growth strongly depends on the balance between energy and protein in the feed. Furthermore, body length (13.54 ± 0.35 cm (control), 14.17 ± 0.45 cm (ASP), and 13.54 ± 0.35 cm (AAP)), which remained broadly similar among treatments, suggests adequate nutritional intake from the formulated feeds. Indeed, tilapia growth in length depends mainly on environmental and nutritional factors (Gabriel et al., 2017). Regarding specific growth rate, the absence of differences among treatments suggests better nutritional utilization of agricultural by-products. Tilapia has digestive capacities adapted to feeds rich in fiber and plant-based materials (Lazard, 2009b; Médale et al., 2013).

Table 1: Growth Parameters of *Oreochromis niloticus*

Parameters	Control	AAP	ASP
Weight (g)	69,51 ± 2,83a	62,1 ± 1,54a	61,24 ± 2,22a
Mean daily weight gain (g/day)	0,57 ± 0,03a	0,71 ± 0,07a	0,517 ± 0,06a
Length (cm)	13,54 ± 0,35a	13,54 ± 0,35a	14,17 ± 0,45a
Specific growth rate (%/day)	0,53 ± 0,03a	0,62 ± 0,06a	0,48 ± 0,08a

*Within the same row, mean values bearing the same superscript letter are not significantly different at the 5% probability level. AAP: probiotic-supplemented feed; ASP: feed without probiotics.

The welfare parameters of *Oreochromis niloticus* showed that only the gonadosomatic index (GSI) varied significantly among treatments (Table 2). The highest value (1.12 ± 0.19) was recorded in fish fed the probiotic-supplemented diet

(AAP), suggesting a beneficial effect of probiotics on fish reproductive function. These results are consistent with those reported by Patterson (2008) and Chemlal-Kherraz (2013), who highlighted that probiotics, particularly *Saccharomyces cerevisiae* and bacteria of the genus *Bacillus*, are known to improve nutrient assimilation and stimulate overall metabolism.

In contrast, no significant difference was observed in the hepatosomatic index (HSI), with values ranging from 2.18 ± 0.07 in the control group, 1.97 ± 0.47 in the AAP group, and 2.19 ± 0.27 in the ASP group. This indicates that the incorporation of probiotics did not affect hepatic energy metabolism. Wang et al. (2017) reported that probiotics can stabilize liver function by reducing oxidative stress and enhancing immunity.

Similarly, Fulton's condition factor (K), an indicator of fish body condition, showed similar values of 1.59 ± 0.06% for the control, 1.73 ± 0.03% for AAP, and 1.72 ± 0.02% for ASP. This indicates that the fish maintained good overall condition regardless of the dietary treatment. Smolders et al. (2005) showed that stability in Fulton's condition factor reflects harmonious growth and a good balance between fish length and body weight.

Regarding the survival rates (SR), which reached 100% in all treatments, the results showed that neither the addition nor the absence of probiotics compromised fish viability. Similar observations were reported by Aly et al. (2008) and Hai (2015), who demonstrated that the incorporation of probiotics into tilapia diets does not negatively affect fish survival.

Table 2: Welfare parameters of *Oreochromis niloticus*

Parameters	Control	AAP	ASP
Indice gonado-somatique (IGS)	0,78 ± 0,05b	1,12 ± 0,19a	0,55 ± 0,12c
Hepatosomatic index (HSI)	2,18 ± 0,07a	1,97 ± 0,47a	2,19 ± 0 ,27a
Constante de Fulton (K)	1,59 ± 0,06a	1,73 ± 0,03a	1,72 ± 0,02a
Survival rate (%)	100a	100a	100a

*Within the same row, mean values bearing the same superscript letter are not significantly different at the 5% probability level. AAP: probiotic-supplemented feed; ASP: feed without probiotics.

4 CONCLUSION

At the end of this study, which aimed to evaluate the zootechnical performance of Oreochromis niloticus fed a formulated diet based on agricultural by-products supplemented with probiotics, the results indicated stable growth parameters across the different treatments. This demonstrates that formulations based on agricultural by-products effectively meet the nutritional requirements of tilapia, resulting in growth performance equivalent to that obtained with commercial feed. Among the welfare indicators evaluated, only the gonadosomatic ratio (GSR) showed significant variability among groups, with the best performance recorded in individuals receiving the probiotic-enriched diet. These observations suggest a positive effect of probiotics on reproductive physiology. Overall, agricultural by-products supplemented with probiotics could constitute suitable alternative feeds to industrial fish feed.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

[1] **Toko I. I., Attakpa Y. E. et WANG E. H. (2017).** Biological, zootechnical, and nutritional performance of **Tilapia guineensis** in natural and culture environments. Int. J. Biol. Chem. Sci. 4(5), pp. 1629-1640.

[2] **Lazard J. (2009a)**. Tilapia farming. Cahiers Agricultutes, **Vol**.18 N°2-3, pp.393–401.

[3] **Amoussou T. O., Chikou A., Toguyeni A., Toko I. I. et Karim I. Y. A. (2016).** Biological and zootechnical characteristics of African tilapias (*Oreochromis niloticus)* (Linnaeus, 1758) et *Sarotherodon melanotheron* Rüppell, 1852 : une revue. *International Journal of Biological and Chemical Sciences*, **Vol**.10 N°4, pp.1869-1887.

[4] **Tanon T. F. E., Coulibaly S., Aboua D. R. B. et Atse C. B. (2026).** Zootechnical performance of juvenile *Oreochromis niloticus* (Brazilian strain) reared in ponds on three local feeds (Côte d'Ivoire). Journal of Applied Biosciences 218, pp. 24205 – 24213 .

[5] **Brou, KJ, N'zué KR, Oswald M, et Bamba Y. (2020).** Use of wheat and rice brans in fish feed. African journal of Agricultural Sciences, 15(2), 45–56.

[6] **FAO. (2014).** The State of World Fisheries and Aquaculture. Rome: Food and Agriculture Organization, pp. 95-120.

[7] **Médale, F., Lefèvre, F., et Corraze, G. (2013).** Nutrition of farmed fish. . INRA Productions Animales, 26(4), pp. 307-318.

[8] **Angoua, A. M. P., Moroh, J.-L. A., N'Dri, A. R., Fofana, F., Angoratchi, M. E. Y.-M., Roque D'Orbcastel, E., Bettarel, Y. et Coulibaly, A., 2025**. Spray incorporation of *Bacillus subtilis* and *Saccharomyces cerevisiae* with different binding agents into granules for *Oreochromis niloticus*. *GSC Biological and Pharmaceutical Sciences.* 30 (1), 223-232.

[9] **Castex M. (2009).** Evaluation of the bacterial probiotic *Pediococcus acidilactici* MA18/5M in the penaeid shrimp *Litopenaeus stylirostris* in New Caledonia. PhD in Nutritional Physiology Institute of life and Environmental Sciences and Industries (Agro Paris Tech), University, 450 p.

[10] **Chemlal-Kherraz D. (2013).** Isolation and phenotypic identification of lactic acid bacteria from Nile tilapia (*Oreochromis niloticus*) and assessment of their probiotic potential. PhD, Environmental Sciences, University of Oran, 217 p.

[11] **Thabet R. (2017).** Comparative study of Nile tilapia *Oreochromis niloticus*farming in fresh water versus geothermal water in Tunisia. Master's degree, Fisheries and Aquaculture Sciences. Agrocampus Ouest, 72 p.

[12] **Bougis, P. (1952).** Relationship between the liver and energy reserves in fish. Journal of Animal Physiology, 44, pp. 55-63.

[13] **Kime, D. E. (1999).** A strategy for assessing the health of fish. Fisheries Research Services, pp. 75-82.

[14] **Smolders, R., Vervets, L., et Blust, R. (2005).** Fulton's condition factor as an indicator of fish health. *Environmental Toxicology*, 20, pp. 172-180.

[15] **Rukera, T.S., Micha, J. & Ducarme, C., (2005)** Trials on adapting mass production of *Clarias gariepinus* juveniles to rural conditions. Tropicultura, 23 (4), 231-244.

[16] **StatSoft France, 2005.**- Statistica, data analysis software version 7.1. www.statsoft.fr .

[17] **Gabriel, U.U., Akinrotimi, O.A., Bekibele, D.O., Onunkwo, D.N. et Anyanwu, P.E. (2007).** Use of local feeds in fish farming. *African Journal of Agricultural Research*, 2(7), 287–295.

[18] **Gabriel, U. U., Akinrotimi, O. A., Bekibele, D. O., Onunkwo, D. N., et Anyanwu, P. E. (2017).** Effect of incorporating plant co-products on tilapia growth. Journal of Aquaculture Research, 8(3), pp. 45–52.

[19] **Lazard J. (2009b).** Summary of fish farming for selected species. Cahiers agricultures, **Vol**.18 N°2-3, pp.174-182.

[20] **Patterson, J. A. (2008).** Probiotics in animal nutrition. Animal Feed Science and Technology, 145, pp. 1–15.

[21] **Chemlal-Kherraz D. (2013).** Isolation and phenotypic identification of lactic acid bacteria from Nile tilapia (Oreochromis niloticus) and assessment of their probiotic potential. PhD, Environmental Sciences, University of Oran, 217p.

[22] **Wang, Y., Li, J., et Lin, J. (2017**). Probiotics aquaculture : challenges and prospects. Aquaculture : challenges and prospects. Aquaculture, 281(1–4), pp. 1–4.

[23] **Aly, S.M., Mohamed, M.F., et john, G. (2008).** Effect of probiotics on the survival, growth and challenge infection in tilapia (*oreochromis nuloticus*). *Aquaculture research*, 39 (6),647-656.

[24] **Hai, N. V. (2015**). Use of probiotics in aquaculture. *Journal of Applied Microbiology*, 119(4), pp. 917–935.