Macrothink Institute™

Journal of Biology and Life Science
ISSN 2157-6076
2025, Vol. 16, No. 2

Effects of Wheat Flour Substitution by Sorrel (*Hibiscus sabdariffa*) Meal on Growth Performance, Feed Efficiency and Survival of Nile Tilapia (*Oreochromis niloticus*) Fry

Mbaye Ba, Jean Fall, Ndeye Codou Mbaye

[1]University Institute of Fisheries and Aquaculture (IUPA), Cheikh Anta Diop University (UCAD), 45784, Dakar, Senegal

Paul Mamadou Ndour

Université du Sine Saloum El-Hâdj Ibrahima NIASS, Kasnack, Face Ex Cinéma ABC, Kaolack, Sénégal.

Alla Ndione

University Institute of Fisheries and Aquaculture (IUPA), Cheikh Anta Diop University (UCAD), 45784, Dakar, Senegal

Received: May 18, 2025 Accepted: June 27, 2025 Published: July 4, 2025

doi:10.5296/jbls.v16i2.22992 URL: https://doi.org/10.5296/jbls.v16i2.22992

Abstract

The present study evaluated the effects of substituting wheat flour with sorrel meal in the diet of *Oreochromis niloticus* fry. A total of 180 fry, with an average weight of 0.09 g, were reared in nine 50 L tanks. Three diets with identical protein content (30%) but different incorporation levels of sorrel (*Hibiscus sabdariffa*) cake meal—0% (R1, control), 50% (R2), and 100% (R3) were formulated. Each diet was tested on three groups of 20 fish, fed for 45 days. The results showed that fish fed diet R3 (100% sorrel meal) achieved the highest growth parameters. Fry receiving diets R2 and R3 exhibited the lowest Feed conversion rate (FCR) compared to the control. Survival rates at the end of the experiment were 55% for the control, 73% for R2, and 58% for R3. Flesh protein content was significantly higher in fish fed diet R3 and lowest in those fed the control diet. In contrast, fat content was highest in fish fed diet R1, while those receiving diets R2 and R3 had the lowest values. Regarding ash content, the highest values relative to initial fish composition were recorded in fish fed diet R3. These findings indicate that sorrel meal had no adverse effects on the survival of *O. niloticus* fry. In conclusion, wheat flour can be effectively replaced with sorrel meal in the diet of *O. niloticus* fry without

compromising growth performance. This suggests that sorrel meal is a viable plant-based protein source for fish feed formulation, potentially lowering production costs and improving farm profitability.

Keywords: Substitution, Wheat, *Hibiscus sabdariffa*, Growth, Tilapia

1. Introduction

For hundreds of millions of people worldwide, fisheries and aquaculture remain vital sources of food, income, and livelihoods. Global aquaculture production has been steadily increasing for many years, reaching a record 130.9 million tonnes (live weight equivalent) between 2020 and 2022—an increase of 8.1 million tonnes compared to the 122.8 million tonnes recorded in 2020. Farmed aquatic animals accounted for 94.4 million tonnes of this total (FAO, 2024), reflecting a 6.7 million tonnes increase over the same period. Notably, in 2022, for the first time in history, global aquaculture production of animal species surpassed wild-capture fisheries, which were estimated at 91 million tonnes.

Aquaculture is currently one of the world's fastest-growing food production sectors, primarily practiced in developing countries, particularly in low-income, food-deficit regions. Recognized as one of the animal production activities with the highest growth potential, aquaculture shares the same fundamental goal as agriculture: to increase food production beyond natural levels.

In Senegal, various fish species are farmed, with Nile tilapia (*Oreochromis niloticus*), a member of the Cichlid family, playing a key role in production. However, tilapia farming faces significant challenges related to feed, not only in terms of cost but also concerning availability, quality and nutritional value.

These concerns are frequently raised in aquaculture-related discussions. In response, extensive research has been conducted to develop alternative feeds using locally available ingredients. While these local raw materials are often preferred for feed formulation, their high incorporation rates can increase production costs. Additionally, the use of certain human food ingredients in fish feed creates competition with human consumption, raising food security concerns. Teixeira et al. (2020) reported that, it is possible to replace wheat flour with oat, quinoa, and amaranth in the tilapia diet. Jiang et al. (2025) indicated that palm kernel cake could completely replace wheat bran without compromising the growth performance of grass carp, with optimal growth observed at 40 % replacement level. Huang et al. (2024) showed that the replacement of wheat bran with palm kernel cake concentrations up to 80% had no significant effect on the growth rate of tilapia or feed utilization. Complete replacement of wheat bran with fermented palm kernel cake promoted intestinal immunity. It also improved dietary nutrient utilization and growth performance. However, the optimal growth was achieved at a 40% replacement level.

Although wheat is cultivated in Senegal, most of the flour used is imported**,** making it costlier than sorrel cake, which is locally produced. This explains the higher cost of feeds containing larger amounts of wheat flour compared to those incorporating sorrel cake.

The seeds of *Hibiscus sabdariffa* contain very high concentrations of proteins, lipids, and total sugars, making them good sources of both proteins and fats. All essential amino acids are present; among these, leucine (7%), phenylalanine (5%), and threonine (4%) are the most abundant. The total concentration of essential amino acids in *H. sabdariffa* seeds is 39.5 g per 100 g of protein (El-Adawy et al., 1994). Therefore, it may be possible to use *H. sabdariffa* seeds to enrich lysine-deficient foods. With an average oil content of 20%, *H. sabdariffa* seeds have an oil richness comparable to that of other seeds such as tomato seeds (Lazos et al., 1998) or baobab seeds (Diop et al., 2005). The crude seed oil consists of more than 70% unsaturated fatty acids.

This study aligns with a strategic effort to replace costly, human-consumed ingredients such as wheat flour with more affordable and locally available alternatives. The primary objective is to evaluate the effects of substituting wheat flour with sorrel (*H. sabdariffa*) cake meal on the growth performance of *O. niloticus*.

2. Materials and Methods

2.1 Feed Formulation

During the experiment, three diets were studied. Diet 1 (R1, control) a standard, nutritionally balanced formulation designed to meet the dietary needs of fish. It contained 100% wheat flour and 0% sorrel meal, serving as the reference diet. Diet 2 (R2) contained 50% wheat flour and 50% sorrel cake. Diet 3 (R3) composed entirely of sorrel cake (100%) with no wheat flour (0%).

The composition of each diet is presented in Table I.

Table I. Composition of diet (100g)

Ingredients (g)	R1 (control)	R2	R3
Fish meal	20	20	20
Poultry meal	25	25	25
Sorrel cake meal	0	5	10
Wheat flour	10	5	0
Corn flour	25	25	25
Cassava flour	10	10	10
Poultry viscera oil : Neocarya oil (1:1)	5	5	5
Vitamins[a]	1	1	1
Minerals[b]	1	1	1
Yeast	3	3	3
Total (g)	**100**	**100**	**100**
Protein	30.43	30.12	29.80
Fat	13.16	13.13	13.09

a=vit A 250000 UI; vit D3 250000UI; vit E 5000mg; vit B1 100mg; vit B2 400mg; vit B3(pp) 1000mg; vit B5 pantode Ca2000mg; vit B6 300mg; vit K3 1000g; vit C 5000mg; H biotin 15mg; choline 100g; anti-oxydant (BHT), crushed and calcined attapulgite qs 1000mg;

b=phosphorus 7%; calcium 17%; sodium 1,5%; potassium 4,6%; magnesium 7,5%; manganese 738mg; zinc 3000mg; iron 4000mg; copper 750mg; iodine 5mg; cobalt 208mg; calcined and ground attapulgite qs 1000g; fluorine 1.5% (approximately).

2.2 Feed Production

The experimental feeds were manually prepared using a Moulinex mincer. The various ingredients listed in Table I were sourced from the local market, while vitamins and minerals were donated. Some ingredients were pre-processed to remove impurities before use. The feed preparation process, involved grinding the ingredients into a fine powder or flour, weighing them, and mixing them thoroughly. Approximately 30% tap water was added to the mixture to form a malleable paste, which was then passed through the mincer. The mincer extruded the paste into spaghetti-like filaments, which were sun-dried before being ground into powder using a mortar. The resulting feed powder was sieved to ensure uniform particle size and then stored for future use.

2.3 Experimental Protocol

The experiment was conducted at the Institut universitaire de Pêche et d'Aquaculture (IUPA) aquaculture station in an isolated system over a six weeks period to evaluate the effects of different diets on the growth of *O. niloticus* fry. A total of 180 Nile tilapia fry were selected and distributed into nine 50 L tanks, with 20 individuals per tank. The initial biomass per tank was approximately 1.92 g.

The fish were fed twice daily (at 10:00 and 17:00) with one of the three experimental diets: R1 (control), R2, and R3 (test diets), in triplicate. The quantity of feed distributed per tank was adjusted based on biomass measurements taken every 15 days. The feeding rate was gradually reduced throughout the experiment: First fortnight: 15% of biomass, second fortnight: 10% of biomass, third fortnight: 8% of biomass.

Physicochemical parameters, including pH and temperature, were recorded twice daily (morning and evening) using multifunction device before tank siphoning. After each siphoning, the removed water was replaced with fresh water.

2.4 Growth, Feed Efficiency and Survival Parameters

At the end of the experiment, weight data were used to evaluate the following parameters:

- Absolute Mean Weight Gain (AMWG, g) = Final average weight − Initial average weight
- Relative Mean Weight Gain (RMWG, %) = (AMWG / Initial average weight) × 100
- Specific Growth Rate (SGR, %/day) = [ln (Final average weight) − ln (Initial average weight)] × 100 / Duration
- Feed Conversion Ratio (FCR) = Total feed distributed / AMWG
- Survival Rate (SR, %) = (Number of surviving individuals / Initial number of individuals) × 100

Flesh analysis

After six weeks of feeding, samples were taken from the initial fish population as well as

from each experimental tank. These samples were sent to the Ecole nationale d'Agriculture (ENSA) laboratory in Thiès for biochemical composition analysis, including dry matter, crude protein, ash, and lipid content, following the standard procedures outlined by the Association of Official Analytical Chemists (AOAC, 1995).

Statistical analysis

Collected data were recorded and processed using Microsoft Excel, then analyzed using SAS-PC statistical software (Joyner, 1985). An analysis of variance (ANOVA) was performed to assess differences between treatments for growth, feed efficiency, survival, and flesh composition parameters. Duncan's multiple range test was used to determine significant differences between treatments, with significance set at $P < 0.05$.

3. Results and Discussion

3.1 Results

3.1.1 Physic-Chemical Parameters

Monitoring of physico-chemical parameters during the experiment (Table II and III) shows the average variation of temperature and pH in the three diets.

Table II. Variation in temperature over the six-week experiment

Diet	**R1 (Indicator)**	**R2**	**R3**
Average temperature	26.05±0.01 [a]	26.07±0.02 [a]	26.12±0.50 [a]

Temperature monitoring indicated that values ranged between 26.05°C and 26.12°C, with an average of 26.08°C. The minimum, average, and maximum temperatures were consistent across all dietary treatments, showing no variation between groups.

Table III. Variation in hydrogen potential (pH) over the six-week experiment

Diet	R 1 (control)	R 2	R 3
Average pH	7.47±0.00 [a]	7.44±0.06 [a]	7.48±0.00 [a]

The data indicate that the R2 diet had the lowest recorded pH value (7.44). However, the mean pH values across all diets were nearly identical. Statistical analysis revealed no significant differences in pH between the dietary treatments.

3.1.2 Growth, Feed Efficiency and Survival Parameters

During the experiment, various growth parameters were determined to evaluate the growth of tilapia fry in each diet (Table IV).

Table IV. Growth, feed efficiency and survival parameters of Nile tilapia fry fed different diet for six weeks.

Diet Parameters	R 1 (control)	R 2	R 3
IW (g)	0.10±0.00[a]	0.10±0.00[a]	0.10±0.00[a]
FW (g)	0.55±0.14 [a]	0.50±0.11 [a]	0.60±0.16 [a]
AMWG (g)	0.46±0.14 [a]	0.41±0.11 [a]	0.50±0.16 [a]
RMWG (%)	481.7±154.15 [a]	428.2±115.40 [a]	532.4±167.43 [a]
SGR (%/d)	4.13±0.63 [a]	3.92±0.54 [a]	4.33±0.66 [a]
FCR	2.89±0.55 [a]	2.37±0.62 [a]	2.26±0.71 [a]
SR (%)	55±5.00[a]	73.33±2.88[b]	58.33±2.88[a]

IW: Initial average weight; FW: Final average weight; AMWG: Absolute mean weight gain; RMWG: Relative mean weight gain; SGR: Specific growth rate; FCR: Feed conversion ratio; SR: Survival rate.

Values in the same row with the same superscript letter are not significantly different ($P > 0.05$). Conversely, values in the same row with different superscript letters are considered significantly different ($P < 0.05$).

At the start of the experiment, the initial mean weight of Nile tilapia fry (0.10 g) was similar across all diets. The final mean weight varied slightly between dietary treatments, ranging from 0.50 ± 0.11 g to 0.60 ± 0.16 g. Mean absolute weight gain showed slight variations, ranging from 0.41 ± 0.11 g to 0.51 ± 0.15 g.

The statistical analysis showed no significant differences ($P > 0.05$) in final mean weight, AMWG, RMWG, SGR, or FCR among the dietary treatments. Regarding relative mean weight gain (RMWG), the highest value was observed in fish fed the R3 diet (532.4 ± 167.43%), followed by those fed the control diet (R1) (481.7 ± 154.15%). The lowest RMWG was recorded in fish fed the R2 diet (428.2 ± 115.40%). Nile tilapia fry fed the different diets exhibited similar specific growth rates (SGR) and feed conversion ratios (FCR), ranging from 3.92 ± 0.54%/day to 4.33 ± 0.66%/day for SGR and from 2.26 ± 0.71 to 2.89 ± 0.55 for FCR. On the other hand, survival rates differed significantly. The R2 diet had the highest survival rate (73%) and was significantly different from the other diets ($P < 0.05$). Diets R1 (55.00 ± 5.00%) and R3 (58.33 ± 2.88%) showed no significant difference from each other.

3.1.3 Flesh Analysis

Biochemical composition analysis was used to determine the protein, fat and ash submissive of Nile tilapia fry on different diet after six weeks of feeding, as shown in Table V.

Table V. Biochemical composition of Nile tilapia fry fed different diet for six weeks

Biochemical composition (%)	Initial fish	R 1 (control)	R 2	R 3
Crude protein	11.19±0.00 [c]	16.05±0.66 [b]	17.06±0.39 [b]	23.35±3.51 [a]
Crude Fat	7.26±0.00 [b]	7.48±0.44 [b]	7.45±0.72 [b]	8.67±0.19 [a]
Crude Ash	4.26±0.00 [a]	4.99±0.20 [a]	5.45±0.82 [a]	4.69±0.85 [a]

Different superscript letters in the same row indicate a significant difference (**P < 0.05**) between diets.

The results indicate that fry fed Diet 3 (R3) had a significantly higher crude protein content (23.35%) than those fed other diets (P < 0.05**).** Fry fed Diet R1 and Diet R2 recorded crude protein levels of 16.05 ± 0.66% and 17.06%**,** respectively, with no significant difference between them **(**P > 0.05**).** The initial fry had the lowest crude protein content (11.19 ± 0.00%).

Fat levels remained relatively stable between Diet 1 (R1) **(**7.48 ± 0.44%) and Diet 2 (R2) **(**7.45 ± 0.72%), showing no significant difference from the initial fry **(**7.26 ± 0.00%). However, fry fed Diet 3 (R3) had the lowest fat content **(**4.69 ± 0.85%**).** Regarding ash content**,** no significant differences were observed between the control (R1**),** R2**,** R3, and the initial fry **(**P > 0.05**)**. Ash content ranged from 4.26 ± 0.00% to 5.45 ± 0.82%**.**

3.1.4 Economic Estimation of Feeds

The results of the economic evaluation are shown in Table VI.

Table VI. Economic estimation of feeds

Ingredients (g)	Price per kg (F CFA)	R 1 (control)	R 2	R 3
Fish meal	450	90	90	90
Poultry meal	250	62.5	62.5	62.5
Sorrel cake meal	200	0	12.5	25
Wheat flour	500	70	35	0
Corn flour	500	100	100	100
Cassava flour	500	50	50	50
Poultry/ Neocarya oil	150	7.5	7.5	7.5
Vitamins	1500	15	15	15
Minerals	1500	15	15	15
Yeast	500	15	15	15
Other expenses	50	50	50	50
Cost of one kg of feed (F CFA)		**475.5**	**452.5**	**430**
Production costs per kg of fish (F CFA		**1374.19**	**1072.427**	**971.8**

The economic evaluation of the feeds was conducted by calculating the price per kilogram based on the cost of ingredients and their respective inclusion percentages in each formulation. The results indicate that Diet 3 (R3**)** was the least expensive (430 FCFA/kg), followed by Diet 2 (R2) at 452.5 FCFA/kg. In contrast, Diet 1 (R1**)** was the most expensive

(475.5 FCFA/kg), making it the costliest option among the three diets. This study showed that the price per kilogram of fish decreased as the level of sorrel cake meal increased.

4. Discussion

Water quality is a fundamental factor in fish farming, as it directly affects fish health, growth, and overall farm profitability. Effective water quality management is therefore essential for ensuring sustainable and productive aquaculture.

To evaluate water quality, key parameters such as temperature and pH were regularly monitored. In this study, temperature values ranged from 24.20 to 26.55°C, which falls within the optimal range of 22 to 29°C recommended for optimal growth and survival of *O. niloticus* (Mires, 1995).

According to Crane (2006), the minimum pH required for fish growth and reproduction is 5. The ideal pH for aquaculture, as noted by Malcolm et al. (2000), is between 6.5 and 8, while Kanangire (2001) and Ouattara et al. (2003) reported that *O. niloticus* thrives within a pH range of 6.5 to 7. In this study, pH values ranged from 6.28 to 7.36, with an average of 7.46, which aligns with these recommended ranges.

Overall, the recorded physico-chemical parameters confirm that the rearing conditions in this study were suitable for Nile tilapia fry.

The present study found no significant effect of sorrel cake meal as a protein source on the growth performance and survival of *O. niloticus* fry. These findings indicate that the protein requirement for *O. niloticus* fry can reach 30% without negatively impacting their development.

The experimental results showed that fry fed the diet containing 100% sorrel meal achieved a mean absolute weight gain of 0.50±0.15 g and a mean relative weight gain of 532.4±167.43%, with a specific growth rate (SGR) of 4.33%/d. In contrast, the lowest growth performance was observed in fry fed the diet containing 50% wheat flour and 50% sorrel cake meal, which recorded a mean absolute weight gain of 0.41±11 g, a mean relative weight gain of 428.2±115.40%, and an SGR of 3.92%/d. However, these results are superior to those reported by Sarr et al. (2023), who studied the effects of agricultural by-products on the growth and survival of *Clarias gariepinus* (African catfish) fry. Their study recorded a relative mean weight gain of 34.96±0.36% and an absolute mean weight gain of 0.60±0.02g, likely due to species-specific differences.

Conversely, the present findings are lower than those reported by Fall et al. (2021), who observed a mean absolute weight gain of 7.22±0.63g, a mean relative weight gain of 24,070±2,325%, and an SGR of 6.53±0.11%/d in their study on the effects of partially replacing corn meal with *Cyperus esculentus* (tiger nut) meal in the diet of *O. niloticus* fry. This discrepancy may be attributed to the longer experimental duration in their study (84 days compared to 45 days in the present study)

In the present study, the best feed conversion rate (FCR) was observed with Diet 3 (100% *H. sabdariffa* cake), which recorded a value of 2.26±0.71, followed by Diet 2 (50% wheat flour

and 50% sorrel cake) with 2.37±0.62. The lowest feed efficiency was recorded with the control diet (R1) (0% *H. sabdariffa* cake), which had an FCR of 2.89±0.55. However, no significant differences were observed between the FCR values of fish fed different diets, indicating that wheat flour can be replaced by sorrel cake meal (at 50% or 100%) without negatively impacting feed efficiency. These results are superior to those reported by Sarr (2023) in his study on the effects of agricultural by-products on the growth of *Clarias* fry, where FCR values ranged between 11.99 and 15.77. This discrepancy may be due to differences in the nutritional requirements of the species studied. Additionally, the FCR values obtained in the present study are comparable to those reported by Fall et al. (2021), who recorded FCRs between 2.19±0.08 and 2.27±0.33 in their study on the effects of raw and processed pumpkin seeds on the growth performance and whole-body composition of *O. niloticus* fry. Similarly, Ndione (2022) obtained FCR values ranging from 2.00 to 3.34 in his research on the incorporation of different forms of *Boscia senegalensis* ("Niandam") seed meal into Nile tilapia fry diets.

The survival rate of *O. niloticus* fry fed the different diets ranged from 55% to 73%. The highest survival rate (73%) was recorded in fry fed the diet containing 50% wheat flour and 50% sorrel cake, which was significantly higher than the lowest survival rate (55%) observed in fry fed the control diet (50% wheat flour and 0% sorrel cake). Fry fed the 100% sorrel meal diet had an intermediate survival rate of 58%. These survival rates are lower than those reported by Sarr (2023) in his study on the growth and survival of *Clarias gariepinus*, where the R2 diet achieved a survival rate of 82%, and Ndione (2022), who recorded survival rates ranging from 73.33% to 81.67%. However, they are higher than those found by Faye (2017), who reported survival rates between 30% and 65% in his study on the effects of incorporating different *Boscia senegalensis* seed flours into *Clarias gariepinus* fry diets.

Overall, the survival rates observed in the experimental groups (58%–73%) were acceptable compared to the control group (55%). The lower survival rates may be attributed to stress from handling and/or infection during the third week of the experiment. Some dead fry exhibited red spots on their bodies, which may suggest disease-related mortality.

In the present study, a significant difference was observed in the protein content of tilapia fry flesh across the tested diets compared to the initial fish. Protein content increased from 11.19±0.00% in the initial fish to 23.35±3.51% in fry fed Diet 3. These protein levels are higher than those reported by Ndione (2022), who recorded protein levels between 16.8% and 17.3% in his study on the effects of incorporating different forms of *Boscia senegalensis* ("Niandam") seed meal on the growth performance, feed efficiency, survival, and biochemical composition of Nile tilapia fry. However, they are lower than those reported by Diago (2020, who recorded protein levels ranging from 89.93% to 93.41% in his experiment on *O. niloticus* fry fed processed *Boscia senegalensis* leaf meal. The protein levels obtained in the present study are somewhat similar to those reported by Fall et al. (2021), who found protein levels between 15.06% and 20.41% when studying the effects of raw and processed pumpkin seeds on the growth performance and whole-body composition of *O. niloticus* fry.

At the end of the trial, fat levels ranged from 7.26±0.00% to 8.67±0.19%. Diet 3 had the highest fat content (8.67±0.19%), which was significantly higher than that of Diet 1

(7.48±0.44%, 100% wheat flour) and Diet 2 (7.45±0.72%, 50% wheat flour and 50% sorrel meal). The initial fish had a slightly lower fat content (7.26±0.00%). These lipid levels are higher than those reported by Diago (2020) (2.72%–3.74%) and Fall et al. (2021) (0.49%–1.5%) in their studies on the effects of raw and processed pumpkin seeds on *O. niloticus* fry.

Ash content recorded at the end of the study ranged from 4.26±0.00% to 5.45±0.82%, with no significant differences between treatments. These values are comparable to those found by Sagne et al. (2013), who reported ash content ranging from 5.7% to 12.7% in their study on the effects of vegetable oils in diets on the growth, survival, and biochemical composition of *O. niloticus* flesh. However, they are higher than those reported by Ndione (2022), who recorded ash levels between 6.53% and 7.05% in his study on the effects of incorporating *Boscia senegalensis* seed meal in Nile tilapia fry diets.

The economic analysis indicates that the feed containing 100% wheat flour is the most expensive and the least efficient. The differences in feed costs can be attributed to two main factors: (1) the price of the ingredients used in feed formulation and (2) the quantities incorporated into each diet. While the diets differ only in the type of ingredient used (wheat flour vs. roselle cake), the proportion of wheat flour mainly influences the variation in feed prices, which is slightly more expensive than sorrel cake.

5. Conclusion

This study demonstrated that sorrel cake meal (*H. sabdariffa*) could effectively replace wheat flour in the diet of Nile tilapia fry (*O. niloticus*) without compromising growth performance or feed efficiency. In fact, its inclusion even contributed to improving body composition. Fry fed diet 2 exhibited the highest survival rates, followed by those fed diet 3, while the control diet recorded the lowest survival rates. The findings indicate that fry fed sorrel meal-based diets achieved growth performance comparable to those on the control diet, confirming that sorrel cake meal is a viable alternative to wheat flour. While wheat flour has traditionally been used in both human nutrition and aquaculture, it is now costly and often scarce. Despite being cultivated in Senegal, local wheat production remains insufficient for sustainable use in fish feed. In contrast, sorrel cake, which is readily available and potentially more affordable, presents a promising alternative for enhancing the sustainability of fish feed.

Future Research Directions:

- Assessing sorrel cake meal as a grow-out feed for Nile tilapia (*Oreochromis niloticus*) and other species, such as Clarias.
- Investigating its effect on digestibility and immune response of farmed fish.
- Enhancing the quality of sorrel cake meal by developing extruded feed pellet to improve accessibility and feed efficiency.

Acknowledgments

Not applicable.

Authors contributions

Not applicable.

Funding

Not applicable.

Competing interests

Not applicable.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Macrothink Institute.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

References

Diago, M., Fall, J., Loum, A., Jatta, S., Sagne, M., Ndong, D., Diouf, M., & Sheen, S. S. (2020). Effects of replacement of corn flour with different forms of Boscia senegalensis leaf meal on growth, feed efficiency and survival of Oreochromis niloticus fry. *International Journal of Fisheries and Aquatic Studies, 8*(2), 153-156.

Diop, A. G., Sakho, M., Dornier, M., Cisse, M., & Reynes, M. (2005). Le baobab africain (*Adansonia digitata* L.): principales caractéristiques et utilisations. *Fruits, 61*(1), 55-69. https://doi.org/10.1051/fruits:2006005

El-Adawy, T. A., & Khalil, A. H. (1994). Characteristics of roselle seeds as a new source of protein and lipid, *J. Agric. Food Chem., 42*, 1896-1900. https://doi.org/10.1021/jf00045a013

Fall, J., Lin, C. H., Sow, M., Mbaye, S., Diagne, N. F., Thiaw, S., … & Chien, A. (2021). Effects of partial replacing dietary corn, *Zea mays* meal by processed tiger nut, *Cyperus esculentus* meal on the growth performance and body composition of Nile tilapia (*Oreochromis niloticus*) fry. *J. Fish. Soc. Taiwan, 48*(4), 239-245. https://doi.org/10.29822/JFST.202112_48(4).0005

Fall, J., Ndiaye, M., Mbaye, S., Jatta, S., Diouf, A., Ndour, P. M., … & Chien, A. (2021). *Effects of raw and processed pumpkin seed meal on the growth performance and whole body composition of Oreochromis niloticus fry. Journal of Fishery Society of Taiwan, 48*(4), 189-197. https://doi.org/10.29822/JFST.202112_48(4).0001

FAO. (2024). *La Situation mondiale des pêches et de l'aquaculture (2024). La transformation bleue en action.* Rome. https://doi.org/10.4060/cd0683fr

Faye, M. (2017). *Effets de l'incorporation de différentes farines de graines de Boscia senegalensis sur les performances de croissance et de survie des alevins de Clarias gariepinus.* Mémoire de Technicien Supérieur des Pêches et de l'Aquaculture, CNFTPA.

Huang, H., Lin, X, Meng, X., Liu, Y., Fan, J., Zhu, L., … & Deng, J. (2024). Effects of replacing wheat bran with palm kernel cake or fermented palm kernel cake on the growth performance, intestinal microbiota and intestinal health of tilapia (GIFT, *Oreochromis niloticus*). *Front. Nutr., 11*, 1368251. https://doi.org/10.3389/fnut.2024.1368251

Jiang, W., Mi, H., Tan, B., Zhang, S., Xie, S., Zhang, L., & Deng, J. (2025). Effects of replacing wheat bran by palm kernel meal on growth performance and intestinal health of juvenile grass carp (*Ctenopharyngodon idellus*). *Aquaculture Reports, 42,* 102763. https://doi.org/10.1016/j.aqrep.2025.102763

Joyner, S. P. (1985). SAS/STAT Guide for Personal Computer, Statistical Analysis System Institute, Cary, NC, USA.

Kanangire, C. K. (2001). *Effets de l'alimentation des poissons avec Azolla sur la production d'un écosystème agropiscicole en zones marécageuses au Rwanda.* Thèse de doctorat, Faculté Universitaire Notre-Dame de la Paix, Namur, Belgique.

Lazos E.S., Tsaknis J., & Lalas S. (1998). Characteristics and composition of tomato seed oil.*Gras as Aceites*, *49*, 440-445. https://doi.org/10.3989/gya.1998.v49.i5-6.755

Malcolm, C., Beveridge, M. H., & McAndrew, B. J. (2000). *Tilapias: biology and exploitation.* Institute of Aquaculture, University of Stirling, Scotland. Kluwer Academic Publishers. https://doi.org/10.1007/978-94-011-4008-9

Mires, D. (1995). Aquaculture and the aquatic environment: mutual impact and preventive management. *Aquaculture, 47,* 163-172. https://doi.org/10.4236/abb.2010.14037

Ndione, N. M. (2022). *Les effets de l'incorporation de différentes formes de farines de graines de Boscia senegalensis « Niandam » sur les performances de croissance, d'efficacité alimentaire, de survie et sur la composition biochimique des alevins de tilapia du Nil Oreochromis niloticus Linnaeus (1758).* Mémoire de master, Institut Universitaire de Pêche et d'Aquaculture/UCAD.

Ouattara, N. I., Teugels, G. G., N'Douba, V., & Philippart, J. C. (2003). *Aquaculture potential of the black-chinned tilapia, Sarotherodon melanotheron (Cichlidae). Aquaculture Research, 34*(13), 1223-1229. https://doi.org/10.1046/j.1365-2109.2003.00921.x

Sagne, M., Loum, A., Fall, J., Ndong, D., Diouf, M., Sarr, A., & Thiaw, O. T. (2013). Effects of different types of oils on growth performance, survival and carcass composition of Nile tilapia (Oreochromis niloticus, Linnaeus, 1758). *Journal of Biology and Life Science, 4*, 1-12. https://doi.org/10.5296/jbls.v4i2.3041

Sarr, A. (2023). *Effets des sous-produits agricoles sur la croissance et la survie des alevins de Clarias gariepinus.* Mémoire de Technicien Supérieur des Pêches et de l'Aquaculture, CNFTPA.

Teixeira, H., Alexandre, C., Nespeca, L. D. S., da Silva ,T. B. V., & Bona, E. (2020). Impact of the Replacement of Wheat Flour by Oat, Amaranth, and Quinoa Flours in Tilapia Balls. *Journal of Aquatic Food Product Technology, 29,* 850-864. https://doi.org/10.1080/10498850.2020.1813859