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Effects of Different Inclusion Levels of *Moringa oleifera* Leaf Meal (MLM) on the Fecundity and Gonadosomatic Index (GSI) of the African Catfish *Heterobranchus longifilis*

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Authors' contributions

This work was carried out in collaboration between all authors. Author OPB managed the literature searches. Author EVO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author UPJ managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

This study was conducted to evaluate the effect of varying inclusion levels of *Moringa oleifera* leaf meal (MLM) on fecundity and gonado-somatic index (GSI-%) of the African catfish *Heterobranchus longifilis*. Fifteen (15) tarpaulin unit measuring 100 by 80 by 100 cm was used to aid triplication of the five experimental groups. Five isonitrogenous diets (43% cp) including Diet A (control), Diet B (5% MLM), Diet C (10% MLM), Diet D (15% MLM) and Diet E (20% MLM) were used for this study. A total of three hundred (300) healthy fingerlings of *H. longifilis* with mean bulk body weight 361.60 ± 0.3 g and total length 11.15 ± 0.04 cm were stocked in the 15 units (20 in each unit). Results of the proximate composition showed that *M. oleifera* leaf meal (MLM) had a rich nutritional profile with crude protein level of 27.80 ± 0.02%, ash (6.45 ± 0.02%), crude fibre (18.50 ± 0.01%), crude fat (2.72 ± 0.02%), moisture (8.36 ± 0.03%) and nitrogen-free extract (36.17 ± 0.02%). Mean fecundity was significantly higher ($P<0.05$) in fish fed Diet C (10% MLM) with 71195.25 ± 9551

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eggs, followed by fish fed Diet D (15% MLM) with 59085.50 ± 8208 egg and least in fish fed Diet A (control) with 43150.75 ± 7964 eggs. Female fish fed Diet C (10% MLM) had the highest GSI value of 9.93 ± 0.87% which was significantly different (P<0.05) from other treatments and the least female GSI 9.93 ± 0.87% was obtained in fish fed Diet A (control). Similarly, male GSI was significantly higher (P<0.05) in fish fed Diet C (10%MLM) with a value of 0.94 ± 0.04% and least (0.79 ± 0.06%) in fish fed Diet A (control). There was no significant difference (P>0.05) in food conversion ratio (FCR), and food conversion efficiency of fish fed all the experimental diets. In conclusion, incorporation of *M. oleifera* leaf meal (MLM) in the diet of *H. longifilis* at 15% level will result in a higher fecundity and improved gonadal development.

Keywords: Heterobranchus longifilis; Moringa oleifera leaf meal; fecundity; gonado-somatic index; varying inclusion levels.

1. INTRODUCTION

The African Catfish *Heterobranchus longifilis* which belongs to the family Clariidae is among the common culturable fish species in Nigeria due to its favorable culturable characteristics such as fast growth, disease resistance, appreciable size, high fecundity, tolerance of harsh of environmental conditions and high stocking densities in captivity, ease of induced spawning, acceptability of formulated feed, high market value, meat quality and good taste [1] and [2]. Catfish is valued in Nigeria because of its pleasant taste, meat quality, cheap nature and its year-round availability. Some nutritional benefits of the African Catfish include omega-3-fatty acid, riboflavin, thiamine, iron, phosphorus, calcium, vitamins A and vitamin D which is required for good health. In Nigeria, aquaculture and fisheries related activities have become a popular source of livelihood to thousands of Nigerians especially the unemployed population [3]. Despite the popularity of aquaculture industry in Nigeria, its growth is limited by high cost of different brands of commercial feed such as Coppens feed which has doubled compared to feed cost in the last ten years. To combat this challenge, farmers have advocated the use of farm made feed, formulated with cheap and locally available ingredients especially those from plant-based origin. Fecundity is a measure of the number of eggs in a gravid female fish or shrimp [4]. It is an important index in aquaculture because it is used in the selection of culturable fish species. It is also used to evaluate the performance of aquaculture feed on fish reproductive biology. Gonadosomatic index (GSI) is defined as the ratio of the fish gonad weight to body weight. In fisheries science and aquaculture, it is an important tool that is useful in the evaluation of reproductive condition. Several findings documented by different researchers have indicated that the quality of aqua feed affects fecundity and gonad development in fishes [5,6,7,8]. Leaf meals are nutritionally rich, cheap and available all year round which gives its users some advantage over other ingredients. *Moringa oleifera* which belongs to the family Moringaceae a popular plant that has the nutritional quality that could be utilised for optimal growth and health of fish. *M. oleifera* which has a wide distribution in Africa and Asia is described by [9] as a horseradish tree (it roots taste like horseradish), drumstick tree (due to its slender, long, triangular seed-pods) and ben oil or benzoil tree (because of the oil derived from the seeds). The incorporation of *M. oleifera* leaf meal as a protein source in aquafeed for different fish species has shown significant and impressive outcome with regards to growth, food conversion ratio and food conversion efficiency. Several authors have documented positive findings on the effect of M. oleifera on fish growth and survival. Ochang et al. [10] recommended that 20% *Moringa oleifera* leaf meal (MLM) is optimal for *C. gariepinus* growth. Richter et al. [11] documented a better performance in Nile tilapia (*Oreochromis niloticus*) fed with diet substituted with 30% of *M. oleifera* leaf meal. Chabi et al. [12] achieved a positive result of *M. oleifera* on the growth of juvenile *Clarias gariepinus*. Bundit et al. [13] achieved a similar result in Bocurtis catfish (*Pangasius bocourti*). Eyo and Ivon [14] recommended 15 % inclusion level of *M. oleifera* leaf meal (MLM) for optimal growth of *H. longifilis*. However, limited studies documented on the effect of *M. oleifera* leaf meal on the fecundity and gonado-somatic index of the African catfish *H. longifilis*. Therefore, the objective of this research is to evaluate and compare the effects of varying inclusion levels of *Moringa oleifera* leaf meal (MLM) on the fecundity and gonado-somatic index of the African catfish *H. longifilis*.

2. MATERIALS AND METHODS

2.1 Collection, Identification and Processing of *Moringa oleifera* Leaves

M. oleifera leaves used for this study were harvested from the botanical garden of the University of Calabar. Authentication and identification of the leaves were done in the Department of Botany, University of Calabar. After identification, the leaves were adequately washed with clean water to remove dirt and debris. After that, the leaves were sun-dried for one week before blending to a fine powder to obtain moringa leaf meal (MLM).

2.2 Experimental Diets Composition and Formulation

Five isonitrogenous diets (Table 1) including Diet A (control), Diet B (5% MLM), Diet C (10% MLM), Diet D (15% MLM) and Diet E (20% MLM) were formulated at 43% crude protein following the Trial and Error method of feed formulation described by [15]. The experimental diets were formulated with the following ingredients: wheat offal, moringa leaf meal (MLM), groundnut meal (GNM), fish meal (FM), soybean meal (SBM), vitamin premix, lysine, methionine, calcium powder, wheat flour, sodium chloride (NaCl), and palm oil. The ingredients were processed to powdery form before mixing them according to the calculated percentages. After mixing, the five different diets were pelletized using a locally fabricated pelletizer. After pelletizing, the pelleted diets were sun-dried.

2.3 Proximate Analysis of *M. oleifera* Leaf Meal and Experimental Diets

Proximate composition of *M. oleifera* leaf meal and the five experimental diets was analysed according to AOAC [16], in the Central Laboratory, Faculty of Agriculture, University of Calabar, Nigeria. Proximate indices analysed were moisture content, carbohydrate content, crude protein, lipids content and ash contents.

2.4 Experimental Design

The experiment was conducted in triplicate for 150 days using 15 tarpaulin unit measuring 100 x 80 x 100 cm^3. The triplicate groups of the five (5) experimental treatments were labeled A, B, C, D, and E. Five experimental diets including Diet A (control), Diet B (5% MLM), Diet C (10% MLM), Diet D (15% MLM) and Diet E (20% MLM) was used in this feeding trial. Three hundred (300) healthy fingerlings of *H. longifilis* were stocked in the 15 units of tarpaulin (20 per unit). Thereafter, the fingerlings were acclimated for 14 days before the start of the experiment. During acclimation, the fish were fed twice daily with Coppens feed to satiation level. After the acclimation period, the experimental fish were starved for 24 hours to control variation in fish weight due to residue food in the gut. Also, this starvation process emptied the gastrointestinal tract in preparation for the experimental feeds and increased appetite of the fish. The initial body weight and total length of fish in each experimental unit was taken according [4] using Metlar MT-5000D electronic weighing balance for weight and measuring board for length. Total weight was measured to the nearest gram while total length was measured to the nearest 0.1 cm. Fish in units A_1, A_2 and A_3 were fed Diet A (control), fish in units B_1, B_2 and B_3 were fed Diet B (5% MLM), fish in units C_1, C_2 and C_3 were fed Diet C (10% MLM), fish in units D_1, D_2 and D_3 were fed Diet D (15% MLM) and fish in units E_1, E_2 and E_3 were fed Diet E (20% MLM). The fish were fed twice daily at 3% body weight by 8.00 am and 5.00 pm.

2.5 Fecundity Estimation

Fecundity (F) was determined as the product of count in 1 g of ovary mass and total weight of eggs in the ovary. Morphometric measurements including total length (cm) and total weight (g) were taken for each gravid fish from the five experimental units. Thereafter, the eggs were removed by cutting-open the fish abdomen with a sharp pair of scissors. Eggs were collected and washed in distilled water before weighing the egg to the nearest 0.1 g with the aid of an electronic weighing balance. The collected eggs were fixed in Gilson fluid or 48 hours before counting.

2.6 Gonado-somatic Index Calculation

Gonadosomatic index (GSI) of female *H. longifilis* fed the five experimental diets was calculated using formula given by [17] as follows:

GSI = [(Gonad weight (g)/ Whole fish weight (g)] X 100

Table 1. Composition of experimental diets (gram/kg) with varying inclusion levels of *M. oleifera* leaf meal (MLM)

Ingredients	**Diet A (control)**	**Diet B (5% MLM)**	**Diet C (10% MLM)**	**Diet D (15% MLM)**	**Diet E (20% MLM)**
Moringa leaf meal (MLM)	0	50	100	150	200
Fish meal (FM)	341	339	317	304	278
Groundnut meal (GNM)	213	202	200	194	187
Soybean meal (SBM)	216	204	203	202	190
Wheat offal (WO)	170	145	120	90	85
Vitamin premix	20	20	20	20	20
Calcium powder	5	5	5	5	5
Lysine	5	5	5	5	5
Methionine	5	5	5	5	5
Sodium chloride	5	5	5	5	5
Wheat flour	10	10	10	10	10
Palm oil	10	10	10	10	10
Total	**1000**	**1000**	**1000**	**1000**	**1000**

2.7 Evaluation of Food Utilization Indices

Food utilization indices including food consumption, food conversion ratio and food conversion efficiency of experimental fish was calculated according to De Silva and Anderson [18] as follows:

Food consumption (g): 3% *fish bulk body weight*No. of days

Food conversion ratio (FCR): feed consumed by fish (g)/ Weight gain (g)

Food conversion efficiency (FCE): [Weight gained by fish (g) / Feed consumed by fish (g)] *100

2.8 Measurement of Water Quality Parameters of the Tarpaulin Units

Water quality parameters of the tarpaulin units including water temperature (°C), pH and dissolved oxygen (mg/l) were measured bi-weekly in each tarpaulin unit. Water temperature was measured using mercury in glass thermometer, pH was measured using a Portable Waterproof pH/EC/TDS Hanna meter (high range) - HI991301 and dissolved oxygen was measured using a Portable Hanna dissolved oxygen meter Model HI9142.

2.9 Statistical Analysis

Data obtained for fecundity, food utilisation indices and gonado-somatic index were subjected to One Way Analysis of Variance (ANOVA) to test for significant difference in fish fed the experimental diets using PASW windows software (predictive analytical software) program (version 19.0). Effects with a probability of P = 0.05 were considered significant.

3. RESULTS

3.1 Proximate Composition of the Dry Matter of Moringa Leaf Meal and Experimental Diets with Varying Inclusion Levels of *Moringa oleifera* Leaf Meal (MLM)

Results obtained for the proximate composition of the dry matter (Table 2) of *M. oleifera* leaf meal (MLM), showed that crude protein was 27.80 ± 139 0.02%, ash (6.45 ± 0.02%), crude fibre (18.50 ± 0.01%), moisture (8.36 ± 0.03%), crude fat (2.72 ± 0.02%) and 36.17 ± 0.02% for nitrogen-free extract. For the experimental diets formulated with varying levels of *M. oleifera* leaf meal, crude protein content was highest in Diet B (42.75 ± 0.01%) and least in Diet C (42.54 ± 0.02%) with no significant difference. Crude fibre content was highest (7.95 ± 0.05%) in Diet C and least (7.51 ± 0.01%) in Diet A with no significant difference (P = 0.05). Highest value of ash (5.87 ± 0.02%) obtained in Diet E was not significantly different from other diets with least value (5.55 ± 0.05%) obtained in Diet A. Similarly, moisture content was not significantly different (P = 0.05) in the five experimental diets although highest value (1.71 ± 0.01%) was obtained in Feed A and Feed D and least value (1.61 ± 0.01%) in Feed B. Crude fat was not significantly different (P = 0.05) in the five experimental diets although highest value (2.62 ± 0.01%) was obtained in Feed D and least value (2.51 ± 0.01%) in Feed A. Also, nitrogen free extract was highest (40.18 ± 0.03%) in Feed A and least (39.31 ± 0.09%)

Feed E but not significantly different (*P* = 0.05) from other experimental diets.

3.2 Feed Utilization Indices of *H. longifilis* Fed Diets with Varying Inclusion Levels of *Moringa oleifera* Leaf Meal (MLM)

Results obtained for food utilization indices of *H. longifilis* (Table 3) fed diets with varying inclusion levels of *M. oleifera* leaf meal (MLM) showed that food intake (g) was highest (33672.50 ± 316.50 g) in fish fed Diet D (15% MLM) and least (29075.00 ± 5.00 g) in fish fed the control diet (Diet A). Food conversion ratio was highest (2.00 ± 0.10) in fish fed Diet A (control) and Diet C (10% MLM) and least in least (1.98 ± 0.10) in fish fed Diet D (15% MLM). Food conversion efficiency (%) was highest (50.46 ± 0.30%) in fish fed Diet D (15% MLM) and least (50.01 ± 0.01%) in fish fed the control diet (Diet A).

3.3 Fecundity and Gonadosomatic Index (GSI) of *H. longifilis* Fed Diets with Varying Inclusion Levels of *M. oleifera* Leaf Meal (MLM)

Mean fecundity (Table 4) of *H. longifilis* fed the experimental diets was highest (71195.25 ± 9551 eggs) in fish fed Diet C (10%MLM), followed by 59085.50 ± 8208 eggs obtained for fish fed Diet D (15% MLM), followed by 48610.37 ±6469 eggs obtained for fish fed Diet E (20% MLM), followed by 45247.87 ± 3621 eggs obtained for fish fed Diet B and least (43150.75 ± 7964 eggs) in fish fed Diet A (control). Mean female GSI was highest (9.93 ± 0.87%) in fish fed Diet C (10%MLM), followed by 11.35 ± 0.58% obtained for fish fed Diet D (15% MLM), followed by 10.53 ± 0.46% obtained for fish fed Diet E (20% MLM), followed by 10.42 ± 1.04% obtained for fish fed Diet B and least (9.93 ± 0.87%) in fish fed Diet A (control). Mean male GSI also followed the same trend with highest (0.94 ± 0.04%) obtained in fish fed Diet C (10%MLM), followed by 0.88 ± 0.05% obtained for fish fed Diet D (15% MLM), followed by 0.86 ± 0.54% obtained for fish fed Diet E (20% MLM), followed by 0.85 ± 0.09% obtained for fish fed Diet B and least (0.79 ± 0.06%) in fish fed Diet A (control).

3.4 Mean Water Quality Parameters of Experimental Units

Measurements of mean water quality parameters of the tarpaulin units (Table 5) showed that the range of mean water temperature (°C) was between 29.50 ± 0.20°C in tank fed Diet C (10% MLM) and 29.60 ± 0.20°C in tank B fed Feed B (5% MLM). The range of mean pH was between 7.05 ± 0.50 in tank D fed Diet D (15% MLM) to 7.10 ± 0.50 in tank A fed Diet A (control diet). The range of mean dissolved oxygen (mg/l) was between 5.18 ± 0.42 mg/l in tank D fed Diet D (15% MLM) and 5.29 ± 0.28 mg/l obtained in tank E fed Diet E (20% MLM).

4. DISCUSSION

Fecundity which is defined as the number of eggs in the ovary of a gravid female fish is an important aspect of fish biology that could be influenced by diet and its quality. Several findings have confirmed this fact in different fish species [7,4,19]. Results obtained for fecundity in this study showed that mean fecundity of the experimental fish at the end of the feeding trial was significantly higher (P<0.05) in fish fed Diet C with 71195.25 ± 9551 eggs, followed by fish fed Diet D (15% MLM) with 59085.50 ± 8208 egg and least in fish fed Diet A (control) with 43150.75 ± 7964 eggs. Eyo et al. [19] attributed the significant variation in fecundity of the African Catfish (*C. gariepinus*) fed Unical Aqua feed and Coppens feed to the composition of the experimental diets. In the present study, proximate composition of the five experimental diets revealed that all the diets contained the required nutrients for the optimal growth of H. longifilis. Ekanem et al. [2] reported a significant influence of diet formulated with plant-based ingredients (*G. kola* and *S. jamaicensisi*) on the fecundity of *C. gariepinus.* A similar obsrevation was reported by [20] when medicinal plants were included in the diets of catfish *C. gariepinus*. Another important factor that could significantly influence fish growth and fecundity is feed intake, food conversion ratio and food conversion efficiency [18] and [19]. In this study, food intake (g) was significantly higher (P<0.05) in fish fed Diet D (15% MLM) compared to other treatments and least in fish fed the control diet (Diet A). However, FCR and FCE were within the range considered by [21] as good for growth in aquaculture. [14] reported an increased growth with increasing level of *M. oleifera* leaf meal up to 15% inclusion level, but further increase (20%) led to reduced growth indices. This observation was attributed to the presence of antinutrients in *M. oleifera* leaf meal such as phytates, tannins, phenol and saponins [22,15,7]. However, [23,24] opined that such antinutrients could be reduced by processing the leaf meal and will

Table 2. Proximate composition of the dry matter of *M. oleifera* leaf meal (MLM) and the experimental diets (g/100g) with varying inclusion levels of *Moringa oleifera* leaf meal (MLM)

Proximate Indices	MLM	Feed A (Control)	Feed B (5% MLM)	Feed C (10 % MLM)	Feed D (15 % MLM)	Feed E (20 % MLM)
Crude protein (%)	27.80 ± 0.02	42.55 ± 0.05	42.75 ± 0.01	42.54 ± 0.02	42.66 ± 0.01	42.59 ± 0.01
Crude fibre (%)	18.50 ± 0.01	7.51 ± 0.01	7.75 ± 0.01	7.80 ± 0.01	7.85 ± 0.01	7.95 ± 0.05
Ash (%)	6.45 ± 0.02	5.55 ± 0.05	5.60 ± 0.01	5.75 ± 0.05	5.81 ± 0.01	5.87 ± 0.02
Moisture (%)	8.36 ± 0.03	1.71 ± 0.01	1.61 ± 0.01	1.69 ± 0.01	1.71 ± 0.01	1.69 ± 0.01
Crude fat (%)	2.72 ± 0.02	2.51 ± 0.01	2.61 ± 0.01	2.58 ± 0.01	2.62 ± 0.01	2.60 ± 0.01
Nitrogen free extract (%)	36.17 ± 0.02	40.18 ± 0.03	39.74 ± 0.12	39.65 ± 0.04	39.36 ± 0.04	39.31 ± 0.09

**Values represents mean ± standard error for triplicate of each treatment. MLM = Moringa oleifera leaf meal*

Table 3. Feed utilization parameters of *H. longifilis* fed diets with varying inclusion levels of *Moringa oleifera* leaf meal (MLM)

Indices	Feed A (Control)	Feed B (5% MLM)	Feed C (10 % MLM)	Feed D (15 % MLM)	Feed E (20 % MLM)
Initial weight (g)	261.00 ± 1.00	261.50 ± 0.50	261.00 ± 1.50	261.50 ± 0.50	262.50 ± 0.50
Final weight (g)	14801.00 ± 3.00 [e]	15470.00 ± 52.50 [d]	16180.50 ± 4.50 [b]	17252.00 ± 60.00 [a]	16026.50 ± 25.50 [c]
Food Intake (g)	29075.00 ± 5.00 [e]	30273.00 ± 42.00 [d]	31821.50 ± 10.50 [b]	33672.50 ± 316.50 [a]	31438.50 ± 61.50 [c]
FCR	2.00 ± 0.10[a]	1.99 ± 0.10 [a]	2.00 ± 0.10[a]	1.98 ± 0.01[a]	1.99 ± 0.10[a]
FCE (%)	50.01 ± 0.01[a]	50.24 ± 0.10[a]	50.03 ± 0.01[a]	50.46 ± 0.30[a]	50.15 ± 0.02[a]

**Values represent mean ± standard error for the triplicate data of each treatment. Mean values having the same superscript are not significantly different (P > 0.05)*

Table 4. Fecundity of *H. longifilis* fed diets with varying inclusion levels of *Moringa oleifera* leaf meal (MLM)

Parameters	Feed A (Control)	Feed B (5% MLM)	Feed C (10 % MLM)	Feed D (15 % MLM)	Feed E (20 % MLM)
Female Total Length (cm)	43.02 ± 2.08 [a]	43.26 ± 0.81 [b]	46.29 ± 1.42 [c]	47.07 ± 1.82 [d]	42.50 ± 1.31 [e]
Female Total Weight (g)	630.50 ± 86.97 [a]	595.25 ± 47.32 [b]	780.00 ± 88.81 [c]	749.12 ± 91.12 [d]	518.12 ± 63.47 [e]
Ovary Weight (g)	62.37 ± 11.46[a]	61.25 ± 5.13 [b]	104.37 ± 14.19 [c]	85.00 ± 11.65 [d]	55.75 ± 9.23 [e]
Fecundity	43150.75 ± 7964 [a]	45247.87 ± 3621 [b]	71195.25 ± 9551 [c]	59085.50 ± 8208 [d]	48610.37 ±6469 [e]
Female GSI (%)	9.93 ± 0.87 [a]	10.42 ± 1.04 [b]	13.14 ± 0.70 [c]	11.35 ± 0.58 [d]	10.53 ± 0.46 [e]
Male Total Length (cm)	41.38 ± 2.89 [a]	47.11 ± 2.54 [b]	51.53 ± 1.97 [c]	45.18 ± 1.80 [d]	46.85 ± 3.28 [e]
Male Total Weight (g)	571.12 ± 117.22 [a]	743.62 ± 98.34 [b]	908.250 ± 107.77 [c]	606.00 ± 66.81 [d]	767.62 ± 153.24 [e]
Male Gonad Weight (g)	4.75 ± 1.12 [a]	6.13 ± 0.69 [b]	8.50 ± 1.07 [c]	5.12 ± 0.58 [d]	6.62 ± 1.25 [e]
Male GSI (%)	0.79 ± 0.06 [a]	0.85 ± 0.09 [b]	0.94 ± 0.04 [c]	0.88 ± 0.05 [d]	0.86 ± 0.54 [e]

**Values represent the mean ± standard error for triplicate unit of each treatment. Mean values having the same superscript are not significantly different (P > 0.05)*

Table 5. Mean water quality parameters of experimental units

Indices	Tank A (Control)	Tank B (5% MLM)	Tank C (10% MLM)	Tank D (15% MLM)	Tank E (20% MLM)
Water temperature (°C)	29.50 ± 0.30	29.60 ± 0.20	29.50 ± 0.20	29.50 ± 0.25	29.55 ± 0.20
pH	7.10 ± 0.50	7.06 ± 0.60	7.08 ± 0.50	7.05 ± 0.50	7.80 ± 0.60
Dissolved Oxygen (mg/l)	5.20 ± 0.50	5.24 ± 0.45	5.28 ± 0.50	5.18 ± 0.42	5.29 ± 0.28

**Values represent mean ± standard error for the triplicate data of each treatment*

result in increased palatability, acceptability and growth in fish. Gonad development in both male and female *H. longifilis* in this study was impressive although fish fed Diet C had the best result. This findings agrees with the findings of [1] that utilization of good quality feed helps in a better development of gonads in *C. gariepinus.* Female fish fed Diet C had the highest GSI value of 9.93 ± 0.87% which was significantly different ($P<0.05$) compared to other treatments while the least female GSI 9.93 ± 0.87% was obtained in fish fed Diet A (control). Similarly, male GSI was significantly higher ($P<0.05$) in fish fed Diet C (10%MLM) with a value of 0.94 ± 0.04% and least (0.79 ± 0.06%) in fish fed Diet A (control). This findings disagrees with observation of [2] who opined that GSI and gonad growth in both male and female *C. gariepinus* cannot be influenced significantly by inclusion of plant-based ingredients such as *G. kola* and *S. jamaicensis* leaf meal in their diets. Comparing *M. oleifera* leaf meal used in this study with *G. kola* and *S. jamaicensis* leaf meal with regards to nutrient composition, *M. oleifera* leaf meal is richer which could be the reason for the significant influence on gonad development and GSI observed in this study. Water quality parameters measured in this study including pH, water temperature and dissolved oxygen were within range accepted and recommended for by [25] and [26] for healthy and optimal growth fish. The implication of this is that fecundity and GSI of *H. longifilis* in this study were not negatively affected by water quality parameters of the tarpaulin tanks used in culturing the experimental fish.

5. CONCLUSION

Findings of this feeding trial indicate that feeding *H. longifilis* with diets formulated with varying inclusion levels of *M. oleifera* leaf meal (MLM) as a plant-based protein ingredient positively influenced fecundity and gonado-somatic index. In conclusion, incorporation of *M. oleifera* leaf meal (MLM) in the diet of *H. longifilis* diets up to 15% level will result in a better fecundity and gonad development.

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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