



Nutritional Utilization and Growth-Enhancing Potentials of Fenugreek (*Trigonella foenum-graecum*) Seed Meal as Dietary Additive in the diet of *Clarias gariepinus* Fingerlings

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Received: June 4, 2020

Accepted: September, 3 2020

ABSTRACT

Efforts to alleviate the conflicting competition between humans, fish and livestock feed industries for orthodox feedstuffs and to maximize aquaculture profitability have led to considering cheaper and locally available alternatives. This 56-day study was conducted to appraise the nutritional and growth-enhancing potential of boiled fenugreek (*Trigonella foenum-graecum*) seed meal (FSM) as an additive in the practical diet of 270 *Clarias gariepinus* fingerlings (weight: $7.14 - 7.19 \pm 0.25$ g; length: $5.2 - 5.5 \pm 0.53$ cm). Boiled fenugreek seed meal was incorporated into diets at 0 (control), 10, 20, 30, 40 and 50%. Fish fed with control diet had the highest (42.24 g) values of MWG, SGR (0.39%/day) and least (0.64) feed conversion ratio, followed by those fed with 20% FSM having MWG (37.07 g), SGR (0.27%/day) and FCR (0.65) while the fish fed with 50% FSM had the least MWG (29.38 g), SGR (0.08%/day) and highest FCR (0.68) respectively. Mean carcass crude protein (50.70 – 64.80%) significantly ($p < 0.05$) exceeded the initial value (48.85%). Growth and feed utilization indices steadily decreased with increase in the levels of fenugreek seed meal in the diets. This study revealed that up to 20% supplementation of boiled fenugreek seed meal as an additive in the diet of *C. gariepinus* could effectively improve growth performance and feed utilization.

Keywords: *Clarias gariepinus*, Fenugreek seeds, additive, growth and feed unitization

INTRODUCTION

Aquaculture production has become increasingly intensive as fish production from the capture fisheries reached its maximum possible potential with diminishing catch on a daily basis (Gabriel *et al.*, 2007). The global demand for fish is very high and fish culture in Nigeria is getting popular both in homesteads and farm-base. The key to abundant fish production is availability of cheap and balanced feed. The quality and quantity of feed used in fish culture are the major factors in determining profitability because feed supply represents the largest single expenditure in semi-intensive or intensive culture operations. Feed cost has been reported to account for over two-thirds of the variable cost of an intensive aquaculture system (Aderolu and Sogbesan, 2010). According to Bake *et al.* (2014), the cost of feed production alone constitutes about 40 - 65% of total operating costs of finfish aquaculture production in Africa. The cost of fish feeds can be significantly reduced if locally available ingredients are incorporated in feed production (Olawepo *et al.*, 2014). There is, therefore, a pressing need to search for alternative cheaper feedstuffs from unconventional sources to reduce cost.

Agricultural by-products are as abundant in the tropics as there are wide varieties of plants and plant by-products such as cereals, fruits, seeds, leaves, stems and roots. More emphasis is being currently placed on the possibility substitution, replacement or inclusion of some of these by-products whose nutritional values have been ascertained. Such by-products are locally available and are not directly consumed by man in most cases (Ibiyo and Olowosegun, 2004). Fenugreek seeds are among such agricultural by-products whose dietary potential has not been fully tapped in fish nutrition in Nigeria.

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Fenugreek (*Trigonella foenum-graecum* L.) plant (Family: *Leguminosae*) is an annual leguminous herb grown in Northern Africa, the Mediterranean, Western Asia, Northern India and North America. Its seeds, which are borne in pods at the extremity of the plant, are used as a spice and leaves as a vegetable which is rich in vitamins and minerals. The seeds contain 12.91% crude protein and are a major source of diosgenin (a steroid saponin) which has anti-ulcer properties in humans and induces apoptosis (death) of human colon cancer cells (Sahalian, 2004; Abdelwahab and El-Bahr, 2012). Fenugreek seeds have been used medicinally as a food supplement due to their enormous beneficial effects on the digestive system such as a laxative, intestinal lubricant, carminative, anti-colitis, febrifuge, digestive and tonic. They have been used to dissolve fat and cholesterol deposits, prevent fat accumulation and water retention as well as to reduce blood glucose levels (Ahmad *et al.*, 2016; Moradi Kor and Moradi, 2013; Madar and Stark, 2002; Platel and Srinivasan, 2000).

Supplementation of diets with fenugreek seeds has been reported to improve growth performance and reduce mortality in *Oreochromis niloticus* fingerlings (Shalaby, 2004; Abdel-Zaher *et al.*, 2009; Abdelhamid and Soliman, 2012). Yilmaz *et al.* (2012) reported that including fenugreek seeds as additive promoted growth in sea bass (*Dicentrarchus labrax*) while Mehboob *et al.* (2017) reported significant improvement in growth and carcass crude protein content in striped catfish (*Pangasius hypophthalmus*) fry. Similarly, the addition of fenugreek seeds was reported to enhance growth in common carp (*Cyprinus carpio*) and gilthead sea bream (*Sparus aurata*) fingerlings (Roohi *et al.*, 2015; Awad *et al.*, 2015) while Shaikhlar *et al.* (2011) reported optimum feed intake and growth response when fenugreek seeds replaced 30% fishmeal in *P. hypophthalmus* fingerlings diet. However, there is a paucity of information on the utilization of fenugreek seeds as feed additive in formulated diets for *C. gariepinus*. Therefore, the objective of this study was to investigate the effects of supplementing boiled fenugreek seed meal as a feed additive in the diet of *C. gariepinus*.

MATERIALS AND METHODS

Collection and processing of fenugreek seeds

Raw fenugreek seeds weighing 1.5 kg used in this study were procured from Rimi Market in Kano, Kano State, Nigeria and taken to the Department of Biological Sciences, Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria where they were identified and validated by a plant taxonomist. They were boiled for 10 minutes at 100°C and oven-dried at 80°C for 6 hours. The dried fenugreek seeds were milled into fine powder kept in an airtight bag until required.

Experimental diets and fish

A total of 320 *C. gariepinus* post-fingerlings (weight: 7.14 - 7.19 ± 0.25 g and 5.2 – 5.5 ± 0.53 cm length) were purchased from Agricultural Development Project (ADP), Akure, Ondo State, Nigeria and transported to the fish laboratory. Prior to the commencement of the feeding trial, the fish were acclimatized for 7 days in three separate plastic tanks (1.5 m × 1.5 m × 0.5m). They were fed twice daily with 2 mm commercial feed to satiation.

Experimental diets

The feed ingredients; Groundnut cake, Fish meal, toasted soybean meal, yellow maize, palm oil, salt and premix. were procure from a in Okitipupa market. The feed stuff were milled using a grinding machine. Six isonitrogenous diets of 40% crude protein were formulated using Pearson's square method (Table 1).

Experimental design

Various concentrations of boiled fenugreek seed meal were incorporated at 0 (control diet), 10, 20, 30, 40 and 50% (Table 1) as an additive into the diets of *C. gariepinus*. Each of the separately mixed diet pastes was forced through a 2-mm die matrix pelletizer (A-2007 Model, Hobart Ltd, London, UK). The pellets were dried at 50°C for 48 hours in an electric oven (Model: Fan Azma Gostar, BM 55), cooled to room

temperature and kept in separate airtight containers before use. The fenugreek seed meal-based diets were allotted to fish into 18 plastic aquaria ($50 \times 40 \times 40 \text{ cm}^3$) at fifteen fish per aquarium containing 20 liters of water each while maintaining constant aeration in each aquarium. Fish were fed twice daily (07:00 and 17:00 hours) at 5% of their body weight administered in two equal portions (morning and afternoon). The fish were cultured for the period of 56 days. Fish in each aquarium were batch-weighted and the quantities of diets administered were adjusted weekly based on new weight gain. Water in the culture media were changed every 48-hour interval while the uneaten feed was siphoned out of the aquaria every morning before feeding.

Table 1: Gross ingredient (g/100 g dry matter) and proximate composition of experimental diets

Ingredients	Fenugreek seed inclusion levels (%)					
	0	10	20	30	40	50
Fenugreek seed meal	0.00	2.08	4.14	6.21	8.28	10.34
Groundnut cake	20.67	18.60	16.54	14.47	12.40	10.34
Fish meal	24.00	24.00	24.00	24.00	24.00	24.00
Soybean meal	19.10	19.10	19.10	19.10	19.10	19.10
Yellow maize	26.23	26.23	26.23	26.23	26.23	26.23
Vit/mineral premix*	1.50	1.50	1.50	1.50	1.50	1.50
Palm oil	2.00	2.00	2.00	2.00	2.00	2.00
Salt	2.50	2.50	2.50	2.50	2.50	2.50
Cassava starch	4.00	4.00	4.00	4.00	4.00	4.00
Total (g)	100	100	100	100	100	100
Proximate Composition (%)						
Moisture	7.30±0.41 ^b	7.50±0.12 ^b	8.60±0.09 ^b	6.60±1.01 ^c	7.00±0.71 ^b	13.30±0.1 ^a
Crude protein	39.75±0.05 ^a	39.70±1.01 ^a	39.60±0.0 ^a	40.90±0.17 ^a	40.10±0.43 ^a	39.10±1.0 ^a
Crude lipid	6.10±0.01 ^a	6.30±0.53 ^a	6.14±0.81 ^a	5.90±0.56 ^b	6.30±0.05 ^a	6.50±0.21 ^a
Crude fiber	3.60±0.51 ^a	3.40±0.01 ^b	3.52±0.73 ^a	3.70±0.36 ^a	3.30±0.07 ^b	3.70±0.37 ^a
Total ash	8.80±0.31 ^{bc}	9.30±0.06 ^b	9.10±0.13 ^b	10.60±0.07 ^a	9.30±0.23 ^b	7.40±0.01 ^c
Nitrogen-free extract	34.45±0.02 ^a	33.80±0.31 ^a	33.03±0.0 ^b	32.30±0.51 ^b	34.09±0.01 ^a	30.01±0.4 ^c

Each kilogram of vitamin/mineral premix contained the following: Vitamin/mineral premix: Vit. A: 1,000,000 IU; Vit. B₁: 250 mg; Vit B₂: 1750 mg; Vit B₆: 875 mg; Vit. B₁₂: 2500 mg; Vit. C: 12,500 mg; Vit D₃: 600,000 Iu; Vit. E: 12,000 IU; Vit. K₃: 15 mg; Calcium D-pantothenate: 5000 mg; Nicotinic acid: 3750 mg; Folic acid: 250 mg; Cobalt: 24,999 mg; Copper: 1999 mg; Iron: 11,249 mg; Selenium (Na₂SeO₃. 5H₂O): 75 mg; Iodine (Potassium iodide): 106 mg; Anti-oxidant: 250 mg

Growth and feed utilization

At the end of the experiment, final weight and feed applied (g) were recorded using digital top loading weighing balance (OHAUS LS, Model 2000), final length (cm) were recorded using measuring board. The following growth and feed utilization indices were estimated for each treatment:

i) Mean Weight Gain (g) = (Final weight – Initial weight) g

ii) Percentage weight gain (PWG %) = $\frac{\text{Weight gain}}{\text{Initial weight}} \times 100$

iii) Specific Growth Rate (%/day) = $\frac{(\text{Ln final weight} - \text{Ln initial weight})}{\text{Time (experimental period in days)}} \times 100$, where: Ln = natural logarithm.

iv) Feed intake (g) = WFI₁ + WFI₂ + WFI₃ + WFI₄ + WFI_n, where: WFI= weekly feed intake by fish per treatment (g), 1, 2, 3, 4, n = number of weeks of the experimental duration

v) Food Conversion Ratio (FCR) = $\frac{\text{Mean feed intake (g)}}{\text{Weight gain (g)}}$

vi) Protein Intake (g of protein in 100g diet/fish) = $\frac{\text{feed intake} \times \% \text{ crude protein in the diet}}{100}$

$$\text{vii) Protein Efficiency Ratio (PER)} = \frac{\text{Weight gain}}{\text{Protein intake (g of protein in 100g of diet/fish)}}$$

$$\text{viii) Nitrogen Metabolism (NM)} = \frac{0.549 \times (\text{Initial weight} + \text{Final mean weight})t}{2}$$

where: t = experimental period in days, 0.549 = metabolism factor

$$\text{ix) Survival (\%)} = \frac{\text{Total number of survival}}{\text{Total number of fish stocked}} \times 100$$

Proximate composition of the fish

Seven grams (7 g) of each diet, six pre-treatment fish samples and four post-treatment fish samples from each treatment were used to determine their respective proximate composition using AOAC (2011) methods. Dry matter (at 105°C for 24 h), crude protein (nitrogen \times 6.25, using Kjeldahl apparatus), crude lipid (extracted with petroleum ether by means of Soxhlet apparatus), total ash {by burning at 600°C for 6 h in a Gallenkamp blast furnace chamber (Gallenkamp, UK)}, moisture content (by oven-drying to a constant weight (in a Gallenkamp oven) and nitrogen-free extract (by subtracting other values from 100%).

Monitoring of water quality

Water quality parameters in the culture media were monitored weekly between 7.00 and 8.00 hours throughout the experimental period. Water temperature was measured using mercury-in-glass thermometer 5 cm below the water surface. Dissolved oxygen was measured using dissolved oxygen meter (Model: YSI 55, Yellow Springs Incorporated, Ohio, 4387, USA), while pH was determined using pH meter (Model: LT-Lutron pH-207, Taiwan).

Statistical analysis

Data obtained from the study were subjected to one-way analysis of variance (ANOVA). Differences between the treatment means were determined using Duncan's New Multiple Range ($P=0.05$) with the aid of SPSS 22.0.

RESULTS

Growth performance and feed utilization of *C. gariepinus* fed fenugreek seed meal as supplement

Table 2 shows the growth and feed utilization of *C. gariepinus* fed fenugreek seed meal (FSM) as supplement. which revealed significant variations ($p < 0.05$) among the fish exposed to the experimental diets. Highest values of growth indices were observed in fish fed with 0% FSM (control diet), followed by those fed with 20% FSM beyond which they showed a decreasing trend with increase in the supplementation level of fenugreek seed meal. Apart from the fish fed with the control diet, mean weight gain (MWG) and specific growth rate (SGR) were highest (11.73 g and 2.13%/day) in the fish fed 20% FSM and lowest (9.06 g and 1.82%/day) in those fed 50% FSM respectively. MWG and SGR significantly ($p < 0.05$) increased in the fish fed 0 -20% FSM after which they assumed a declining trend in those fed 30

- 50% FSM. The values of 0.64 - 0.68 recorded for feed conversion ratio (FCR) significantly varied ($p < 0.05$) across the treatments and the fish fed 20% FSM showed efficient feed utilization next to those fed with the control diet. Likewise, protein intake, protein efficiency ratio and nitrogen metabolism showed a similar reducing trend with significant ($p < 0.05$) variations and the fish fed with 20% FSM had the highest values of these indices among the test treatments. Survival was highest (90.33%) in the fish fed with 0% FSM but was not significantly different ($p > 0.05$) from 89.2% in those fed with 20% FSM while those placed on 50% FSM had the least (80.11%).

Table 2: Mean (\pm SD) growth performance and feed utilization of *C. gariepinus* fed fenugreek seed meal supplemented diets

Growth Parameters	Fenugreek Seed Meal Supplementation levels (%)					
	0	10	20	30	40	50
IW (g)	7.14 \pm 0.31 ^a	7.15 \pm 0.01 ^a	7.16 \pm 0.42 ^a	7.14 \pm 1.09 ^a	7.16 \pm 0.35 ^a	7.19 \pm 0.09 ^a
FW (g)	49.38 \pm 0.21 ^a	39.98 \pm 0.53 ^d	44.23 \pm 0.40 ^b	39.72 \pm 1.04 ^d	41.92 \pm 0.24 ^c	36.57 \pm 1.48 ^c
WG (g)	42.24 \pm 0.20 ^a	32.83 \pm 0.52 ^d	37.07 \pm 0.40 ^b	32.58 \pm 1.04 ^d	34.76 \pm 0.24 ^c	29.38 \pm 2.95 ^c
PWG (%)	591.60 \pm 0.45 ^a	459.16 \pm 1.24 ^d	517.74 \pm 0.14 ^b	456.30 \pm 1.31 ^d	485.47 \pm 0.52 ^c	408.62 \pm 0.59 ^c
SGR (%/day)	0.39 \pm 0.12 ^a	0.18 \pm 0.05 ^d	0.27 \pm 0.01 ^b	0.17 \pm 0.07 ^d	0.22 \pm 0.01 ^c	0.08 \pm 0.06 ^c
SR (%)	90.33 \pm 1.08 ^a	86.82 \pm 0.95 ^{ab}	89.20 \pm 1.56 ^a	85.89 \pm 1.23 ^{ab}	87.56 \pm 0.58 ^{ab}	80.11 \pm 1.43 ^b
FCR	0.64 \pm 0.10 ^b	0.67 \pm 0.06 ^a	0.65 \pm 0.03 ^a	0.67 \pm 0.07 ^a	0.66 \pm 0.04 ^a	0.68 \pm 0.13 ^a
NM	868.83 \pm 2.23 ^a	724.48 \pm 1.15 ^d	789.97 \pm 0.75 ^b	720.33 \pm 0.20 ^d	754.46 \pm 1.32 ^c	672.68 \pm 1.03 ^c
PER	3.94 \pm 0.01 ^a	3.77 \pm 0.42 ^b	3.87 \pm 0.31 ^a	3.65 \pm 0.03 ^c	3.77 \pm 0.61 ^b	3.74 \pm 0.04 ^b
PI	10.72 \pm 0.23 ^a	8.71 \pm 0.17 ^c	9.59 \pm 0.01 ^b	8.92 \pm 0.71 ^c	9.21 \pm 0.19 ^b	7.86 \pm 1.04 ^d

Mean with similar superscripts are not significantly different ($p > 0.05$).

Key: IW= Initial weight, FW=Final weight, WG=Weight gain, PWG=Percentage weight gain, SGR=Specific growth rate, SR= Survival rate, FCR=Feed conversion ratio, NM=Nitrogen metabolism, PER=Protein efficiency ratio, PI=Protein intake.

Carcass proximate composition

Table 3 shows the carcass proximate composition of *C. gariepinus* fed fenugreek seed meal as supplement. The values of proximate parameters showed significant difference ($p < 0.05$) which, however, did not follow any specific trend. Crude protein values in the post-treatment fish carcass were significantly ($p < 0.05$) higher than 48.85% in the pre-treatment fish.

Table 3: Carcass proximate composition of *C. gariepinus* fed fenugreek seed meal as a supplement

Nutrients	Fenugreek seed meal supplementation levels (%)					
	0	10	20	30	40	50
CP (%)	54.35 \pm 0.45 ^b	52.80 \pm 0.71 ^b	53.35 \pm 0.83 ^b	64.80 \pm 0.31 ^a	52.45 \pm 0.0 ^b	50.70 \pm 1.02 ^c
DM (%)	79.50 \pm 1.36 ^c	86.20 \pm 0.61 ^b	80.01 \pm 0.73 ^c	90.40 \pm 0.09 ^a	79.79 \pm 1.0 ^c	79.19 \pm 0.56 ^c
CL (%)	8.01 \pm 0.51 ^a	8.40 \pm 0.73 ^a	8.60 \pm 0.69 ^a	8.90 \pm 0.42 ^a	8.30 \pm 1.01 ^a	8.10 \pm 0.76 ^a
Ash (%)	8.03 \pm 0.25 ^d	7.70 \pm 0.51 ^d	11.30 \pm 0.63 ^b	12.80 \pm 0.02 ^a	12.20 \pm 0.7 ^a	12.30 \pm 0.31 ^a
NFE (%)	9.10 \pm 0.24 ^c	17.30 \pm 0.01 ^a	6.75 \pm 0.65 ^d	3.90 \pm 0.02 ^c	6.84 \pm 0.43 ^d	8.09 \pm 0.03 ^c
MO (%)	20.50 \pm 0.24 ^a	13.80 \pm 0.01 ^c	20.00 \pm 0.05 ^a	9.60 \pm 0.02 ^d	20.21 \pm 0.4 ^a	20.81 \pm 0.03 ^a

Mean with similar superscripts are not significantly different ($p > 0.05$).

Key: CP=Crude protein, DM=Dry matter, CL=Crude lipid, Nitrogen-free extract, MO= Moisture content.

The fish fed with 30% FSM supplementation had the highest value (64.8%) while those fed with 50% FSM had the least (50.7%). Initial crude lipid content was 8.4% while the final values ranged from 8.01% in the fish fed with 0% FSM to 8.9% in those fed with 30% FSM. Ash content was initially 9.0% while the final values varied between 7.7% in the fish fed with 10% FSM and 12.8% in those fed with 30% FSM. Initial moisture content was 18.3% while the final values ranged between 9.6 and 20.81%. Nitrogen-free extract was initially 15.45% while the final values varied between 3.9 and 17.30%.

Water quality parameters of experimental treatment units

Table 4 shows the water quality parameters recorded during the experiment. Temperature ranged between 26.65 and 27.68°C, dissolved oxygen from 5.39 to 6.71 mg/L while pH varied from 7.25 to 7.83. However, the parameters were not significantly different ($p > 0.05$) among all the treatments.

Table 4: Water quality parameters

FSM inclusion levels (%)	Temperature (°C)	DO (mg/L)	pH
0	27.54 ± 0.32 ^a	5.57 ± 0.21 ^a	7.27 ± 0.37 ^a
10	26.65 ± 0.15 ^a	6.45 ± 0.37 ^a	7.25 ± 0.25 ^a
20	27.68 ± 0.21 ^a	5.39 ± 0.42 ^a	7.32 ± 0.43 ^a
30	27.25 ± 0.07 ^a	5.68 ± 0.17 ^a	7.47 ± 0.16 ^a
40	26.95 ± 0.28 ^a	6.71 ± 0.41 ^a	7.56 ± 0.35 ^a
50	27.20 ± 0.20 ^a	5.87 ± 0.32 ^a	7.83 ± 0.04 ^a

Mean values with similar superscripts along the same row were not significantly different ($p > 0.05$).

Key: FSM = Fenugreek feed meal

DISCUSSION

Supplementation of boiled fenugreek seed meal in the diet of *C. gariepinus* post-fingerlings in this study resulted in a significant decrease in the growth and feed utilization of the fish compared to that of the fish group fed with the control diet. This varied from the findings of Abdel-Zaher *et al.* (2009) who reported positive growth responses in *O. niloticus* fingerlings as well in *C. carpio* fingerlings Roohi *et al.* (2015) and *P. hypophthalmus* fry reported by Mehboob *et al.* (2017) fed FSM supplemented diets. Similarly, Awad *et al.* (2015) reported considerable improvement in the growth of *S. aurata* fingerlings treated with FSM-based diets, while Shaikhlar *et al.* (2011) reported optimum growth and feed consumption when FSM replaced 30% fishmeal in the diet of *P. hypophthalmus* fingerlings. Besides, Abdelhamid and Soliman (2012) found that FSM inclusion significantly improved growth performance, carcass crude protein and feed utilization in terms of protein productive value and energy retention in *O. niloticus* fry. The higher growth and feed utilization observed at 20% FSM evidently signified better diet utilization and feed conversion to flesh that was not feasible at higher supplementation levels. The reducing growth trend beyond 20% FSM supplementation also suggested that FSM has the potential to effectively enhance

growth when it is incorporated at low levels. It has been stated that addition of new ingredients as feed supplements in fish diets depends on the nutrient composition of such supplements (Roohi *et al.*, 2015), supplementation levels (Liener, 2003), processing methods and tolerance levels of the fish species being cultured (Roohi, *et al.*, 2015; Mehboob *et al.*, 2017). Hence, FSM supplementation beyond the tolerable level of the fish possibly led to the reduced growth response as reported by Nwanna *et al.* (2009) for *O. niloticus* fingerlings fed potato peel supplemented diets. Besides, the progressive reduction in growth recorded at higher levels of FSM supplementation could be due to reduced feed intake/acceptability which in turn could possibly be associated with the presence of anti-nutrients in it (Mehboob *et al.*, 2017). Also, fish generally seem to have compensatory physiological mechanisms that can tolerate the negative effects of anti-nutrients when their quantities are below certain threshold levels (Nwanna *et al.*, 2009). This condition possibly explains why higher levels of FSM supplementation led to poorer feed utilization by the fish.

By contrast, the MWG values (29.38 – 42.24 g) obtained in this study plausibly implied superior growth response compared to 4.13 – 5.25 g and 11.46 – 17.09 g reported for *C. carpio* fingerlings (Roohi *et al.*, 2015) and *P. hypophthalmus* fry (Mehboob *et al.*, 2017) respectively fed with similar FSM- supplemented diets. However, the present SGR values (0.08 – 0.39 %/day) were lower than 0.85 – 1.12 %/day, 1.12 – 1.35%/day and 1.76 – 2.07%/day respectively obtained in *O. niloticus* fingerlings (Abdel-Zaher *et al.*, 2009), *P. hypophthalmus* fry (Mehboob *et al.*, 2017) and *C. carpio* fingerlings (Roohi *et al.*, 2015) fed with similar FSM-supplemented diets.

According to De Silva (2001) who maintained *O. niloticus* fry on mixed feeding schedules of different protein levels, an ideal FCR varies from 1.2 to 1.8 for fish fed with adequately formulated diets. The FCR values (0.65 – 0.68) obtained in the present study were marginally below this range. In addition, the present

FCR values probably suggested better feed utilization when compared to 1.64 – 2.08, 1.84 – 2.32 and 1.90 – 2.46 respectively earlier reported for *C. carpio* fingerlings (Roohi *et al.*, 2015), *P. hypophthalmus* fry (Mehboob *et al.*, 2017) and *O. niloticus* fingerlings (Abdel-Zaher *et al.*, 2009) fed with FSM-supplemented diets. An organism's ability to efficiently assimilate and utilize dietary nutrients, especially protein, will positively boost its growth response. This assertion was justified by the highest protein intake, protein efficiency ratio (PER) and growth indices exhibited by the fish group fed with 0% FSM supplementation which showed superior dietary protein utilization when compared with the fish groups fed with FSM-supplemented diets. In addition, the present PER values (3.74 – 3.94) possibly implied better dietary protein utilization when compared with 1.48 – 1.88 reported by Abdel-Zaher *et al.* (2009) for *O. niloticus* fingerlings fed with FSM-supplemented diets. According to Davis (2004), protein efficiency ratio is an indicator of how effectively the protein components in a diet can provide the required essential amino acids in the fish fed with such a diet.

The high survival recorded in this study signified a considerable acceptance of the FSM-supplemented diets by the fish and was similar to 80.00 – 90.00%, 93.30 – 95.60% and 100.00% earlier reported for *P. hypophthalmus* fry (Mehboob *et al.*, 2017), *O. niloticus* fingerlings (Abdel-Zaher *et al.*, 2009) and *C. carpio* fingerlings (Roohi *et al.*, 2015) respectively fed with similar FSM-supplemented diets. The high survival obtained during this study connoted that feeding *C. gariepinus* with FSM-supplemented diets did not cause significant fish mortality as inferred by Roohi *et al.* (2015) and Mehboob *et al.* (2017).

Proximate composition of *C. gariepinus* fed FSM as supplement

The significant increase in the crude protein content of post-trial *C. gariepinus* fingerlings indicated that both the control and FSM-supplemented diets enhanced protein synthesis and tissue formation in them as earlier reported by Fountoulaki *et al.* (2003) and Yusuf *et al.* (2016) for gilthead bream (*S. aurata*) fingerlings and *C. gariepinus* juveniles respectively. Similar trends of elevated carcass crude protein (59.29 – 60.75% and 59.20 – 63.50%) were respectively documented for *O. niloticus* fingerlings (Abdel-Zaher *et al.*, 2009) and striped catfish *Pangasius hypophthalmus* fry (Mehboob *et al.*, 2017) fed with FSM-supplemented diets. The non-significant variations in the crude lipid values of post-treatment fish carcass signified that different dietary inclusion levels of FSM did not affect body lipid of the fish. However, these values were similar to 7.50 – 8.40% reported for *P. hypophthalmus* fry (Mehboob *et al.*, 2017) but lower when compared to 20.03 – 21.86% observed in *O. niloticus* fingerlings (Abdel-Zaher *et al.*, 2009). Ash content also increased due to the dietary treatment but its values were below 16.58 – 16.93% and 17.55 – 18.40% respectively reported for *O. niloticus* fingerlings (Abdel-Zaher *et al.*, 2009) and *P. hypophthalmus* fry (Mehboob *et al.*, 2017) fed similar diets. By contrast, Abdel-Zaher *et al.* (2009) reported non-significant variations in dry matter, crude protein, crude lipid and ash contents of *O. niloticus* fingerlings exposed to graded FSM-based diets.

Water quality parameters

Values of these parameters recorded during this study corresponded to 26.0 - 29.0°C temperature, 5.40 - 6.30 mg/ L DO and pH 7.60 - 8.20 as well as 26.35 - 26.82°C, 4.59 – 4.75 mg/ L and 7.56 - 7.67 respectively reported during similar studies involving the culture of *O. niloticus* fingerlings in Egypt (Abdel-Zaher *et al.*, 2009) and *P. hypophthalmus* fry in Pakistan (Mehboob *et al.*, 2017). Moreover, the present values also agreed with those reported by Idowu *et al.* (2020) for *O. niloticus* juveniles exposed to varied stem bark aqueous extract of *Kigelia africana* tree. Comparable results were documented by Tolan and Sherif (2007), Musa *et al.* (2013) and Samkelisiwe and Ngonidzashe (2014) in related fish nutritional studies. Water pH, dissolved oxygen and temperature are among critical parameters in both laboratory-based and on-farm fish culture which considerably affect feed and/or protein intake and growth. The current values also aligned with 25 – 30°C reported by Okechi (2004) as most favorable temperature for warm-water fish culture. The present results indicated that boiled fenugreek seed meal can be gainfully utilized in aquaculture without impairing the ideal water quality conditions.

Conclusion

Fenugreek seed meal supported growth and feed utilization in *Clarias gariepinus*. It can therefore be used as supplement at lower level (20%) in the diet of *Clarias gariepinus* and other commercial fish species.

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