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The effect of floating and sinking diets on growth performance, feed conversion efficiency, yield and cost-effectiveness of African sharptooth catfish, *Clarias gariepinus* reared in earthen ponds

Samwel Mchele Limbu

Abstract
Dependence on floating diets limits the development of African sharptooth catfish, *Clarias gariepinus* farming because they are more expensive, require specialized facilities to produce and arguably inappropriate based on bottom feeding behaviour of the species. This study evaluated the effect of floating and sinking diets on the growth performance, feed conversion efficiency, condition factor, yield and cost-effectiveness of *C. gariepinus*. Fingerlings of 14.95 ± 0.24 g initial mean weight (± standard error) were reared in triplicate earthen ponds at a stocking density of 10 fish m^{-2} for eight weeks. The results showed that, feeding *C. gariepinus* using either floating or sinking diets did not significantly affect growth and survival rate ($p > 0.05$). Equally, *C. gariepinus* fed on sinking and floating diets had similar feed conversion efficiency ($p = 0.426$). The fish in both treatments had similar condition factors and were growing isometrically ($p > 0.05$). Rearing *C. gariepinus* either on floating or sinking diets did not affect gross, net and annual yields ($p > 0.05$). However, *C. gariepinus* fed on floating diet had significantly higher incidence cost by 33% more than feeding them on sinking diet ($p = 0.001$). Furthermore, the profit index for *C. gariepinus* fed on the floating diet was significantly lower by 35% less than those fed on the sinking diet ($p = 0.001$). The present study indicates that, *C. gariepinus* farmers can reduce feeding cost up to more than 30% by using sinking diet without affecting the growth performance, survival, nutrient utilization, condition factor and yield of their fish.

Keywords: Feeds, profit index, incidence cost, percentage survival, condition factor

1. Introduction
Feed is one of the operating cost mostly limiting the expansion of cultured species [1]. Feeds commonly accounts for 40-60% of the operating costs depending on the level of intensification and species [2, 3]. The cost of feeding is usually exacerbated when the cultured species requires higher protein level in the diet. The African sharptooth catfish *Clarias gariepinus* is one of the most important fish species currently being cultured both within and outside its natural range of tropical and subtropical environments [4]. It is generally accepted as an omnivore that feeds on fish, invertebrates, plant material, plankton, reptiles and amphibians in its natural range [5]. Under aquaculture conditions, *C. gariepinus* accepts a variety of diets from plant, animal based and their mixtures with protein levels between 300 and 400 g kg^{-1} depending on its size [6]. Based on its predatory feeding habit, it can utilize wet or dry feeds as meals, sinking or floating pellets, blocks or crumbles [7].
The farming of *C. gariepinus* in many countries normally involves the purchase or production of on-farm sinking or floating feeds. Whether purchased or produced on-farms, floating diets are usually more costly than sinking diets because extrusion process which is the main activity that makes them float adds extra cost [3]. The sinking pelleted diets are fairly common and less costly to produce than the floating diets [8]. A study by [9] indicated that farmers prefer floating diets for feeding *C. gariepinus* because it is easier to observe satiation level when the fish is cultured in tanks. However, due to its bottom feeding behaviour, its culture in ponds causes higher turbidity that obscure water visibility [5]. This makes impossible for *C. gariepinus* farmers to observe satiation level, consequently excluding the need for relying on floating diets.
Previous studies in fish species such as halibut, *Hippoglossus hippoglossus* have shown that

growth, nutrient utilization and yield are affected by the form of the diets used [10, 11]. Studies in *C. gariepinus* have yielded inconsistence results when floating and sinking diets are compared on their effect on growth, nutrient utilization and yield. [12] found similarity in mean weight gain and daily feed intake for *C. gariepinus* fed on floating and sinking feeds. [13] showed significant higher weight increase, specific growth rate for *C. gariepinus* fed with coppens (floating feed) than those fed with local feed (sinking). These discrepancies call for more studies in *C. gariepinus* to unveil the underlying causes.

Limited studies have been carried out to explore the bottom feeding habit of *C. gariepinus* in order to recommend the suitable diet between floating and sinking diets [13]. Consequently, famers do not know which diet to choose for their *C. gariepinus* due to paucity and inexistence of published scientific information on growth, nutrient utilization and yield when the fish is fed on floating and sinking diets. This has been costly to *C. gariepinus* farmers because they tend to use the costly floating diets. The present study was undertaken to compare the growth performance, percentage survival, feed conversion efficiency, condition factor, yield and economics of *C. gariepinus* fed on floating and sinking diets. It was hypothesized that, growth performance, percentage survival, feed conversion efficiency, condition factor, yield and economics will be higher for *C. gariepinus* fed on floating than sinking diet.

2. Materials and Methods

2.1 Experimental feeds

A sinking diet was formulated with the aid of a computer programme (Winfeed 2.8) using locally available ingredients. The ingredients used were cottonseed cakes, fishmeal (*Rastrineobola argentea*), whole maize, soy bean whole, sunflower oil cakes and wheat pollard. The sinking diet was intentionally formulated to supplement the natural foods in the ponds. The floating diet was purchased from a local feed manufacturer in Uganda. The formulation and proximate composition of the diets used in the study are given in Table 1.

Table 1: Formulation and proximate composition of the diets (g kg^{-1} dry weight), cost (USD kg^{-1}), gross energy (kJ g^{-1}) and protein to gross energy ratio (P/GE) (mg kJ^{-1}).

	Diet	
Feed ingredients	Floating diet	Sinking diet
Cottonseed cake	-	150.00
Fishmeal (*Rastrineobola argentea*)	-	300.00
Maize	-	70.00
Soya bean whole	-	170.00
Sunflower oil cake	-	180.00
Wheat pollard	-	130.00
Cost[1]	0.71	0.46
Proximate analysis		
Moisture	103.45	143.61
Crude protein	327.10	242.07
Crude lipid	59.20	78.86
Fibre	59.15	100.67
Ash	67.70	223.68
NFE	383.40	311.78
Gross energy (GE)[2]	16.32	13.95
P/GE ratio	20.04	17.35

The cost of on-farm feeds were calculated by including 25% processing costs for the ingredients. [2]Calculated using the factors: carbohydrates, 4.1 kcal g^{-1}, protein, 5.4 kcal g^{-1} and lipids, 9.5 kcal g^{-1} [14] and transformed to kJ g^{-1} using the factor 4.184. Blank space "–" means information not disclosed by the feed manufacturer.

Ingredients for the production of sinking diet were purchased from local suppliers at the site based on nutrient composition, cost and availability determined using available literature. All the ingredients were obtained in dry form. During the production of the sinking diet, whole maize and soybeans were processed in order to reduce anti-nutritional factors and improve nutrient bioavailability to the fish [15]. Apart from grinding, the other ingredients used in the production of the sinking diet were not subjected to any processing. Thus, whole maize and soybeans were soaked in freshwater for overnight and 8 hours respectively. They were then boiled for half to one hour followed by solar-drying for about a day. Solar-drying was followed by dry cooking (roasting) and finally solar-dried again.

Dried ingredients were milled into fine particles using a grinder machine (hammer mill) with a screen size of 0.8 mm, weighed and mixed in the required proportions according to formulation. The mixture was then blended with sufficient hot water to form a dough. Pellets were produced by extruding this dough through a meat grinder/mincer with a die size of 4 mm and subsequent solar-dried for several hours until dry.

A dried sample of each diet was sent to Stirling University laboratory for proximate nutrient analysis (moisture, protein, oil, fibre, ash) using standard methods [16]. Moisture was determined by oven drying the ingredients at 105 ºC for 24 h. Crude protein (N X 6.25) was determined by the Kjeldahl method after digestion with concentrated H_2SO_4. Ash content was determined by incineration in a muffle furnace at 600 ºC for 16 h. Crude lipid was determined by the Soxhlet method using petroleum ether and crude fibre was determined by digestion with 1.25% NaOH and 1.25% H_2SO_4. Gross energy was calculated using the conversion factors for protein, lipids and carbohydrates provided in [14]. Nitrogen free extract (NFE) was calculated by subtracting the sum of moisture, protein, oil, fibre and ash from 100.

2.2 Experimental design

The above diets were used in a feeding trial conducted in a set of 6 identical earthen ponds (5 x 4 m^2) with mean depth of 0.5 m. The ponds were randomly stocked with 10 week old *C. gariepinus* at a density of 10 fingerlings m^{-2} with an initial average weight (± standard error) of 14.95 ± 0.24 g. The fingerlings were acclimatized for two weeks prior to the start of the experiment. Fingerlings were fed the two diets each in triplicate at approximately 4% body weight spread over two meals per day (09:30 h and 16:30 h) for 53 days. Feeding for the sinking diet was carried out using two rectangular wooden feeding trays (0.6 x 0.5 x 0.05 m^3) fitted with a 1 mm nylon net material at their bottoms. The two feeding trays were submerged at diagonal opposite corners of each pond. The floating diet was fed by broadcasting from the periphery of each pond. Fingerlings were weighed every two weeks and feeding ration was adjusted accordingly.

2.3 Data collection

A total of 30 fingerlings were randomly sampled from each pond every two weeks for the first six weeks and on 11th day for the last sampling using a seine net with mesh size of 12.70 mm for weight and length measurements. Total length (cm) of individual fingerling was measured from the tip of the snout (mouth closed) to the extended tip of the caudal fin using a measuring board (± 0.1 cm). Weight was determined by using an electronic precision balance (Model number CST-1000 made in India by Caliber Scales India PVT. LTD) to the nearest ± 0.01 g. Length and weight of fingerlings as well as diet data were used to determine growth performance parameters [17] and condition factor (K) of fingerlings [18] using the following formulae:-

i. $$\text{Daily weight gain, } (\text{DWG, g day}^{-1}) = \frac{\text{Wf} - \text{Wi}}{\text{Time (days)}}$$

where Wf and Wi are the final and initial mean weights respectively.

ii. $$\text{Specific growth rate, } (\text{SGR \% day}^{-1}) = \left(\frac{\ell\text{nWf} - \ell\text{nWi}}{\text{Time (days)}}\right) x\,100$$

The amount of diet fed were used to calculate feed conversion efficiency (FCE) according to [17] using the following formula:-

iv. $$\text{FCE} = \frac{\text{Total wet weight gain of fish (g)}}{\text{Total amount of dry diet fed (g)}}$$

At the end of the experiment, water in all ponds was emptied and fish were counted. The number of fingerlings at the start and end of the experiment was used to calculate percentage survival rate (SR %) using the formula:-

v. $$\text{SR, \%} = \left(\frac{\text{TFf}}{\text{TFi}}\right) \text{x } 100$$

where TFf and TFi refer to total final and initial number of fingerlings and adult fish respectively.

The *C. gariepinus* obtained at the end of the experiment were weighed for determination of gross fish yield (GFY) using an electronic precision balance (Model number CST-1000 made in India by Caliber Scales India PVT. LTD). Net fish yield (NFY) and net annual yield (NAY) were calculated using the following formulae:-

vi. $$\text{NFY} = \frac{W_h - W_s}{A}$$

where W_h = Total weight of fish harvested (kg)
W_s = Total weight of fish stocked (kg)
A = Pond area (ha)

vii. $$\text{NAY} = \frac{\text{NFY x } 365}{t}$$

An economic analysis was used to assess the cost-effectiveness of diets used in the study. The cost of feed was calculated using market prices, taking into consideration the cost of diets and the transport fare with the assumption that other costs such as construction of ponds, cost of fingerlings and labour remained constant. Indices for economic evaluation used were incidence cost (IC) and profit index (PI) estimated according to [19] using the following formulae:-

viii. $$\text{IC (USD kg}^{-1}) = \frac{\text{Cost of feed}}{\text{Weight of fish produced}}$$

ix. $$\text{PI} = \frac{\text{Value of fish produced}}{\text{Cost of feed}}$$

During the study period, *C. gariepinus* price at the site was 3.57 USD kg^{-1}and 1 USD = 2242.50 Ugandan shilling (UGX) for June 2010.

Water temperature, dissolved oxygen (DO) and pH in the ponds were monitored twice-daily (0900 h and 1700 h). Water temperature and dissolved oxygen were both measured using DO meter (VWR 2000) and pH was determined using pH meter (Hanna Replacement pH electrode HI 98128). Other water quality parameters such as unionised ammonia, nitrite, hardness and alkalinity were measured on a week basis using a Palintest kit (Photometer 7100).

2.4 Statistical analyses

Results are presented as means ± standard error (SE) of means and data were tested for homogeneity of variance using Levene's test to safeguard violation of parametric statistics. After confirming homogeneity of variances, a two sample t-test was utilized to test for significant difference in growth parameters, survival, nutrient utilization, yield and economic parameters between the floating and sinking diets. Percentage data were arcsine-transformed prior to t-test. Results with $p \leq 0.05$ were considered statistically significant [20]. All statistical analyses were performed using SPSS for windows version 20 (SPSS, Inc).

3. Results

3.1 Growth performance, feed conversion efficiency, condition factor and percentage survival

The increase in average fortnightly weights for *C. gariepinus* during the study is shown in Figure 1. The final weight were 49.20 ± 0.77 g and 47.22 ± 1.70 g for *C. gariepinus* fed on floating and sinking diets respectively. Final weight of *C. gariepinus* did not differ significantly between floating and sinking diets ($t_{(4)} = -1.087$, $p = 0.338$).

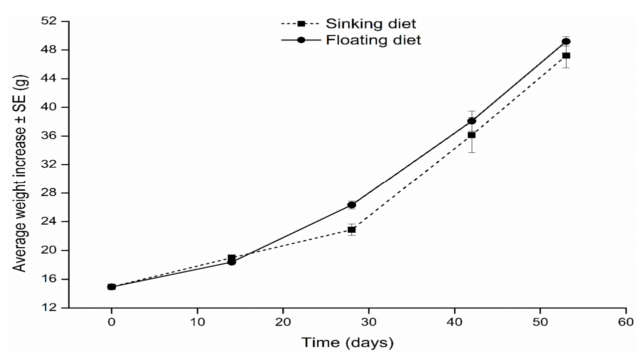

Fig 1: The growth response of the African sharptooth catfish (*Clarias gariepinus*) fed on floating and sinking diets during the study period

The results on growth parameters showed that, floating and sinking diets had no significant effect on DWG ($t_{(22)} = -0.224$, $p = 0.824$), SGR ($t_{(22)} = 0.029$, $p = 0.977$) and percentage survival ($t_{(4)} = -0.719$, $p = 0.512$) of *C. gariepinus* during the study (Table 2). Furthermore, *C. gariepinus* fed on the sinking and floating diets had similar feed conversion efficiency ($t_{(22)} = 0.811$, $p = 0.426$). Similarly, the condition factor of *C. gariepinus* was similar in both treatments ($t_{(16)} = -2.189$, $p = 0.054$; Table 2). *C. gariepinus* in both treatments grew isometrically ($t_{(16)}$ = 1.629, p = 0.123) with *b* values similar to an isometric growth value of *b* = 3.00 (p > 0.05; Table 2).

Table 2: The results of growth performance parameters, feed conversion efficiency, condition factor and percentage survival of the African sharptooth catfish (*Clarias gariepinus)* fed on floating and sinking diets

	Diet	
Parameter	Floating diet	Sinking diet
DWG	0.66 ± 0.11	0.63 ± 0.11
SGR	2.22 ± 0.31	2.23 ± 0.25
Percentage survival	98.56 ± 0.73	96.47 ± 2.81
FCE	0.59 ± 0.05	0.68 ± 0.10
K	0.63 ± 0.01	0.59 ± 0.00
b value	2.81 ± 0.10	3.03 ± 0.09

Values in each row are not significant different (p ≤ 0.05).

3.2 The yield of *Clarias gariepinus* fed on floating and sinking diets

The results on yield performance showed that, rearing *C. gariepinus* either on floating or sinking diet did not affect the measured gross, net and annual yields ($t_{(4)}$ = -1.581, p = 0.189; Table 3).

Table 3: The yield parameters for the African sharptooth catfish (*Clarias gariepinus*) fed on floating and sinking diets during the study period

	Diet	
Yield parameters	Floating diet	Sinking diet
GFY (kg ha^{-1})	4,995.63 ± 73.40	4,688.47 ± 179.82
NFY (kg ha^{-1})	3,351.13 ± 73.40	3,043.97 ± 179.82
NAY (kg ha^{-1} $year^{-1}$)	23,078.55 ± 505.50	20,963.19 ± 1238.37

Values in each row are not significant difference (p ≤ 0.05).

3.3 Economic analysis

The results on economic analysis showed that, the floating diet had comparatively higher cost kg^{-1} (0.71 USD kg^{-1}) than the sinking diet (0.46 USD kg^{-1}). The incidence cost obtained during the study were 1.77 ± 0.02 USD kg^{-1} for *C. gariepinus* fed on sinking diet and 2.72 ± 0.01 USD kg^{-1} for those fed on floating diet (Figure 2). This represents approximately 33% lower cost of production for the sinking diet than the floating diet. The incidence cost for floating diet was significantly higher than that of sinking diet ($t_{(4)}$ = -42.748, p = 0.001).

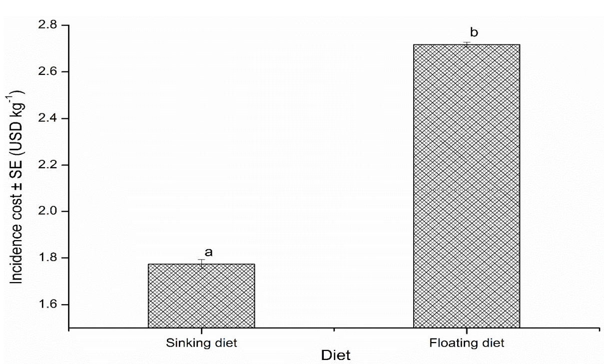

Fig 2: The incidence cost for production of the African sharptooth catfish (*Clarias gariepinus*) using floating and sinking diet during the study. Different letters above bars indicate significant difference (p < 0.05).

Feeding *C. gariepinus* on sinking diet resulted in a profit index of 2.01 ± 0.02 compared to 1.31 ± 0.01 when they were fed on the floating diet (Figure 3). The profit index for *C. gariepinus* fed on the sinking diet was approximately 35% higher than those fed on the floating diet. The profit index for *C. gariepinus* fed on sinking diet was significantly higher than those fed on floating diet ($t_{(4)}$ = 31.106, p = 0.001).

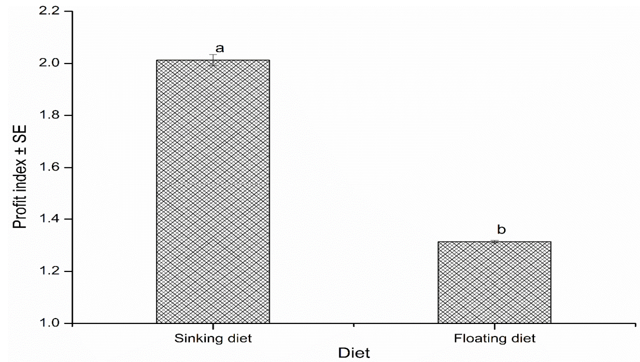

Fig 3: The profit index for production of the African sharptooth catfish (*Clarias gariepinus*) using floating and sinking diet during the study. Different letters above bars indicate significant difference (p < 0.05).

3.4 Water quality parameters

Water temperatures and pH remained fairly stable among all treatments (Table 4). Water temperature (25.10 – 29.75 ºC), pH (7.22 – 8.42), nitrite (0.04 – 0.64 mg L^{-1}), total alkalinity (> 300 mg $L^{-1}CaCO_3$) and total hardness (> 300 mg $L^{-1}CaCO_3$) were within the optimum range recommended for culture of *C. gariepinus* [21]. Dissolved oxygen was very low, it ranged from 2.63 ± 0.18 mg L^{-1} to 2.87 ± 0.25 mg L-^{1}. Unionised ammonia concentration ranged from 0.52 ± 0.22 mg L^{-1} to 0.66 ± 0.29 mg L^{-1} (Table 4). All the measured water quality parameters did not differ significantly among the feeding treatments throughout the study (p > 0.05).

Table 4: Results of water quality parameters for African sharptooth catfish (*Clarias gariepinus*) fed on floating and sinking diet during the study

	Diet	
Water quality parameter	Floating diet	Sinking diet
Temperature (ºC)	27.57 ± 0.03	27.73 ± 0.08
Dissolved Oxygen (mg L^{-1})	2.75 ± 0.28	2.63 ± 0.18
pH	7.59± 0.02	7.67 ± 0.02
Water transparency (cm)	5.13 ± 0.59	4.66 ± 0.16
Unionized ammonia (mg L^{-1})	0.65 ± 0.22	0.52 ± 0.22
Nitrite (mg L^{-1})	0.18 ± 0.01	0.19 ± 0.04
Total alkalinity (mg L^{-1})	728.33 ± 121.05	823.89 ± 84.79
Total hardness (mg L^{-1})	483.61 ± 129.02	512.64 ± 83.50

Values in each row are not significant difference (p ≤ 0.05).

4. Discussion

The water quality parameters in the current study were not affected by the forms of the diets. None of the parameters measured differed significantly between floating and sinking diets. The water quality parameters obtained in the current study are similar to those found by [22] and [23]. The low dissolved oxygen obtained in this study is not worrisome because *C. gariepinus* is known to survive under extremely low dissolved oxygen (0 – 3 mg L^{-1}) [22, 24], especially with fully developed arborescent organs (aid in air breathing). Such conditions make *C. gariepinus* to survive in extremely poor conditions than any other fish species [7]. Nevertheless, farmers are advised to maintain water quality parameters including dissolved oxygen in the recommended level (> 5.00 mg L^{-1})

for optimum *C. gariepinus* growth and survival [25]. These results pinpoint that, farming *C. gariepinus* using floating and sinking diets does not cause significant deterioration of water quality parameters provided the diets are formulated correctly.

The current results have shown similar growth performance between *C. gariepinus* fed on floating and sinking diets. These results agree in one hand and disagree on the other hand with the previous studies. [12] reported similar mean weight gain for *C. gariepinus* fed on floating and sinking feeds while [26] and [13] found higher growth performance for *C. gariepinus* fed sinking and floating diets. The similarity in growth performance between *C. gariepinus* fed on floating and sinking diets is related to the feeding habit of this species. *C. gariepinus* feed actively on any materials it perceives as food [27] by combining efficiently biting and suction actions during its ingestion [28]. In its biting feeding, *C. gariepinus* scrapes algae or picks any food particles off the substrate using its oral jaws. On the other hand, during its suction feeding, *C. gariepinus* generates a flow of water that drags the food towards and into the mouth. It can feed both at the bottom or at the water surface either individually or in groups [29]. This feeding habit makes *C. gariepinus* more versatile on its feeding [30]. By using the two actions, *C. gariepinus* were able to capture both the floating and sinking diets resulting in similar growth performance. These results imply that, *C. gariepinus* farmers can use either floating or sinking diets without affecting the growth performance of the fish in ponds.

The present study has indicated similar percentage survival between *C. gariepinus* fed on floating and sinking diets. Survival has never been a main fear in the culture of *C. gariepinus* because of its resistance to water quality stress as well as diseases [31, 32]. Likewise, survival rate was not a major concern in the present study because floating and sinking diets both provided essential nutrients required for survival and water quality parameters were optimum for *C. gariepinus* survival in the ponds.

Feed conversion efficiency of *C. gariepinus* was similar between the two diets during the study period. Similarly, [12] found feed conversion efficiency in the same fish species was not affected significantly by the forms of the feeds used. The lack of differences in feed conversion efficiency between *C. gariepinus* fed on floating and sinking diets is due to optimum consumption of the diets and efficiency utilization of the nutrients contained in the two diets [33]. Both floating and sinking diets were effectively consumed by *C. gariepinus* and it managed to assimilate and metabolize the nutrients contained in the diets for growth and other body functions. This suggests that, both floating and sinking diets used in the present study contained adequate nutrients that were efficiently converted by *C. gariepinus* into growth. Thus, fish farmers can either use floating or sinking diets to feed their *C. gariepinus* without significantly affecting the feed utilization efficiency of the fish.

The general condition of *C. gariepinus* found in the present study was similar in fish fed on floating and sinking diet. The condition factors of 0.59 ± 0.00 and 0.63 ± 0.01 recorded in this study for floating and sinking diets respectively are similar to 0.65 ± 0.19 for mixed sex *C. gariepinus* obtained by [34]. Generally, condition factor indicates the health status, fitness or well-being of fish in their habitat and it is assumed that the fish with higher condition factors are in better condition [35, 36]. Generally speaking, similarity in condition factors between floating and sinking diets signifies that, both diets did not significantly affect the condition of the cultured *C. gariepinus*. This is further supported by the fact that, all the *C. gariepinus* fed the two diets were growing isometrically, indicating good condition in both diets. These findings highlights that, rearing *C. gariepinus* using floating or sinking diets does not significantly affect the general body condition of the fish.

The present study showed that, the use of either floating or sinking diets did not affect the yield performance of *C. gariepinus*. The NAY of 20,963.19 ± 1238.37 kg ha^{-1} $year^{-1}$ and 23,078.55 ± 505.50 kg ha^{-1} $year^{-1}$ obtained in the current study for sinking and floating diets respectively are similar to values projected by [37] under monoculture static pond conditions for *C. gariepinus* fed on a complete, pelleted feed or on farm-made feeds. The similarity in yield between floating and sinking diets is related to similar growth, survival rate, condition factor as well as feed conversion efficiency and water quality parameters during the study. During this study, growth, survival rate, condition factor, feed conversion efficiency and water quality parameters did not differ between *C. gariepinus* fed on floating and sinking diets. In captivity, yield is determined by growth rate of the cultured fish [38], their survival rate [39], their ability to utilize nutrients [33] and the state of water quality parameters in the culture system [23]. Variation in these parameters significantly affect fish yield production from an aquaculture system [40]. Thus, the lack of differences in growth, survival, feed conversion efficiency and water quality parameters between the two diets during the study led to similarity in yield performances of *C. gariepinus*. Farmers with access to either floating or sinking diets can use them without significantly affecting the yield of *C. gariepinus* under similar conditions.

The current study has shown higher incidence cost and lower profit index for the floating than sinking diet. The incidence cost of 2.52 ± 0.04 USD kg^{-1} obtained in the present study for sinking diet is similar to 2.13 ± 0.29 found by [41] on *O. niloticus* fed agro-industrial by-products. The profit index for the floating diet (1.31 ± 0.01) reported in the present study is similar to 1.16 -1.23 given by [42] on *C. gariepinus* fed on various levels of soybean oil. The higher incidence cost and lower profit index for the floating diet than sinking diet is related to its cost. The cost of floating diet was almost twice that of the sinking diet. It is known that, incidence cost reflects the cost of feed used to produce a kg of fish where by a lower value for a particular feed indicate more profitability [43]. Thus, the incidence cost and profit index were more than 30% higher and lower respectively for the floating diet than sinking diet. Thus, the sinking diet enhanced production of *C. gariepinus* at lower cost than floating diet. This implies that, based on the current results, *C. gariepinus* farmers can reduce cost of feeding up to 30% by using sinking diet. Accordingly, sinking diets when correctly formulated and blended can increase benefits to *C. gariepinus* farmers by lowering feeding cost.

5. Conclusion

Dependence on floating diets limits the development of *C. gariepinus* farming because it is more expensive and requires specialized facilities to produce; besides most farmers have no technology to produce it. The present study results demonstrate the use of sinking diet at a lower cost without affecting growth performance, survival, nutrient utilization, condition factor and yield. These results encourage feed manufacturers and *C. gariepinus* farmers to continue on improving the sinking diets that are mostly produced on-farms. The present study recommends that, *C. gariepinus* farmers can reduce the feeding cost up to more than 30% by using sinking diets without affecting the growth performance, survival, nutrient utilization, condition factor and yield of their fish.

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