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Evaluation of the reproductive performance of African catfish (*Clarias gariepinus*) brood stock fed on three locally manufactured commercial feeds

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Abstract
Brood stock management experiment was conducted at Kireka fish farm Uganda, to evaluate the fecundity and economic performance of three new local commercial feeds for African catfish brood stock development and conditioning. The fish were conditioned in earthen ponds, stocked at 0.5 kg/m^3 for three months before spawning. The feeds were code named N2, B3 and N3 for Kajjansi 35%, Ugachick 35% and Tende Innovative Farm feeds respectively. Results indicated that there was no significant difference in the crude protein composition of all the test diets. Significantly lower lipid contents (2.326%) were noticed in N3. Mean number of eggs per unit brood stock weight differed significantly across all feed treatment (F = 10.179, P= 0.002), with N2 producing the highest N = 57,075± 18,922; B3= 51,477±16,266; N3= 45,375±13,399, generally improved from the baseline of 6,874±1001. Fertilization was significantly different (F=3.695E30, P=0.0001), across all diets (Mean; (N2= 78.13±8.99%; B3= 72.93±16.02%; N3= 59.95±19.96%). Hatchability differed significantly across all feed treatments (F=3.6E31, P=0.0001), compared to the baseline, Mean; (N2= 77±10.01%; B3= 67± 2.5%; N3= 58±11.15%; baseline= 45.80±5.45%). It was established that a farmer using N2 (Kajjansi) feeds would generate up to $1,114 net profit per kilogram of female brood stock spawned. While using B3 (Ugachick 35%), would generate $196 per kilogram female above total cost. N2 was the best feed overall, with the highest fecundity, percent fertilization, hatchability & net returns above total cost, followed by B3 and lastly N3. The findings of this study show that, though the profitability of a hatchery business depends on management and the germplasm, fecundity plays a crucial role in determining the net returns of the business and is greatly affected by type and quality of brood stock feeds.

Keywords: African catfish, brood stock feeds, fecundity, fertilization, hatchability, net returns

1. Introduction

The African catfish is one of the most cherished and sought after commercial aquaculture species produced in a range of production systems and intensity in Uganda [1]. The attributes that make this species a farmers choice include faster growth rate and its bigger maturity size, easy to reproduce, accepts artificial feeds, tolerates high stocking densities, tolerates poor water quality, lucrative local, regional and international markets, and its economical viability in pond culture systems - the most common culture system in the East African Community bloc currently [2]. The production of *Clarias gariepinus* increased three fold from 7000 tons in 1999 to 50000 tons in 2010 [3]. In sub-Saharan Africa, the African catfish (*Clarias gariepinus*) has replaced tilapia as the most-produced fish in aquaculture since 2004 with notable progressive dominance of catfish species in aquaculture particularly pronounced in Nigeria and Uganda [3].

In Uganda, the fish is still largely produced in earthen ponds and to a small extent in concrete and plastic tanks with artificial aeration where the unit production average is 2 kg/m^3 and 50 kg/m^3 in earthen ponds and tanks respectively [4]. Despite the rise in volume of production and increasing popularity across Africa, African catfish production still faces hatchery based constraints that curtail the whole seed value chain [5]. Phelps [6], observed that three issues namely brood stock management, induced spawning and larval feeding had greatly contributed to advancement in hatchery management world over. But in sub-Saharan Africa, brood stock management is still haphazard and poorly done [7, 8]. The availability of grow-out formulated feed has not guaranteed the supply of essential nutrients and management apparatus for brood stock development and conditioning [9]. Nigerian hatchery operators import brood stock feeds from Northern Europe [3], while Uganda has majorly relied on locally available feeds for brood stock except for some very few hatchery operators who purchase imported feeds from South Africa, Israel and United States of America [10]. Whereas imported brood stock feed may be biologically beneficial in stimulating good gonad development, the delivery process to Uganda compromises hatchery profitability due to long duration on transit that contribute to deterioration in quality and excessive taxation that increases the cost of production [11]. Local initiatives have succeeded with the establishment of Ugachick and Kajjansi feed mills that produce fish feeds sold across the East African region. This goes a long way to replace the widely and individually formulated farm made feeds that seem to be lacking vital nutrients to improving egg production, fertilization, hatchability and larval survival rates as evidenced from poor quality and quantity fish seed in the country [12]. However, hatchery operators still view the locally available commercial feeds as expensive and are unsure of their performance or contribution to the increased larval survival rates [2].

The brood stock management and conditioning is one of the factors that greatly affect the survival of the offspring [6, 13]. The type, nature, quantity and quality of feeds provided to the brood fish will influence and affect the quantity and quality of eggs produced which consequently have a bearing in the fertilization rates, hatchability and survival rates [6]. The effect of feed activity on egg production has been reported in other catfishes such as the channel catfish [9].

One major issue with the locally manufactured fish feeds is that there has never been substantial technical evaluation to establish their suitability for African catfish brood stock development and conditioning and therefore, their potential is uncertain. This study investigated and evaluated the extent of the usability and biological and economic performance of locally available feeds on conditioning of the African catfish brood stocks in Uganda with the view of helping the hatchery operators to improve the quality and quantity of seed in the region.

2. Materials and methods

2.1 Feeds evaluation experiments

The evaluation experiments were carried out at Kireka fish farm in Wakiso District (N00.35212 E032.64111, ELV. 1172). This farm was preferred because of its well established African catfish hatchery infrastructure.

2.2 Brood stock selection and conditioning

A total of 554 homogeneous African catfish brood fish (150 females and 404males) weighing on average 500±23 g, were procured from Tende Innovative Farm (TIF) located in Central Uganda (N00.05080 E032.55790, ELV. 1134), one of the commercial catfish hatcheries in the country. The female fish were stocked at a density of 0.5 kg/m^3 in 3 protected earthen ponds of 100m^3 each, while the males were stocked separately in one pond at a density of 2 kg/m^3 in 100 m^3. The female fish conditioning ponds surface were restrained by gill nets of 1inch mesh size, in which water level was constantly maintained above one meter deep so as to avoid interruption by walking and diving bird predators. The female brood stocks were fed on three different diets, Ugachick floating pellets (grower 35% CP), code named B3 and made by Ugachick poultry breeders ltd; Kajjansi feed (35% CP) sinking pelleted feeds code named N2 and made by ARDC and crumble sinking feeds code named N3 and made by Tende Innovative Farm (TIF), trading as TIF feed (35% CP). Female brood stocks were fed 5% of the body weight twice a day between 0900 and 1100 hrs; and between 1600 and 1800hrs respectively. The male fish management also followed the same procedure as the female cohorts. The brood fish were fed for three months to attain average weight of 800±57 g. To ascertain the true identity composition of all the feeds given to the fish in the experiment, proximate analysis was done as described by [15] at ARDC. Dissolved oxygen, pH, temperature in the pond water were monitored twice daily at 0700 and at 1800 hrs using multi-parameter water quality test meter model Yellow Spring Instrument (YSI) 556-Environmental, while ammonia was detected using ammonia test kit, distributed by LaMotte Inc.

2.3 Induced spawning ovulation and egg incubation

Spawning trials were conducted monthly in four batches in November 2012, February, April and June 2013. Male and female spawners were selected from the conditioned stock on the test diets. Induced ovulation was stimulated in the females by an intra-muscular injection of macerated solution of natural pituitary gland hormone extract, suspended in a physiological saline solution. The collection of ovulated eggs and their fertilization was carried out using the dry-method described by [16, 17]. The body weight of the females, the egg weight and the number of eggs from each female were recorded. Eggs from each female were stripped and fertilized separately in clean dry plastic bowls of known weight in which milt was added. The egg milt mixture was gently swirled for a few seconds before hydration with physiological saline solution. The suspended milt residue and other debris in the fertilized eggs were decanted and the embryo introduced onto plastic mesh hatching trays (0.75 X 0.3 m, with 0.5-mm mesh size) held in wooden frames. Eggs from females fed on a given feed were randomly placed in three triplicate circular incubation tanks which were filled 50ltrs volume. To limit fungal infections, fertilized eggs were subjected to 0.002% potassium permanganate bath for 15 minutes before the solution was gradually flashed off. Incubation was maintained at between 26 and 28 ^oC and at dissolved Oxygen of over 4 gml^{-1}1. Water circulation was maintained at 5 litres per minute through the incubation tanks to get rid of ammonia. And maintain a good environment for egg incubation. Fecundity was determined by gravimetric method as described by [18, 19, 20], applying records of total weight of gravid females and total weight of oocytes ovulated. Records of percentage fertilization, hatchability, hatching and larval survival at initial exogenous feeding were taken and compared within and between diet treatments.

2.4 Data Analysis

Data obtained were pooled for each treatment means and compared by one way ANOVA to test significant differences ($p<0.05$) in fecundity, fertilization and hatchability in SPSS software version.

3. Results

3.1 Proximate composition of brood stock feeds

The proximate composition of the broodstock feeds used did not show significant variation in all nutrients and components. More essential nutrients including lipids and energy did not vary significantly between feeds N2 and N3, while the latter duo, varied significantly from B3, which had the lowest protein (32.188%), lipids (2.326%) and 2292.5Kcal/Kg (Fig. 1).

Whereas B3, had the lowest quantity of macronutrients, it had the highest level of total ash (22.811%) than both N2 and N3, and slightly higher level (92.188%) of dry matter than N2 which had 91.558% respectively.

Table 1: proximate nutrient composition of the feeds used in the experiment

Feed type	Dry matter (%)	Crude protein (%)	Crude lipids (%)	Total Ash (%)	Fiber (%)	ME (Kcal/Kg)
N2	91.6	33.0	8.8	7.7	10.3	2727.5
N3	94.8	33.5	8.7	7.7	10.4	2503.5
B3	92.2	32.2	2.3	22.8	2.7	2292.5

3.2 Fecundity, fertilization and hatchability rates

There was a significant difference in the mean number of eggs produced per kilogram brood stock fed on the different feed treatments (F=10.179, P=0.002). Tukey's HSD test indicated that the overall mean number of eggs ovulated by female brood stocks fed on diet N2 differed significantly from that of B3. Means were N2=57,075± 18,922; B3=51,477±16,266; p=0.005. However, very significant difference was further observed between feed N2 and B3 combined and N3 (Mean N3= 45,375±13,399).

The general fecundity compared to the baseline data (Fig.1 (c), portrays a remarkable difference as such before this experimentation, the average egg production per kilogram female African catfish was 6,874±1001 verses; 57,075± 18,922; 51,477±16,266; 45,375±13,399 obtained from N2, B3 and N3, respectively. Observing the performance of different diets over the successive batches, there is clear trend of increase in the fecundity (Fig. 1 (a) & 1(b)) but this had reached declining phase for N2 and B3 in the fourth spawning batch.

Eggs obtained from individuals fed on different diets, fertilized at significantly different rates (F=3.695E30, P=0.0001). Tukey's HSD test indicated that the difference was significant across all diets (Mean; (N2= 78.13±8.99%; B3= 72.93±16.02; N3= 59.95±19.96). Across all the experimental diets, there was an improvement to better levels compared to baseline before this study (Fig.2). Percentage of larvae (fig. 3) that hatched out and were alive to the date when the hatching trays were lifted (hatchability), differed significantly across all feed treatments (F=3.6E31, P=0.0001). Tukey's HSD test indicated that the percentage hatchability was very significantly different compared to the baseline, Mean; (N2= 77±10.01%; B3= 67± 2.5%; N3= 58±11.15%; baseline= 45.80±5.45%).

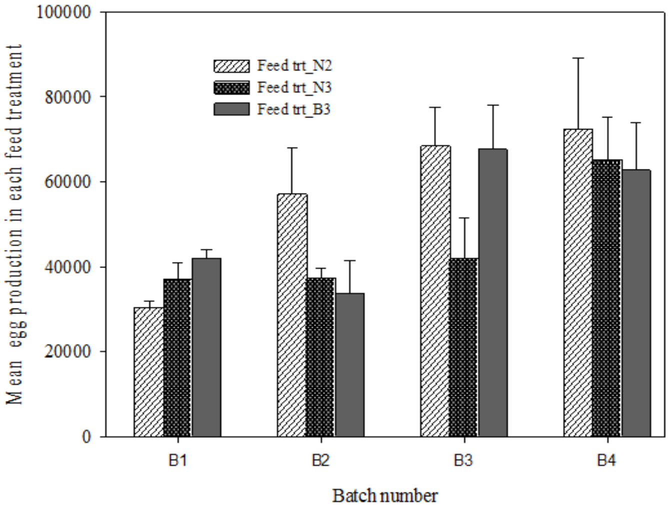

Fig 1 (a): The mean number of eggs produced per kg of female brood stock in each of the feed treatments in the successive batches

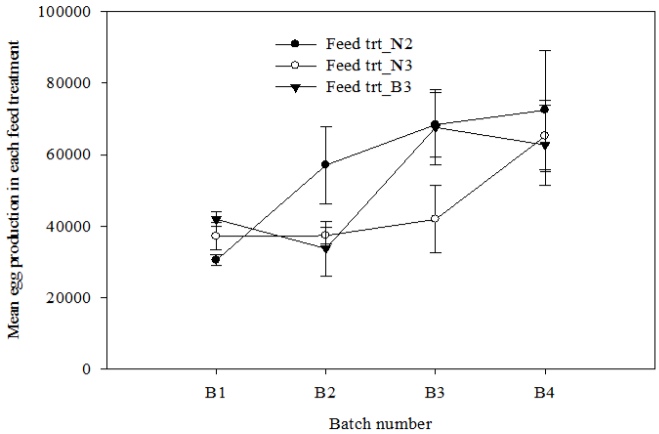

Fig 1 (b): The mean number of eggs produced per kg of female brood stock in each of the feed treatments in the successive batches

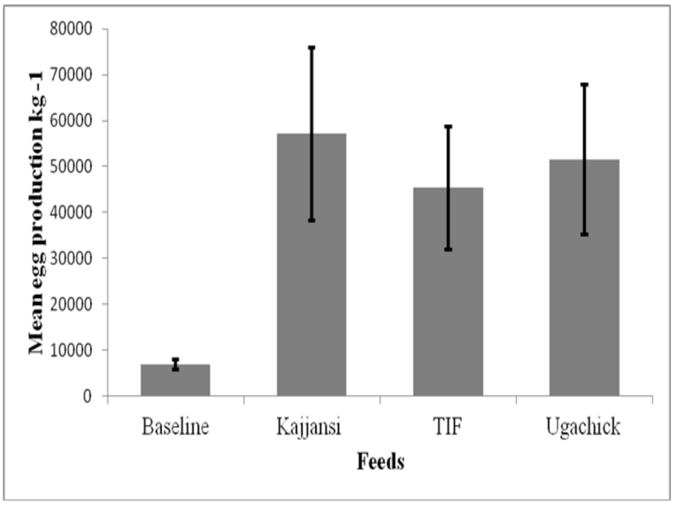

Fig 1 (c): Over all mean egg production per kilogram of the female brood stock across all the batches compared to the baseline.

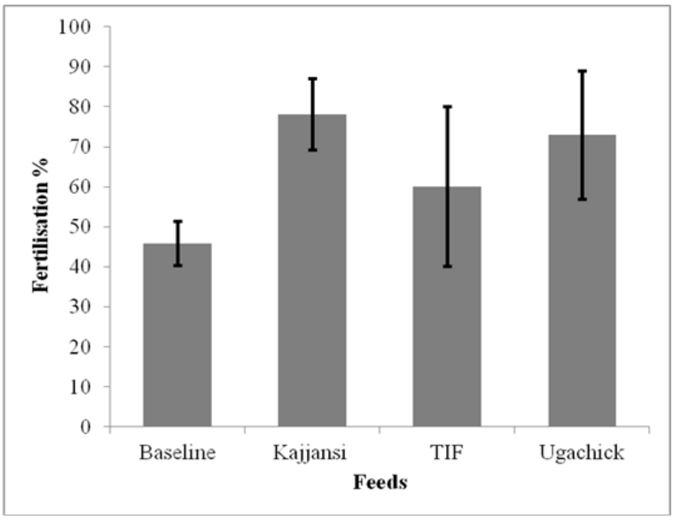

Fig 2: Mean percent fertilization across all diets against baseline

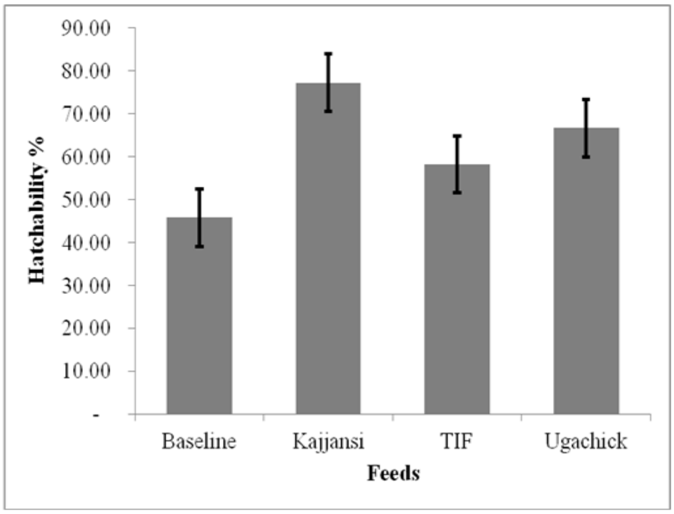

Fig 3: Mean percentage hatchability of larvae against across all diets against baseline.

Enterprise budget of African catfish brood stock management on either diets in Uganda

Cost Benefit Analysis (CBA) of the hatchery enterprise based on N2, B3, and N3 feeds shows, the business is more profitable using N2 and profitable with B3 feeds. N3 did not register any profit above the total cost. It is established that a farmer using N2 (Kajjansi) feeds would generate about $1,114 net profit per kilogram of female brood stock spawned. While using B3 (Ugachick 35%), would generate $196 per kilogram female above total cost (table 2).

Table 2: Cost Benefit Analysis of fry production per kilogram female brood stock on either diet

Brood stock feed treatment	Fry/kg female	Gross sales	Total Variable Costs (TVC)	Total Fixed Cost (TFC)	Net returns above (TVC)	Total Cost (TC)	Net returns above (TC)
		US Dollars	US Dollars	US Dollars	US Dollars	US Dollars	US Dollars
N2	43,947	4975	2,747	1,114	2,228	3,861	1,114
N3	26,318	2979	2,463	1,114	517	3,577	(597)
B3	34,490	3904	2,594	1,114	1,311	3,708	196

4. Discussion

Dietary protein content affects African catfish performance and the higher the protein levels in the diet the better the hatchability [21, 22]. The C.P of 35% is only good for catfish grow-out but for brood stock conditioning better requires levels CP of >40%, [22]. From the results of the proximate nutrient composition of the three types of feeds used in this study – their C.P was between 30% and 35% that means none would be suitable for catfish brood stock conditioning. Varying protein content from 32% to 42% did not influence spawning, fecundity or fertilization in channel cat fish [23]. But it's also known that the higher the protein content of a feed the more expensive it is and the lower its affordability [24]. Commercial fish feed producers have a challenge of producing quality and standard feeds and yet make them widely affordable to the farmers [25]. There was no significant difference in the crude protein content of the three types of feeds though they all had CP of <35%. This implies that though the three types of feeds could be used for conditioning catfish brood stock they may not maximize potential benefits of the brood fish.

Referring to the observation in the successive batches, there was vividly an increase in fecundity with number of repeats across all the experimental feeds. This suggests the baseline observation is contributed largely by poor management in terms of selection, storage and management of shelf life of respective feeds.

Basing on the experimental findings the broodstock conditioned on the three types of feeds for the longest time produced the best egg production, fertilisation rate and hatchability compared to the baseline (broodfish used without conditioning). This implies that type of feed used in conditioning of broodfish is very important in hatchery management/production, which is supported by earlier work by [26] , who concluded that the growth of fish is directly dependent on feed composition, quality and quantity. The findings also revealed of broodfish conditioned on the three types of feeds, broodfish fed on N2 performed best followed by B3 and N3 in that order in terms of egg production, fertilisation rate and hatchability. N3 being a farm formulated feed could have experienced problems of balancing the ingredients to always come up with uniform nutrient content. The likelihood of inconsistent balancing with on-farm made is also demonstrated by the curvelinear flactuation in unit body egg production in N3. (fig. 1 (a) and (b). Whereas the inconsistent perfomance in N3 may be attributed to flactuation in balancing nutrients in the sucessive batches, B3 also showed a similar trend, mainly attributed to floating form which in a way could have led the fish to spend more energy swiming upsurface to ingest the feed

As fecundity largely contributes to the final outcome of a seed production business [27] even in this study findings showed that the highest net return above total cost was realized in the order of N2 , B3, and N3, which is the order of decreasing fecundity respectively. The net returns above total cost like the hatchery production parameters – egg production, fertilization rate and hatchability above also increased with time of conditioning for the different types of feeds respectively. This most probably because brood stock management contributes to survival and the economics of the hatchery business, since the quality and

quantity of nutrients deposited in the yolk determine viability of eggs, fertilization, hatchability and consequently progeny survival.
The findings of this study should be collaborated with findings of the amino acids and fatty acids profiles of the three different feeds together with their economics in order to determine the best locally available conditioning feed.

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