A COMPARATIVE STUDY OF THE GONADO-SOMATIC INDEX (GSI) AND GONAD GROSS MORPHOLOGY OF AFRICAN CATFISH (Clarias gariepinus) FED UNICAL AQUA FEED AND COPPENS COMMERCIAL FEED

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ABSTRACT
A comparative study of the gonado-somatic index (GSI) and gonad gross morphology of African catfish, Clarias gariepinus fed Unical Aqua feed and Coppens commercial feed was carried out for six months in concrete tanks. Two triplicate groups of 50 postfingerlings with a mean bulk weight of 0.50 ± 0.02 kg were stocked in circular concrete tanks, area 16.63 m² labeled A₁, A₂, A₃, B₁, B₂ and B₃. Fish in units A₁, A₂ and A₃ were fed Coppens feed while fish in units B₁, B₂ and B₃ were fed Unical Aqua feed twice daily at 3% of their body weights. Results obtained showed that mean gonad weight (99.03 ± 16.57 g) and the GSI (15.89 ± 2.10%) of female C. gariepinus fed Unical Aqua feed was not significantly different (P>0.05) from fish fed Coppens feed with mean gonad weight (91.80 ± 12.83 g) and the GSI (13.81 ± 2.49%). In male fish fed Unical Aqua feed, mean gonad weight (7.08 ± 1.17 g) and the GSI (1.16 ± 0.30%) were not significantly different (P>0.05) from male fish fed Coppens feed with mean gonad weight (6.77 ± 1.09 g) and the GSI (1.12 ± 0.32%). In female fish fed both feeds, there was a positive significant relationship between the GSI and total length, total weight and gonad weight. In male fish fed both feeds, there was also a positive non-significant (P>0.05) relationship between the GSI and total length, total weight and gonad. Food conversion efficiency (FCE) was insignificantly higher (P>0.05) in fish fed Coppens feed (50.94 ± 0.91%) than fish fed Unical Aqua feed (50.37 ± 1.29 %). Histology of ovaries and testes of fish fed the two experimental diets showed normal development and distribution of oocytes and interstitial cells. Proximate analysis of the dry matter showed that moisture content, fat content, crude fibre content, ash content, carbohydrate and caloric value (C/V) differed significantly among experimental groups (P<0.05), while significant difference for crude protein content was not found (P>0.05). Physicochemical parameters were within acceptable range for fresh water fish culture. Based on these findings, Unical Aqua feed competed favorably with Coppens feed in terms of the GSI and gross gonad morphology of C. gariepinus and, on the basis of affordability, Unical Aqua feed is more economical and therefore recommended for fish farmers.

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INTRODUCTION
African catfish (Clarias gariepinus) belonging to the family Clariidae is the most cultivated species in Nigeria. This could be attributed to its ability to tolerate a varying range of environmental conditions, high stocking densities under culture conditions, fast growth rate, disease resistance, acceptability of artificial feed, high feed conversion efficiency, good taste and meat quality, ease of artificial breeding, high market value etc. According to FAO (2012), fish provides more than 1.5 billion people with almost 20 percent of their average per capita intake of animal protein, and 3.0 billion people with...
MATERIALS AND METHODS

Study area

This research was carried out at the Institute of Oceanography Fish Farm Hatchery complex, University of Calabar, which is geographically located within the historic peninsula between the Calabar River and the Great Kwa River with an elevation of 41 meters above sea level. This area has latitude of 04°55.9˝N and longitude of 08°26˝E with a total surface area of three hectares (3Ha).

Experimental design

This research lasted for six (6) months and was carried out in the Hatchery complex of the Institute of Oceanography, University of Calabar, where 3 ETF circular concrete tanks of area 16.63 m² were used. The three tanks were divided into two equal parts with hard wood covered with tapeline, each giving a total of six experimental units. The six units were labelled A₁, A₂, A₃, B₁, B₂, and B₃ to aid triplication of the experiment. Water volume in each unit was (8.32 m³). A total of 300 post fingerlings of C. gariepinus were stocked in each of the six experimental units (50 in each unit). The stocked fish were acclimated for seven days prior to the start of the feeding trial. During the acclimation period the fish were fed twice daily to satiation. At the start of the feeding trial the acclimated fish were starved for 24 hours after which the average initial wet body weight of the fish in each experimental unit was measured using a METLAR MT-5000 D electronic balance to the nearest gram (Eyo and Ekanem, 2011). Fish in units A₁, A₂, and A₃ were fed with Coppens feed, while fish in units B₁, B₂, and B₃ were fed Unical Aqua feed. Feeding was carried out twice daily (9:00 am and 4:00 pm) at 3% of their body weight. Measurement of the fish body weight and gonad in each experimental unit was done at the end of the experiment. Physicochemical parameters like dissolved oxygen (DO), pH, ammonia and temperature were measured once weekly. Food conversion efficiency was determined as follows: Weight gain (g) / Feed consumed (g) * 100, where food consumed is given as 3% x body weight x Number of days.

Coppens feed composition, characteristics and collection

Coppens feed containing 42% crude protein is composed of high quality ingredients such as marine fish meal, calcium, phosphorus, lysine, methionine, copper sulphate (CuSO₄), selenium refined fish oil and several grains. The combination of these ingredients makes the feed extremely attractive for freshwater fish and also for the promotion of fast growth. Three sizes of Coppens feed (2 mm, 4 mm and 6 mm) were purchased from a fish feed store in Calabar, Nigeria.

Formulation, composition and preparation of Unical Aqua feed

Unical Aqua feed is a product of University of Calabar fish feed mill. It was formulated using Pearson’s square method to 42% crude protein level. Unical Aqua feed composition is shown in Table 1.

Measurements of body parameters and gonad development

At the end of the experiment, a total of one hundred and twenty male and one hundred and twenty female C. gariepinus (twenty from each experimental unit) were harvested from the experimental tanks and transported immediately to the Fisheries and Aquaculture laboratory, Institute of Oceanography, University of Calabar, for further analysis. Differentiation of sexes were based on external features (elongated genital papilla for male and around serrated opening for female) and internal features such as gonad. The following body parameters were measured for each specimen: Total length (TL), Total weight (TW) and Gonad weight (GW). Total length was measured from snout to the base of the caudal fin rays. Measurements were taken to the nearest 0.1 cm and 0.1 g using measuring board for length and Metlar-2000 D electronic weighing balance for weight.
Table 1. Unical feed composition in grams per kilograms

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Composition in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial fishmeal (IFM)</td>
<td>244.4</td>
</tr>
<tr>
<td>Groundnut meal (GNM)</td>
<td>244.4</td>
</tr>
<tr>
<td>Soybean meal (SBM)</td>
<td>244.4</td>
</tr>
<tr>
<td>Corn meal</td>
<td>206.8</td>
</tr>
<tr>
<td>Vitamin premix</td>
<td>10</td>
</tr>
<tr>
<td>Bone ash</td>
<td>5</td>
</tr>
<tr>
<td>Sodium chloride (NaCl)</td>
<td>5</td>
</tr>
<tr>
<td>Lysine</td>
<td>5</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>10</td>
</tr>
<tr>
<td>Palm oil</td>
<td>10</td>
</tr>
<tr>
<td>Molasis</td>
<td>20</td>
</tr>
<tr>
<td>Methionine</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>1000 g</td>
</tr>
</tbody>
</table>

Gonadal development was determined using the gonado-somatic index (GSI) and was calculated using the formula below:

\[ GSI = \frac{\text{Gonad weight (g)}}{\text{Whole fish weight (g)}} \times 100 \] (Boiler and Connolly, 1989)

For histological purpose, *C. gariepinus* gonads (female ovary and male testis) were extracted from fish fed with two experimental diets and were fixed in Bouin’s fluid for 48 hours, manually processed and sectioned at 10 µ with a rotary microtome, dewaxed in xylene, stained with haematoxylin and eosin standard method (Bancroft and Cook, 1994) for microscopic examinations.

**RESULTS**

**Water quality parameters**

Water quality parameters measured in the present study showed that in experimental units fed Unical Aqua feed, mean pH ranged between 6.54 ± 0.03 to 7.31 ± 0.08, whereas in experimental units fed Coppens feed, pH ranged between 6.87 ± 0.07 to 7.24 ± 0.17. Mean dissolved oxygen ranged between 4.83 ± 0.35 mg/L to 5.87 ± 0.23 mg/L in experimental units fed Unical feed and 4.97 ± 0.21 mg/L to 5.57 ± 0.11 mg/L in experimental units fed Coppens feed. Mean water temperature ranged between 30.04 ± 0.44 °C to 31.30 ± 0.17 °C in experimental units fed Unical feed and 29.73 ± 0.84 °C to 30.93 ± 0.49 °C in experimental units fed Coppens feed. Mean ammonia ranged between 0.00 ± 0.00 mg/L to 0.53 ± 0.12 mg/L in experimental units fed Unical feed and 0.00 ± 0.00 mg/L to 0.37 ± 0.06 mg/L in units fed Coppens feed. Statistical analysis of water quality parameters did not differ significantly among experimental groups (P>0.05).

**Proximate composition of Coppens and Unical Aqua feed**

Mean proximate analysis of the dry matter (mg/100 g) of Coppens and Unical Aqua feed shows that moisture content was higher in Unical feed (9.53 ± 0.15) than Coppens (8.23 ± 0.07). Mean crude protein content was also higher in Unical feed (43.30 ± 0.23) than Coppens (42.94 ± 1.34). Mean fat content also followed the same trend with Unical feed showing a higher value (12.03 ± 0.02) than Coppens feed (11.57 ± 0.15). Mean crude fibre content was higher in Coppens feed (3.53 ± 0.31) than Unical feed (3.34 ± 0.10). Mean ash content was higher in Coppens feed (9.42 ± 0.04) than Unical feed (9.03 ± 0.20). Mean carbohydrate content was higher in Coppens feed (24.31 ± 2.10) than Unical feed (22.77 ± 1.27).

**Food utilization of C. gariepinus fed Coppens and Unical Aqua feed**

Food utilization evaluated using food consumed and food conversion efficiency (FCE) showed that fish fed Coppens feed significantly consumed more food (55.69 ± 5.09 kg) than fish fed Unical Aqua feed (48.84 ± 5.07 kg). Food conversion efficiency (FCE) was insignificantly higher (P>0.05) in fish fed Coppens feed (50.94 ± 0.91%) than fish fed Unical Aqua feed (50.37 ± 1.29%).

**Gonado-somatic index (GSI) of male C. gariepinus fed Coppens and Unical Aqua feed**

At the end of the experiment, mean female body weight for fish fed Unical Aqua feed was 628.93 ± 109.46 g, mean total length (43.90 ± 1.81 cm), mean gonad weight (99.03 ± 16.57 g).
The gonado-somatic index (GSI) of female *C. gariepinus* fed Unical Aqua feed showed a linear relationship with the total length (cm), total weight (g) and gonad weight (g). Power regression equation for the gonado-somatic index (GSI) and total length (cm), total weight (g) and gonad weight (g) of male *C. gariepinus* fed Unical Aqua feed is as follows:

\[
\text{GSI} = 39321TL^{-2.704} (r = 0.6663 \text{ and } r^2 = 0.4439, P>0.05)
\]

\[
\text{GSI} = 658.54TW^{-0.991} (r = 0.7268 \text{ and } r^2 = 0.5283, P>0.05)
\]

\[
\text{GSI} = 0.1643GW^{0.9898} (r = 0.6799 \text{ and } r^2 = 0.4622, P>0.05)
\]

The gonado-somatic index (GSI) of male *C. gariepinus* fed Coppens feed showed a linear relationship with the total length (cm), total weight (g) and gonad weight (g). Power regression equation for the gonado-somatic index (GSI) and total length (cm), total weight (g) and gonad weight (g) of male *C. gariepinus* fed Coppens feed is as follows:

\[
\text{GSI} = 377225TL^{0.726} (r = 0.7699 \text{ and } r^2 = 0.5928, P>0.05)
\]

\[
\text{GSI} = 2007.4TW^{-0.4622} (r = 0.8136 \text{ and } r^2 = 0.6620, P>0.05)
\]

\[
\text{GSI} = 1035GW^{0.5737} (r = 0.7326 \text{ and } r^2 = 0.5367, P>0.05)
\]

**Histology of *C. gariepinus* gonads fed Unical and Coppens feed**

The results of the histology of ovaries and testes of fish fed Coppens and Unical Aqua feed showed normal distribution of cells in their developments. The oocytes were fully matured in *C. gariepinus* fed both experimental diets (Plate 1 and 2). Similarly, the interstitial cells of the testes of *C. gariepinus* fed both experimental diets showed normal testicular cells (Plate 3 and 4).
Results obtained in the present study indicate that utilization of good quality feeds plays a major role in gonad development in *C. gariepinus*. According to Guraya (1994), differentiation of spermatogonia and oogonia into mature spermatozoa and sperm cell occurs in adult fish. Before sex differentiation in fish, the undifferentiated gonad contains all the cell types required to make it capable of developing into either a testis or an ovary (Francis, 1992). The study indicated that sub-adults of *C. gariepinus* had developed gonad (matured) between 6 to 8 months under standard outdoor circular concrete tank conditions with a natural photoperiod (12 h light and 12 h dark). Environmental factors such as temperature, photoperiod, nutrient supply, dissolved oxygen, disease (parasites) etc. are observed to influence gametogenesis (process by which gamete [egg and sperm] are produced from the gonia of matured gonad during reproductive cycle in fish) (Maitra, 1997; Jay et al., 1992). Thus, their effective management is important for productive aquaculture, especially in relation to broodstock management and egg and larval quality (Horwood, 1993; Bromage and Roberts, 1995). In the present study, physicochemical parameters including pH, dissolved oxygen, water temperature were maintained at optimum level as recommended by Boyd (1979) for freshwater fish culture. It was observed in this study that maturation in male *C. gariepinus* (development of genitals papilla and spermatozoa) was first detected at 4 months of culture. Early maturation in fish has been achieved either by genetic selection or better nutrition, revealing a correlation between maturation and growth (Le Bail, 1996). Full maturation of *C. gariepinus* was found to be 10 months of age in fish fed both Unical and Coppens feed which agrees with the findings of Cek and Yilmaz (2005). In the present study, the mean gonado-somatic index of both male and female *C. gariepinus* fed Unical Aqua feed was not significantly different from fish fed Coppens feed. The gonadal development of fish fed the two experimental diets is an indication that the two feeds have met the nutritional requirements of *C. gariepinus* broodstock in a culture system without any insignificant variation between them.

In the present study, food conversion efficiency (FCE) was insignificantly higher in fish fed Coppens feed than fish fed Unical Aqua feed. FCE of fish fed Coppens (50.94 ± 0.91%) and Unical Aqua feed (50.37 ± 1.29%) falls within the range (above 50%) considered as good growth in fish culture (Ndome et al., 2011). This finding is similar to Ekanem et al. (2012) who reported that *C. gariepinus* responded positively to Unical and Coppens feed in terms of growth performance indices such as weight gain, length gain, specific growth rate and mean growth rate. Gonad development was not observed to be affected by body size in both male and female fish fed the two experimental diets. For instance, the highest gonad weight of 148 g was recorded in female fish fed Unical diet with body weight of 762 g, whereas fish with the highest body weight (832 g) had gonad weight of 132 g. A similar observation was also found in female fish fed Coppens feed where female fish weighing 762 g had the highest gonad weight of 119 g, whereas fish with the highest body weight (843 g) had gonad weight of 94 g. However, a similar observation was also found in male *C. gariepinus* fed both experimental diets. These findings are similar to Schulz et al. (1994) who stated that maturity is related to age in *C. gariepinus* and disagrees with Cek and Yilmaz (2005) whose observations showed that maturity was related to size rather than age. Also, findings from the present study counter earlier reports by El-Sayed et al. (2003) and Chong et al. (2004) who related body size to maturation of gonads and early occurrence of egg in larger broodstocks. Different types of relationships were observed between gonado-somatic development and body parameters such as male/female body weight (MBW/FBW), male/female gonad weight (MGW/FGW) and male/female body weight (MBW/FBW). In this study, the gonado-somatic index of both male and female *C. gariepinus* fed Coppens and Unical Aqua feed showed a non-significant positive correlation with body parameters including male/female body weight (MBW/FBW), male/female gonad weight (MGW/FGW) and male/female body weight (MBW/FBW). These findings disagree with Akpaniteaku (2012) who reported a significant relationship between total length and total weight of *C. gariepinus* and size of their gonads. Results from this study corroborate with Sotolu and Kigbu (2011) who reported that increased dietary protein level of catfish diet up to 40% would produce high gonadal development. This finding is also similar to the findings of Sotolu (2010) who observed that performance of catfish broodstock can be affected by dietary protein level. Gu-

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e. Ovary of *C. gariepinus* fed Unical Aqua feed using digital camera
f. Ovary of *C. gariepinus* fed Coppens feed using digital camera
g. Testis of *C. gariepinus* fed Unical feed using digital camera
h. Testis of *C. gariepinus* fed Coppens feed using digital camera

DISCUSSION

Results obtained in the present study indicate that utilization of good quality feeds plays a major role in gonad development in *C. gariepinus*. According to Guraya (1994), differentiation of spermatogonia and oogonia into mature spermatozoa and sperm cell occurs in adult fish. Before sex differentiation in fish, the undifferentiated gonad contains all the cell types required to make it capable of developing into either a testis or an ovary (Francis, 1992). The study indicated that sub-adults of *C. gariepinus* had developed gonad (matured) between 6 to 8 months under standard outdoor circular concrete tank conditions with a natural photoperiod (12 h light and 12 h dark). Environmental factors such as temperature, photoperiod, nutrient supply, dissolved oxygen, disease (parasites) etc. are observed to influence gametogenesis (process by which gamete [egg and sperm] are produced from the gonia of matured gonad during reproductive cycle in fish) (Maitra, 1997; Jay et al., 1992). Thus, their effective management is important for productive aquaculture, especially in relation to broodstock management and egg and larval quality (Horwood, 1993; Bromage and Roberts, 1995). In the present study, physicochemical parameters including pH, dissolved oxygen, water temperature were maintained at optimum level as recommended by Boyd (1979) for freshwater fish culture. It was observed in this study that maturation in male *C. gariepinus* (development of genitals papilla and spermatozoa) was first detected at 4 months of culture. Early maturation in
The present study has shown that Unical Aqua feed competed favorably with Coppens feed in terms of the gonado-somatic index and gross gonad morphology of *C. gariepinus*. The implication of the result is that Unical Aqua feed have met the nutritional requirements of *C. gariepinus* broodstock in a culture system. On the basis of affordability, Unical Aqua feed is more economical (about 50% the cost of Coppens feed) and is hereby recommended for the production of *C. gariepinus* broodstock.

**SUMMARY AND CONCLUSION**

The present study has shown that Unical Aqua feed competed favorably with Coppens feed in terms of the gonado-somatic index and gross gonad morphology of *C. gariepinus*. The implication of the result is that Unical Aqua feed have met the nutritional requirements of *C. gariepinus* broodstock in a culture system. On the basis of affordability, Unical Aqua feed is more economical (about 50% the cost of Coppens feed) and is hereby recommended for the production of *C. gariepinus* broodstock.

**Ključne riječi:** *Clarias gariepinus*, težina gonada, gonadosomatski indeks, *Unical Aqua* hrana, komercijalna hrana proizvođača *Coppens*

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