Development and Diversification of Species for Aquaculture in Ghana

Indigenous Species Development/Experiment/09IND06PU

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EXECUTIVE SUMMARY

Sub-Saharan Africa has abundant land and water resources, but these have not been tapped to increase aquaculture production significantly in global terms. Recent analyses of Sub-Saharan Africa aquaculture have noted a relative lack of public sector research and development attention to alternative culture systems (e.g., cage culture) in Africa and recommended increased attention to alternative production systems while striving to increase intensity and production from the traditional earthen ponds. Likewise, the analyses identified progress made in Nigeria and Egypt in the production of species other than the tilapias as dictated by local demands for those alternative species, leading to their recommendations for expansion of production of high-demand indigenous species for niche markets. As a business model, diversification of species and systems provides a safety net and access to new markets for investors. This project involved complementary investigations of the opportunities and challenges to the adoption of cage culture as an alternative production system in Ghana, experimental studies of nutritional requirements and a market survey of indigenous, non-traditional aquaculture species with potential for development.

Experiments on optimal dietary protein of *Chrysichthys nigrodigitatus* (substituted for *C. maurus*) revealed that best growth of fingerlings was achieved when the diet contained 42.9% crude protein. In a parallel study with juvenile *Heterotis niloticus* the optimal dietary crude protein level was estimated to be at least 32.1%. These results are within the range of available data for similar species and the studies constitute some of the first of their kind for these specific species. This report also provides a brief review of the natural food habits, habitat requirements, and distribution of the *C. nigrodigitatus* and *H. niloticus*.

Because of its refusal to accept pelleted feed in initial laboratory trials, experimental study of *Parachanna obscura* dietary protein requirements was not feasible. A more in-depth study of the distribution and natural food and habitat requirement and acceptability as a potential aquaculture species in Ghana was completed. The survey of market potential and distribution trends of *Parachanna obscura* showed that the species has widespread occurrence and popularity as food in the four regions studied but with seasonal supply and not clearly sustainable harvest methods. Aquaculture will be a useful intervention for consistent supply and to protect reproductive populations in the wild.

These investigations have produced valuable insight not previously available to farmers and the private sector of Ghana, the Fisheries Commission of Ghana and other relevant government institutions. We expect these results to contribute to diversification and rapid acceleration of aquaculture development in Ghana and the sub-region. A comprehensive Strength Weaknesses Opportunities and Threats (SWOT) analysis of the aquaculture industry in Ghana is underway utilizing lessons learned from past, the current, and ongoing AquaFish CRSP projects. This analysis is being undertaken with input from the Fisheries Commission of Ghana.

Ecology And Effects Of Dietary Protein Levels On Growth Performance Of Claroteid Catfish, *Chrysichthys Nigrodigitatus*, Fingerlings

ABSTRACT

Chrysichthys nigrodigitatus is a relatively new aquaculture species in Ghana and knowledge about its culture, especially dietary requirements, is limited. Knowledge of optimal dietary protein level of this species is important for the development of a suitable feed for sustainable culture. A 10-week experiment was conducted to determine the optimal protein requirement of *C. nigrodigitatus* (initial weight 16.30 ± 0.07 g, mean ± SE) in twelve 60-L indoor flow through rectangular glass tanks provided with aerated underground water. Four isoenergetic diets were formulated to contain varying crude protein (CP) levels: 32.1%, 34.6%, 42.8%, and 47.1% using fish meal/soybean meal as protein sources in a ratio of 2:1. Each diet was assigned to triplicate groups of 12 fish in a completely randomized design. Twelve uniform-sized fish were stocked in each tank. A digestibility trial was conducted with all the diets. Fish was fed to apparent satiation with experimental diets twice a day. Results after ten weeks of feeding showed an increase in weight gain (WG) and specific growth rate with increasing levels of dietary protein up to 42.8% (P <0.05) but a decline at 47.1% CP. Protein efficiency ratio followed similar trend but there were no significant differences between the treatments. Feed conversion ratio (FCR) reduced as dietary protein level increased, with the minimum FCR in the 42.8% protein diet, although this was not significantly different from the 34.6% and 47.1% protein diets. The results of the present study indicate that the maximum growth of juvenile *C. nigrodigitatus* was achieved at about 42.8% dietary protein. Analysis of dose (protein level)-response (WG) with third-order polynomial regression suggested that the optimal dietary protein requirement for the juvenile of *C. nigrodigitatus* was 42.9%.

INTRODUCTION

Members of the genus *Chrysichthys* are widely distributed in the freshwater systems of Tropical Africa and support thriving commercial fisheries of many West African waters, Ghana being no exception. In Ghana Claroteid catfish forms about 40% of the catch from the Volta Lake alone. *Chrysichthys nigrodigitatus* (Lacepede, 1803) a common silver coloured African catfish of the family Claroteidae has been demonstrated to be omnivorous having a wide variety of food preferences (Offem *et al*, 2008). According to Adewolu and Benfey (2009), *C. nigrodigitatus* can be cultured in both fresh and brackish waters. Considerations for the culture of the fish have resulted in several biological studies on the species. *C. nigrodigitatus* is a relatively new species in aquaculture and the knowledge of its ecology and biology, especially its dietary requirements is still limited. *C. nigrodigitatus* is similar to *Chrysichthys maurus*. In a preliminary survey of indigenous species being tried for aquaculture in Ghana, it was thought that *C. maurus* was common on fish farms but these were later determined to be C. *nigrodigitatus* based on further information obtained about the natural distribution of the two species. The distribution of *C. maurus* in Ghana is limited to the southwestern border of the country as the species is more common in neighboring Ivory Coast. *C. nigrodigitatus*, on the other hand, is found in all the major river basins of

Ghana, making it naturally adaptable to captivity in pond systems in the country. A consultation with farmers revealed that *C. nigrodigitatus* are not only common in farmers' ponds but also they grow faster and bigger than *C. maurus.*

Although some farmers in Ghana keep *C. nigrodigitatus* in their ponds, they have little or no knowledge of the nutrient requirements and general management of the species. Few studies have been conducted on the nutrition and the recent one was by Adewolu and Benfey (2009). In determining the minimum nutrient requirements of a cultured species, protein is usually given first consideration because of its high cost and essential role for growth, tissue maintenance and reproduction. Therefore, investigating the protein requirement entails determining the minimum amount required to produce maximum growth and not to be used for energy needs. The objectives of the present study was to evaluate the effects of dietary protein levels in diets on growth performance, feed utilization, body composition and apparent digestibility coefficient (ADC) so as to determine the optimum dietary protein requirement for juvenile *C. nigrodigitatus.*

Literature review of habitat, food habits, life-history and distribution

C. nigrodigitatus is abundant and widely distributed. It is found in all the three river basins in Ghana namely; Volta (Black and White Volta Rivers, the Oti River and the Lower Volta, including Lake Volta), South Western (Bia, Tano, Ankobra and Pra Rivers) and Coastal Basins (Ochi-Amissah, Ochi-Nakwa, Ayensu, Densu and Tordzie/Aka Rivers) but *C. maurus* is restricted to the South Western basin (Dankwa et al., 1999). It is a bottom-dwelling freshwater fish widely distributed in the freshwater systems of Tropical Africa including Ghana (Nwadiaro and Okorie, 1985; Dankwa et al., 1999). *C. nigrodigitatus* is found in all the three river basins in Ghana namely; Volta, South Western and Coastal Basins (Dankwa *et al.*, 1999), consisting of numerous rivers and streams and the Volta Lake and covering about 70% of the country. *C. nigrodigitatus* is largely omnivorous (with strong tendency towards predation), with large proportions of animal component and detritus in their diet and they are adequately adapted for such habits (Offem *et al*, 2008). Juvenile members of the species have been found to be plankton feeders feeding mainly on zooplankton including copepods (Ogwumba, 1988). *C. nigrodigitatus* is known to breed seasonally and usually spawn during the rainy and flooding season. The reproductive cycle of *C. nigrodigitatus* has been reported to be around September and November, with vitellogenesis duration of 4 months (Nuñez *et al*, 1995). However, Offem *et al* (2008) indicated that *C. nigrodigitatus* has a long spawning period, extending from April to August. The completely different records on spawning season suggests that *C. nigrodigitatus* is a serial spawner with possibly two peaks in reproduction coinciding with the major rainy seasons in the humid tropics of West Africa. The species spawns in crevices (speleophil) like many catfishes, and we have seen in our experimental ponds and on some farms that under the right conditions the female enters hollow structures such as wood or bamboo to deposit its eggs.

MATERIALS AND METHODS

Experimental system and fish handling

This study was conducted at the Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. Fish were reared in glass tanks (60 L) in a flow-through system, which was supplied with water at a flow rate of 0.5 L min^{-1}. Water quality parameters measured weekly during the experiment were as follows (mean ± SD): temperature, 26.76 ± 0.02^{o}C; pH, 7.22 - 6.71; dissolved oxygen, 4.04 ± 0.08 mg L^{-1}; salinity, 0.09 ± 0.00 and ammonia, 0.01 ± 0.01 mg L^{-1}. *C. nigrodigitatus* obtained from the Volta River near Akuse, Ghana were kept in hapas and fed commercial feed for three weeks before the experiment. One week before the start of the experiment, fish were transferred to the experimental tanks for acclimation. Fish of mean initial weight 16.30 ± 0.07 g were stocked randomly 12 fingerlings per tank in triplicates per treatment.

Diet formulation and preparation

All ingredients used in this study were obtained from commercial sources in Ghana. Four isoenergetic diets were formulated to contain varying crude protein (CP) levels ranging from 30%, 35%, 40%, and 45% using fish meal and soybean meal as protein sources in a ratio of 2:1 (Table 1). Fish were hand-fed twice a day (09:00, 16:00) to satiation. Feeding rates were adjusted every week and the growth experiment lasted ten weeks. At the end of the growth trial feces were collected for digestibility study by siphoning into centrifuge bottles and immediately centrifuged using Universal 16A, Centrifuge at 3,000 rpm for 10 min and the supernatant discarded. Feces were then oven dried at 60^{o}C for 24h, ground into a fine powder and stored in a desiccator for chemical analysis.

Table 1. Composition of diets fed to *Chrysichthys nigrodigitatus* with varying protein levels.

Ingredients	Protein levels (g/100 g as-fed)			
	30	35	40	45
Fish meal	23.7	29.8	35.0	40.7
Soy bean Meal	18.8	22.2	27.5	32.2
Rice Bran	30.5	23.0	15.0	8.0
Wheat Bran	15.5	13.5	11.0	7.6
Salt	1.0	1.0	1.0	1.0
Palm oil	2.0	2.0	2.0	2.0
Di Calcium Phosphate	2.0	2.0	2.0	2.0
Cassava Flour (Binder)	2.0	2.0	2.0	2.0
Vitamin & mineral Premix	4.0	4.0	4.0	4.0
Chromic Oxide	0.5	0.5	0.5	0.5
Proximate Composition (%)				
Dry matter	95.2	95.5	96.7	96.7
Crude protein	32.1	34.6	42.8	47.1
Crude lipid	9.1	8.8	10.7	14.5
Crude fibre	7.3	4.9	4.3	
Ash	15.9	15.9	15.9	18.2
Gross energy, (kJ g^{-1})	17.3	17.8	18.9	19.6

Biochemical, biological and statistical analyses

Ingredients, diets, carcass and feces were analyzed in triplicates for proximate composition according to standard methods (AOAC, 1990) and chromic oxide of diets and feces analyzed using the method by Furukawa and Tsukahara (1966). Performance in growth and feed utilization were determined in terms of weight gain (WG), specific growth rate (SGR), feed intake (FI), feed conversion ratio (FCR), and protein efficiency ratio (PER) as follows: WG (%) = final body weight – initial body weight/ initial body weight x 100; SGR (% day^{-1}) = 100 × [ln(final body weight) - ln(initial body weight)]/no. of days; FI (g) = Total feed intake per fish/no. of days; FCR = feed intake/live weight gain; PER = live weight gain/crude protein intake. The apparent digestibility coefficients (ADC) for the nutrients of the diets were calculated as follows: ADC (%)=100×[1-(%nutrient in feces/%nutrient in feed)×(%marker in feed/marker in feces)]. Whole body composition was determined where whole body samples were analyzed for moisture, crude protein, crude lipid and ash and results expressed as percentage of live weight. All data were subjected to ANOVA using SPSS 16.0. Differences between the means were tested by Tukey's test ($\alpha = 0.05$). The optimum dietary protein requirement for juvenile *C. nigrodigitatus* based on percentage weight gain (WG) was estimated by third-order polynomial regression analysis ($Y = a + bX + cX^2 + dX^3$) (Neter *et al.*, 1996).

The present study indicated that dietary protein level had an effect on growth performance, and the optimum protein level in diets for *C nigrodigitatus* juvenile, defined by the percentage WG, was 42.9% when fish meal and soybean meal were used as the main protein source and the dietary energy value was 18.9 kJ/g. This value was similar to those used in omnivorous fish diet, for example, bagrid catfish, *Mystus nemurus* (44%; Ng *et al.* 2001); silver perch, *Bidyanus bidyanus* (42.2%; Yang et al. 2002); black sea bream, *Sparus macrocephalus* (41.4%; Zhang *et al.* 2010) but higher than those reported for other omnivorous species, such as, channel catfish *Ictalurus punctatus* (28-32%; Robinson *et al*. 2000) and *Heterotis niloticus* (30.6-31.1%; Monentcham, 2009). Adewolu and Benfey (2009) also studied protein requirements for juvenile *C. nigrodigitatus* and reported at least 35% dietary protein and stated that optimum protein requirement was not established for the species because no growth plateau was reached.

RESULTS AND DISCUSSION

Growth performance of *C. nigrodigitatus* fed the diets containing varying dietary protein levels for 10 weeks is presented in Table 2. There was no significant difference in the initial body weight of *C. nigrodigitatus*; however, after the 10-wk feeding trial, the fish grew and weight gain (WG) ranged between 21.3 and 44.9%, and the fish fed 42.8% dietary protein showed the highest WG value (44.9%) ($P < 0.05$) than other treatments except for fish fed 47.1% protein diet. SGR increased significantly with increasing dietary protein levels up to 42.8% protein diet (0.53% day^{-1}) and decreased slightly at 47.1% protein (0.40% day^{-1}).

Table 2. Growth responses and feed utilization of juvenile *Chrysichthys nigrodigitatus* fed varying levels of protein for 70 days.

	Crude protein levels in the diet (%)			
Parameter	32.1	34.6	42.8	47.1
Initial weight (g)	16.42 ± 0.05	16.34 ± 0.07	16.10 ± 0.27	16.35 ± 0.10
Final weight (g)	19.91±0.31^{b}	20.40± 0.48^{b}	23.32 ± 0.33^{a}	21.67 ± 0.72^{ab}
Weight gain (g)	3.49 ± 0.36^{b}	4.06 ± 0.42^{b}	7.22 ± 0.31^{a}	5.31 ± 0.64^{ab}
Weight gain (%)	21.25 ± 2.29^{a}	24.85 ± 2.46^{a}	44.88 ± 2.29^{b}	32.46 ± 3.78^{ab}
Specific growth rate (%.day^{-1})	0.28 ± 0.03^{b}	0.32 ± 0.03^{b}	0.53 ± 0.03^{a}	0.40 ± 0.04^{ab}
Feed intake (g)	22.11 ± 0.12	22.18 ± 1.30	23.83 ± 0.24	21.27 ± 0.67
Feed conversion ratio	6.48 ± 0.67^{b}	5.63 ± 0.83^{ab}	3.32 ± 0.18^{a}	4.13 ± 0.56^{ab}
Protein intake (g)	7.09	7.12	7.64	6.82
Protein efficiency ratio	0.49 ± 0.05	0.54 ± 0.09	0.71 ± 0.04	0.53 ± 0.07
Survival (%)	80.55 ± 2.78	83.33 ± 9.62	77.78 ± 2.78	88.89 ± 5.56

Values are presented as means ± SE (n = 3) and values within the same row with different letters are significantly different ($P< 0.05$).

Growth, as expressed by percentage weight gain and specific growth rate, increased with increasing dietary protein level within the range of 32.1%–42.8% crude protein. Increases in dietary protein have often been associated with higher growth rates in many species as this component provides the essential amino acid building blocks for protein synthesis (McGoogan *et al.* 1999). Third-order polynomial regression analysis based on WG ($y = 38.47 + 2.884(x - 39.15) – 0.182(x – 39.15)^2 – 0.035(x – 39.15)^3$; adjusted $R^2 = 0.783$; x = dietary protein levels (%), y = WG (%)) showed that the optimum dietary protein level was 42.9% (Fig 1).

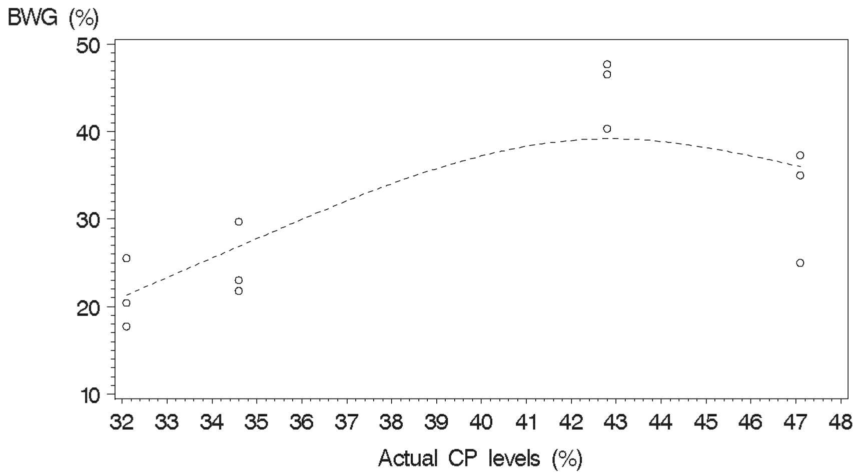

Fig 1 The relationship between weight gain (%, *y*) and dietary protein levels (%, *x*) in juvenile *C. nigrodigitatus.*

The present study indicated that dietary protein level had an effect on growth performance, and the optimum protein level in diets for *C nigrodigitatus* juvenile, defined by the percentage WG, was 42.9% when fish meal and soybean meal were used as the main protein source and the dietary energy value was 18.9 kJ/g. This value was similar to those used in omnivorous fish diet, for example, bagrid catfish, *Mystus nemurus* (44%; Ng *et al.* 2001); silver perch, *Bidyanus bidyanus* (42.2%; Yang et al. 2002); black sea bream, *Sparus macrocephalus* (41.4%; Zhang *et al.* 2010) but higher than those reported for other omnivorous species, such as, channel catfish *Ictalurus punctatus* (28-32%; Robinson *et al*. 2000) and *Heterotis niloticus* (30.6-31.1%; Monentcham, 2009). Adewolu and Benfey (2009) also studied protein requirements for juvenile *C. nigrodigitatus* and reported at least 35% dietary protein and stated that optimum protein requirement was not established for the species because no growth plateau was reached. Protein requirements between fish species is complicated by differences in species, size and age of fish, diet formulation, stocking density, protein quality, hygiene and experimental conditions between studies (NRC 1993).

Feed utilization by *C. nigrodigitatus* improved as dietary protein level increased. Feed intake (FI) increased slightly with the increase in dietary protein up to 42.8% (23.8 g) but reduced a bit at 47.1% (21.3 g) however, there was no significant differences between treatments. FCR data showed approximately the opposite pattern as FI with diet containing 42.8% protein being better utilized (3.3) than the others, although it was not significantly different from fish fed 47.1% protein diet. The observation that (FCR) decreased with increasing dietary protein levels has also been reported for many other species, irrespective of culture conditions, including Mozambique tilapia (Jauncey 1982), African catfish (Degani et al. 1989) and Bagrid catfish (Adewolu and Benfey, 2009). The high FCR values (3.3–6.5) observed in this study may be a result of the use of locally available cheap ingredients for practical diet formulation; high FCR values have been reported for a number of fish species fed on practical diets using locally available feed ingredients (Khan *et al.* 1993). This also probably led to low growth performance, although water supply problems were encountered during the experiment, which could have been one of the reasons. In a majority of similar studies, researchers employed various purified and semi purified diets with high quality protein sources such as casein, gelatin or synthetic amino acids that gave good growth and feed utilization leading to more precise values.

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ADCs of protein, organic matter and lipid increased as protein content of the diets increased (Table 3) but the increase was not significant for ADCs of protein and organic matter. However, ADC of lipid showed a significant increase as dietary protein content increased with 47.1% protein diet recording the highest (91.33%).

Table 3. Apparent digestibility coefficients (%) of main nutrients in diets for juvenile *Chrysichthys nigrodigitatus* fed varying levels of protein for 70 days.

	Crude protein levels in the diet (%)			
	32.1	34.6	42.8	47.1
Crude protein	70.59 ± 4.78	71.60 ± 4.67	72.57 ± 1.08	71.75 ± 1.46
Crude lipid	83.41 ± 2.67[b]	88.83 ± 0.30[ab]	88.91 ± 1.96[ab]	91.33 ± 0.96 [a]
Dry matter	49.29 ± 2.83	53.05 ± 2.59	55.78 ± 2.43	56.36 ± 0.56

Values are presented as means ± SE (n = 3) and values within the same row with different letters are significantly different (P< 0.05).

Whole body composition of *Chrysichthys nigrodigitatus* is presented in Table 4. Percentage moisture, ash content, whole-body protein were not significantly affected by dietary protein level (P>0.05). The whole-body protein was positively correlated with dietary protein level. Whole-body lipid and ash also followed a similar trend up to 42.8% dietary protein and decline slightly at 47.1%. Percentage moisture was negatively correlated with dietary protein level. Increasing dietary protein level increased lipid content in body composition significantly (*P* <0.05). Similar results were observed in the carcass composition of Nile tilapia (El-Saidy & Gaber 2005) and Silver perch (Yang *et al*. 2002).

Table 4. Whole body composition (% wet weight) and energy of juvenile *Chrysichthys nigrodigitatus* fed varying levels of protein for 70 days.

Components	Crude protein levels in the diet (%)			
	32.1	34.6	42.8	47.1
Moisture content	75.66 ± 0.61	75.56 ± 1.67	73.69 ± 0.23	73.26 ± 1.18
Crude protein	15.77 ± 0.83	16.39 ± 1.22	19.12 ± 0.30	19.37 ± 0.94
Crude lipid	2.83 ± 0.46[b]	4.05 ± 0.54[ab]	5.00 ± 0.31[a]	4.23 ± 0.33[ab]
Ash	3.58 ± 0.15	4.34 ± 0.65	4.96 ± 0.75	4.65 ± 0.22

Values are means ± SE (n = 3) and values within the same row with different letters are significantly different (P< 0.05).

CONCLUSION

The results of the present study indicate that the maximum growth of juvenile *C. nigrodigitatus* was achieved at about 42.8% dietary protein when fish and soybean meals were used as the major sources of protein. Using a polynomial regression analysis of WG, the dietary protein requirement for the juvenile of *C. nigrodigitatus* was estimated to be 42.9%.

Ecology And Dietary Protein Requirement Of Juvenile African Bony-Tongue, *Heterotis Niloticus*

ABSTRACT

The study evaluated the effect of four isoenergetic diets with varying crude protein (CP) levels of 26.2%, 32.1%, 34.6% and 42.8% on growth, feed utilization and whole body proximate composition of *Heterotis niloticus* juveniles. *H. niloticus* juveniles (initial weight 32.65±0.03g) were stocked in rearing hapas (2x1m^2) at 5 fish per hapa. Each diet was assigned to triplicate groups of fish in a completely randomized design and the experiment lasted for ten weeks. An increasing growth trend and better feed utilization was observed as dietary protein levels increased from 26.2% to 42.8%. Fish fed 42.8% protein diet had the best growth performance and nutrient utilization, with a mean weight gain of 202.30±19.6%, feed conversion ratio of 1.20±0.15 and protein efficiency ratio of 1.66±0.2, however this was not significantly different from values of fish fed 32.1% and 34.6% dietary protein. Significantly lower values were recorded for fish fed 26.2% dietary protein. Whole body nutrient composition was not affected by the diets. The results of this study suggest that *H. niloticus* juveniles would grow best when fed diets containing at least 32.1% protein.

INTRODUCTION

Among the most highly valued species in West African inland fisheries is the African bony tongue, *Heterotis niloticus* (Cuvier, 1829), a species widely distributed in tropical rivers, freshwater lakes of Western and Central Africa (Moreau 1982). The African bony tongue is exploited by fisheries in Southern Benin, the middle Niger River Delta and other regions of West Africa (Adite *et al*., 2005). The species is classified within the opportunistic omnivorous fish category and consume a variety of food resources, ranging from aquatic invertebrates to small seeds, including small benthic organisms, fishes, shrimps, plant remains and terrestrial insects. In captivity, remarkable growth performances have been reported, individual mean body mass reaching up to 3 to 4 kg in 12 months. However, its use for profitable fish-farming in Africa relies on the knowledge of ecological, behavioral and nutritional factors which condition its reproduction, the resolution of massive mortality during early rearing, the estimate of its nutritional needs at various ontogenetic stages and the identification of an efficient breeding. The prospect for Heterotis contribution to the rise of African aquaculture depends on the solutions which will be found to the mentioned crucial problems (Monentcham, 2009). In spite of the great evolutionary and fishery significance, the bony tongue fishes of the family Osteoglossidae generally have not received extensive study (Adite *et al*., 2005). Considering the bony tongue's great ecological and economic importance in Ghana, more information is needed on natural feeding habits and nutritional requirements of the species in order to inform both fisheries management and development of aquaculture technology. This study, therefore was undertaking to evaluate the growth performance, feed utilization and whole body composition of *H. niloticus* fed on varying dietary protein levels.

Literature review of habitat, food habits, life-history and distribution

H. niloticus is a pelagic freshwater fish usually found in waterbodies with aquatic vegetation (e.g., Swamps) particularly during spawning seasons (Adite *et al.,* 2005). The African bony tongue has been characterized as microphagous on phytoplankton (Lowe-McConnell, 1975; Holden and Reed, 1991) and feeding on variable amounts of plant material, including seeds, and benthic water column invertebrates. *H. niloticus* spawn in nests, which are circular clearings within dense stands of rooted and submerged or emergent aquatic macrophytes in shallow water (Padi, 2006; Adite *et al.,* 2005). Spawning occurs during the rainy seasons in Ghana. *H. niloticus* occurs in large rivers of West Africa. In Ghana it occurs mainly in the Volta basin (Dankwa *et al*., 1999).

MATERIALS AND METHODS

Experimental system and diet preparation

This study was carried out at the premises of the Data Stream Hatchery at Old Akrade in the Eastern Region of Ghana. Twelve hapas (2x1m^2) mounted in concrete tanks (5x20 m^2) were used for the feed trial. Before mounting the hapas, the concrete tank was cleaned with calcium carbonate to kill bacteria and other micro-organisms and left to dry for about a week and then filled with water from the Volta River. The concrete tank was fitted with an air blower for water aeration and ultra violet clarifier for water disinfection. All ingredients used for diet preparation in this study were obtained from commercial sources in Ghana. Four isoenergetic diets were formulated to contain varying crude protein (CP) levels of 25%, 30%, 35%, and 40%, using fish meal and soybean meal as protein sources in a ratio of 2:1 (Table 1).

Table 2. Composition of diets fed to *Heterotis niloticus* with varying protein levels.

Ingredients	Protein levels (g/100 g as-fed)			
	25	30	35	40
Fish meal	18.0	23.7	29.8	35.0
Soy bean Meal	13.9	18.8	22.2	27.5
Rice Bran	38.0	30.5	23.0	15.0
Wheat Bran	18.6	15.5	13.5	11.0
Salt	1.0	1.0	1.0	1.0
Palm oil	2.0	2.0	2.0	2.0
Di Calcium Phosphate	2.0	2.0	2.0	2.0
Cassava Flour (Binder)	2.0	2.0	2.0	2.0
Vitamin & mineral Premix	4.0	4.0	4.0	4.0
Chromic Oxide	0.5	0.5	0.5	0.5
Proximate composition				
Dry matter	97.0	95.2	95.5	96.7
Crude protein	26.2	32.1	34.6	42.8
Crude lipid	9.1	9.1	8.8	10.7
Crude fibre	8.56	7.3	4.9	4.3
Ash	13.6	15.9	15.9	15.9
Gross energy, (kJ g^{-1})	16.9	17.4	17.9	18.4

Experimental fish, acclimation, stocking and feeding

A total of sixty Fingerlings of *H. niloticus (*initial weight of 32.7g*)* obtained from Zewu Farms, Akuse were used for the study. The fish were randomly stocked 5 fish per hapa in triplicates per treatment. The fish were allowed to acclimatize for two weeks prior to the start of the feeding trial. During this period, the fish were fed on (crumbles) imported feed with 45% crude protein (Raanan feed from Israel). The fish were hand-fed to satiation twice daily at 0700h and 1600h. Feeding rates were adjusted every week and the growth experiment lasted ten weeks.

Biochemical, biological and statistical analyses

Ingredients, diets, carcass and feces were analyzed in triplicates for proximate composition according to standard methods (AOAC, 1990). Performance in growth and feed utilization were determined in terms of weight gain (WG), specific growth rate (SGR), feed intake (FI), feed conversion ratio (FCR) and protein efficiency ratio (PER) as follows: WG (%) = final body weight – initial body weight/ initial body weight x 100; SGR (% day^{-1}) = 100 × [ln(final body weight) - ln(initial body weight)]/no. of days; FI (g) = Total feed intake per fish/no. of days; FCR = feed intake/live weight gain; PER = live weight gain/crude protein intake. Whole body composition was determined where whole body samples were analysed for moisture, crude protein, crude lipid and ash and results expressed as percentage of live weight. All data were subjected to ANOVA using SPSS 16.0. Differences between the means were tested by Tukey's test ($\alpha = 0.05$).

RESULTS AND DISCUSSION

In this study, varying inclusion levels of dietary protein had effect on the growth performance (FBW, WG and SGR) and feed utilization (FI, FCR and PER) of *Heterotis niloticus* ($P< 0.05$; Table 2). FBW, WG and SGR increased with increasing dietary protein levels with the maximum values in the 42.8% protein diet, although this was not significantly different from the 32.1% and 34.6% protein diets. FI and PER followed a similar trend but there was no significant differences between the diets. The reverse trend was true for FCR with the least value (1.2) recorded for fish fed 42.8% protein diet, but did not differ significantly from the 32.1% and 34.6% protein diets. The survival rate generally showed a decreasing trend with increasing dietary protein level but was not significantly different between the diets.

Table 2. Growth and feed utilization of *H. niloticus* fed at varying inclusion levels of dietary protein for 70 days.

Parameter	Crude protein levels in the diet (%)			
	26.2	32.1	34.6	42.8
IBW	32.30±0.40	32.73±0.03	32.80±0.06	32.77±0.03
FBW	65.56±4.57^{a}	76.12±9.07^{ab}	90.40±7.19^{ab}	99.07±6.50^{b}
WG	102.80±12.42^{a}	132.60±27.77^{ab}	175.6±21.85^{ab}	202.30±19.56^{b}
FCR	1.85±0.17^{a}	1.77±0.13^{ab}	1.69±0.07^{ab}	1.20±0.15^{b}
SGR	0.90±0.08^{a}	1.06±0.15^{ab}	1.29±0.11^{ab}	1.41±0.08^{b}
SUR	93.33±6.67	91.67±8.33	73.33±13.33	71.67±17.40
PER	1.27±0.16	1.44±0.30	1.65±0.21	1.66±0.16
FI	60.49±3.45	74.33±10.14	76.53±8.69	77.45±3.0630
K	2.46±0.16	2.48±0.29	2.19±0.14	2.06±0.24

IBW (g)=Initial body weight, FBW (g)=Final body weight, WG (%)=Weight gain, FCR=Feed conversion ratio, SGR (%day^{-1})= Specific growth rate, SUR (%)= Survival, PER=Protein efficiency ratio, FI (g)=Feed intake, K= Condition factor. Values are presented as means ± SE (n = 3) and values within the same row with different letters are significantly different ($P< 0.05$)

These results are in agreement with (Al-Hafedh *et al*., 1999) who found that better growth of Nile tilapia was obtained at high dietary protein levels 40-45 % rather than 25-35 % protein in the absence of live algae and (Tacon, 1987) who found that dietary protein level varied from 42% for fry and 35% for growing adult. It also compares with Monentcham, (2009) who concluded that maximum growth of

Heterotis fingerlings was achieved at about 34.5% protein, however using the broken line model the dietary protein requirement was estimated to be 31.0%.

The decrease in FCR with increase in dietary protein in this study, suggests a corresponding increase in feed conversion efficiency of the fish in accordance with the fact that protein is the major dietary nutrient affecting performance of fish (Lovell, 1989) since it provides the essential and nonessential amino acids which are necessary for muscle formation and enzymatic function and in part provides energy for maintenance.

The condition factor (K) was not affected by the varying levels of protein inclusion in the diets. The K values range from 2.06 to 2.46 (Table 2). These results are in close agreement with those of (Osman, 1991) who reported that K values in general, for fish ranged between 2.20 and 2.33 and also agreed with those of (Ahmad *et al.*, 2004).

There were no significant differences ($P<0.05$) in the whole body composition of the fish (Table 4.5) among the diets in relation to protein, moisture, crude lipid, crude fibre, ash and nitrogen free extracts at the end of the feeding trial. The whole body protein, lipid, moisture and ash contents were not were not significantly affected by dietary protein levels (Table 3). Similar results were observed in *H. niloticus* (Monentcham, 2009) and Nile tilapia (El-Saidy & Gaber 2005).

Table 3. Whole body compositions (% wet weight) of *H. niloticus* fed varying inclusion levels of protein for 70 days.

Parameter	Initial value	Crude protein levels in the diet (%)			
		26.2	32.1	34.6	42.8
Moisture content	74.25 ± 0.26	76.02±0.71	75.22±0.72	76.35±0.49	75.03±0.95
Crude protein	18.66 ±0.21	17.77 ±0.42	18.40 ±0.56	18.43±0.38	18.54±0.71
Crude lipid	1.66± 0.03	1.65±0.12	1.57±0.05	1.69±0.03	1.71±0.03
Ash	1.59±0.04	1.51±0.14	1.51±0.04	1.44±0.04	1.56 ±0.10

Values are means ± SE (n = 3) and values within the same row with different letters are significantly different ($P< 0.05$).

CONCLUSION

The results of this study shows that the maximum growth and feed utilisation of *H. niloticus* fingerlings were achieved when dietary protein was about 42.8% using practical diets with fish and soybean meals as the major sources of protein. In conclusion, the use of a practical diet containing at least 32.1% protein would be appropriate for growth and nutrient utilization of juvenile *H. niloticus* under the conditions of this study.

Ecology And A Survey Of Market Potential And Distribution Trends Of Snakehead, *Parachanna Obscura*, In Four Regions In Ghana

While the original objective of this project included experiments to determine the dietary protein requirements of juveniles of the three species, initial laboratory trials with *Parachanna obscura* failed because the individuals kept in tanks refused pelleted feed, although they would readily take live feed like tilapia. Experimental study of *Parachanna obscura* dietary protein requirements was therefore not feasible. A more in-depth study of the distribution and natural food and habitat requirement and acceptability as a potential aquaculture species in Ghana completed in lieu of the experimental diet studies.

Literature review of habitat, food habits, life-history and distribution

Snakeheads are voracious predators (Fagbenro, 2002) and have been observed to exhibit ontogenetic changes in their diets. Juveniles of *P. obscura* prey on insects' larvae, nematodes and fish fry whilst adults prey on larger fish (USEPA, 2002, Ajah et al., 2006). Juveniles have been reported as benthic feeders (Ajah et al., 2006). When starved, some snakeheads have a tendency to be cannibalistic on their young (USEPA 2002). Snakeheads are likely to be encountered in flood plains, both in the open water and the swamps (Oti, 2003; Brummet and Teugels, 2002). In rivers and streams, they have been reported to occur in vegetated areas (USEPA, 2002). All the species in the family Channidae are air-breathing, therefore, they can survive hypoxic conditions as early as late juvenile stages (USEPA, 2002; UGSS, 2010a). Optimum pH ranges are reported to differ among species in the family (UGSS 2010a). Information on spawning activities in African snakehead is lacking. However, spawning has been observed in summer (June to August) in many of the species in the family Channidae (USEPA, 2002). Fecundity in *P. obscura* in a monoculture farm in Nigeria (Victor and Akpocha, 1992) was reported to be variable and highest in October and November with 35- 4,010 eggs. Some species are also capable of spawning up to five times in a year (USGS, 2010a). For mouth brooding species, fecundity is very low ranging from about 20 eggs at first maturity and increasing to about 200 as the fish grows (USGS, 2010a). Prior to spawning, adults build circular nests in water columns in vegetated areas where spawning occurs (Gascho Landis and Lapointe, 2010). However, presence of vegetation may not always be a prerequisite for spawning because some species in the genus *Channa* have been reported to spawn in the absence of vegetation (USGS, 2010a). Higher temperatures appear to speed up hatching rates of eggs among species; eggs were observed to hatch in 45-120 hours at 16°C-26°C and 28-31 hours at 28°C-33°C (USGS, 2010a). Fry begin to feed on zooplankton when yolk sacs are depleted (USGS, 2010a). Snakeheads are very aggressive in protection of their young. Parental care in the family has been observed to differ from species to species but all species exhibit some parental care (USEPA, 2002).

Description of the study areas

The study was conducted in the Ashanti, Brong Ahafo, Eastern and Western Regions of Ghana. The selection of these regions was as a result of the apparent availability of snakehead (*Parachanna obscura*) from rivers in the regions. The specific towns surveyed include Barekese (Ashanti), Offinso (Offinso), Ekye-Amanfrom (Eastern), Sefwi- Wiawso (Western), Techiman (Brong Ahafo) and Yeji (Brong Ahafo). These towns both had rivers or reservoirs within which thrived active fishing. In addition, the towns had markets where a market survey could be conducted.

METHODS

Sample selection and survey data Collection

The study was conducted with fishermen/women and fish traders in the four regions selected. Due to lack of a sampling frame for both fisher folk and fish traders, we resulted to total population sampling when the numbers were small (40 or below) and random sampling when the numbers were large (above 200). Fortunately, all fisher folk encountered were willing to be interviewed but some fish traders (about 10) were not available by their goods or unwilling to be interviewed. Apart from Yeji and Sefwi-wiaso where the fish traders were randomly surveyed, we employed total sampling in all the markets. A total of 177 respondents were surveyed comprising 51 fisher folk (including one woman) and 126 fish traders (including one man).

The survey was conducted between July and August 2011. The fisher folk were interviewed at the river side, their homes or market centers. Most of the fish traders were interviewed at the market centers with a few in the Eastern Region interviewed at their homes. We administered all 177 questionnaires through personal interviews. To avoid confusion about the species being studied, we presented a photograph and a sample of the species to all respondents.

Questionnaire design

We employed both close-ended and open-questions in the survey and used multiple measures to assess changes in snakehead distribution in the four regions. These include frequency of encounter with snakehead, towns where snakehead are caught or purchased and the rivers from which they are caught. To assess relative abundance of snakehead, fisher folk were asked to indicate their current estimated catches. In addition, they had to indicate if they had observed any changes in catches and to provide information about the changes. The snakehead market potential was assessed through asking respondents to compare the price of snakehead to other commonly sold species. We also assessed market potential by asking respondents to indicate whether or not they are meeting the demand for snakehead.

RESULTS AND DISCUSSION

Distribution, abundance, and market potential of snakehead in Ghana

Data analysis for the survey is ongoing but preliminary findings suggest that snakeheads thrive in the major watersheds in Ashanti, Brong Ahafo, Eastern, and Western Regions. The rivers mentioned by fishermen as their sources of snakehead include Afram, White Volta, Subin, Offin, and Tano. This was corroborated by the market women who also provided town names such as Yeji, Bupe, Afram plains, Kwahu and Kumasi as their sources of fish for trade. When asked how frequently they encountered snakehead, majority of the fisher folk and fish traders said “once in a while”. A few fishermen said they encountered them daily if they set traps for them.

Species abundance appears to be driven by type of gear used and the seasonal patterns. However, seasonal patterns seem the common determinant of abundance for all four regions. The fisher folk best described the species as one that fluctuates in abundance yearly. This fluctuation occurs because of the two major seasons in Ghana. When the rivers overflow their banks between April to July, flood water which collects in pools in vegetated areas provide spawning habitats for snakehead. Subsequently, the fishermen target these areas and encircle them. Even with their traditional gill nets, large numbers of snakehead are caught. While they could only capture two to three snakehead in a typical week, they obtain as many as 1000 between August and December when the water recedes. For the fishermen who target snakehead every day of the year, relying on the same gears used for the open water species is not an option. They used baited hooks, since the species is carnivorous, to ensure catches about three snakeheads daily.

Comparing snakehead to commonly caught species such as tilapias and catfishes, the snakehead market is not well established. Snakeheads are typically processed before they are sold on the market. The most common processing method is smoking. However, on some occasions, they are salted. Only one trader indicated she sometimes sold them fresh. With the exception of Barekese (Ashanti Region) and Afram plains (Eastern Region) where we encountered samples from fishermen and on the open market, all other market had no snakehead. Most of the respondents who were familiar with the species suggested it was a high quality fish which they relished. To support that, they explained that since snakehead catches were low compared to Tilapia and Chrysichthys, they seldom sold snakehead. Evidently, snakeheads were rarely seen on the market. Snakeheads were largely not sold separately as other species. Due to the low catches, fisher folk and fish traders alike sold them mixed with other species such as Chrysichthys. Some traders indicated they discarded them hence it was difficult to determine its price. The fisher folk also added that their neighbors often bought snakeheads before they could be sent to the market. When snakeheads were sold separately, it appears they sold just like Clarias with the same size or weight. However, this was not a general consensus. Depending on who bought the fish, the price was higher or lower compared to Tilapia or Clarias. With respect to demand for snakeheads, most of the respondents indicated they rarely had customers requesting for snakeheads. Nevertheless, many respondents suggested they would be able to sell more snakeheads if they obtained numbers above current levels.

Training

Besides several MS student theses supported at KNUST, this study provided two short-term trainings that were part of its original objectives. The first training, in Experimental Design and Analysis for Aquaculture Professionals, was conducted in July 2010 at the Providence Hostel in Kumasi, hosted by KNUST. The workshop, taught by Dr. Emmanuel Frimpong, was attended by 20 participants, including technicians and aquaculture scientists from KNUST, the Water Research Institute, and the Fisheries Commission and AquaFish-supported graduate students. The second training was a symposium on the culture of indigenous species, held at the Independence Hall of KNUST in July 2010. This symposium was attended by 151 participants and led by Drs, Nelson Agbo, Steve Amisah, Emmanuel Frimpong, and Ms. Gifty-Anane Taabeah.

PRELIMINARY CONCLUSION AND RECOMMENDATION

Snakeheads occur in major river basins in the Ashanti, Brong Ahafo, Eastern and Western regions of Ghana. Currently, their catches are low, resulting in fewer numbers reaching local markets. Even though the snakehead market is not developed like that of Tilapia or Clarias, the species has potential to penetrate local markets if the public is well educated about the species as an alternative food fish. In view of the current findings, a countrywide survey of the market potential of snakeheads will be a good study to pursue. This should provide a clearer picture of potential markets for the species. Commercial aquaculture appears a vital avenue for ensuring snakehead availability on the market and should be explored.

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