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Profitability of using different crude protein contents of the most commonly used commercial tilapia feed in Ghana for Nile tilapia (*Oreochromis niloticus*) fingerlings production

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Abstract
For profitability of commercial fish farming, it is important to use economically viable fish feed. The profitability of using a commercial tilapia feed of different crude protein (CP) contents (30.0, 33.0, 38.0 and 40.0%), designated A, B, C and D respectively to produce an average of 5.0 g Nile tilapia, *Oreochromis niloticus* fingerlings was investigated. The declared CP contents were compared with analyzed figures. The study was carried out in hapa-in-pond system and it lasted 9 weeks. Analyzed CP contents were 30.6, 32.8, 36.5 and 38.1% for A, B, C and D respectively. Recorded final mean fingerling weights were 4.69 ± 1.92, 5.21 ± 2.11, 4.42 ± 1.94 and 5.47 ± 2.19 respectively, with B and D being significantly higher (Tukey's HSDT, $P<0.05$). The 30.0% CP content feed was recommended for Nile tilapia fingerling production, as it recorded the highest profitability index and the least incidence cost.

Keywords: Fish farming, hapa-in-pond system, incidence cost, profitability index

1. Introduction
Feed utilization by a culture fish and its subsequent growth depend on the nutritive value, particularly the crude protein content of the feed (Mahmud *et al*., 2012) [1]. Protein makes up the main component of fish tissue, and when culture fish are fed with the right dietary protein levels, the fish retain comparably high quantity of protein in the body, which is used for body growth (Vásquez-Torres *et al*., 2011) [2]. However, when culture fish are fed with feeds containing protein levels far above their needs, only part of the protein is effectively utilized in the body whilst the remaining is excreted in the form of ammonia which promotes water quality deterioration, reduces fish growth rate and increases production cost (Furuya and Furuya, 2010) [3]. Feeding culture fish with optimal protein level feeds has been reported as a possibility to avoid water quality deterioration and for economical fish production (Thomas *et al*., 1999) [4].
The protein levels in most commercial starter feeds for tilapia are often far above their needs, with most ranging between 40 to 58% (El-Sayed, 2004; Anani, 2015) [5, 6]. The costs of these feeds are very high as they strongly correlates positively with the crude protein contents of feeds. The high feed cost further compounds an overall increase in production cost. For optimum growth of Nile tilapia fingerlings, the estimated range has been 30 to 40% crude protein (Fitzsimmons, 2005; Lim and Webster, 2006) [7, 8].
There are varying crude protein contents of commercial tilapia feeds on the Ghanaian markets, with their prices being based on the declared crude protein contents by the producers. A unit increase in percentage crude protein contents of some of these feeds could attract as much as over 10% in price, although this may not reflect in the growth performance of the target fish. The protein contents of Nile tilapia fry feeds used by Ghanaian tilapia hatchery operators have not yet been standardized, although some farmers used feeds with crude protein contents of 40%, most farmers used feeds with higher levels. Since protein is the most expensive macronutrient in fish feeds and it determines the price per unit weight (kg) of the feed, it is imperative for tilapia hatchery operators to opt for the appropriate protein level of feeds for economic production of healthy fingerlings. For this reason, the present study was undertaken to investigate the profitability of using varying (30.0, 33.0, 38.0 and 40.0%) crude protein

contents of the most used commercial tilapia feed on the Ghanaian market for Nile tilapia, *Oreochromis niloticus* fingerling production, with the view of establishing which of the declared CP content feeds would be more profitable to use by tilapia hatchery operators in the country.

2. Materials and Methods

2.1 Study Area

The evaluation of the commercial tilapia feeds with varying crude protein levels was conducted at the Aquaculture Research and Development Centre (ARDEC) of Water Research Institute (WRI) of the Council for Scientific and Industrial Research (CSIR), Ghana. The area lies between latitude 6° 13′ North and the longitude 0° 4′ East at Akosombo in the Eastern Region of Ghana.

2.2 The Commercial Tilapia Feeds

The most commonly used commercial tilapia feed, *Raanan* by tilapia farmers in the country (Anani *et al*., 2017a) [9], was used for the study. Four (4) different declared crude protein levels (30, 33, 38 and 40%) designated A, B, C and D were procured at a fish feed retail shop near the study area. The feeds, which were originally in extruded pellet forms, were separately milled thoroughly using a maize milling machine into powdered forms and they were subsequently sieved through a 800 µm sieve to rid them of relatively large-sized particles (Anani *et al*., 2017a) [9].

2.3 Proximate Composition and Gross Energy of Feeds Determination

Proximate analyses of the feeds were carried out in triplicates following standard methods (AOAC, 2000) [10]. The gross energy contents of the feeds were computed using the average physiological fuel values of 23.64, 39.54 and 17.15 MJ kg^{-1} for protein, fat and carbohydrate respectively (Anani *et al*., 2017b) [11].

2.4 Experimental System and Fish

The feeding trials were carried out in twelve (12) netting hapas, each of dimensions 1.0 x 1.0 x 1.0 m. A monofilament nylon gill net of stretched mesh size 30.0 mm was sewn over each of the hapas to keep predatory animals such as birds and frogs from injuring or picking/eating the experimental fish (Anani *et al*., 2017b) [11]. The hapas were mounted in a 0.2 hectare earthen pond which was supplied with water from the Volta Lake to a mean height of about 1.4 ± 0.2 m; and each hapa was separated from others by about 6 m distance (Anani *et al*., 2017b) [11].

A cohort of mixed-sex swim-up Nile tilapia fry produced by parents of the tenth (10) generation of the *Akosombo Strain* of the Nile tilapia developed by CSIR-WRI at ARDEC, Akosombo through selective breeding were used for the study. The fry, at an initial mean weight of 0.03 ± 0.00 g, were stocked at a density of 50 fry m^{-2} in each of the 12 hapas.

2.5 Feeding Schedule

Feeds of each crude protein level were randomly assigned to three hapas and feeding of the experimental fish commenced the day after they were stocked. All the fishes under each treatment were manually fed at 20% of their body weight (biomass) five times (between 0800-0830, 1000-1030, 1200-1230, 1400-1430 and 1600-1630 GMT) daily throughout the culture period.

2.6 Water Quality Determination

Water quality parameters [temperature, dissolved oxygen (DO), pH, nitrite, total ammonia and total alkalinity] in the experimental hapas and the open pond water were determined weekly. Water temperature was measured with a thermometer and DO was measured with oxygen meter (YSI Environmental model no: DO 200), whilst pH with a pH meter (HANNA model no: HI 98128). Nitrite and total ammonia were measured using a spectrophotometer (UV mini-1240). Total alkalinity was measured using a digital titrator (HACH).

2.7 Fish Growth Measurements

The weights of all surviving fish in each hapa under each treatment were measured weekly. The total weight of fish in each hapa under each treatment was computed and subsequently the quantity of each feed type for each fish group was adjusted accordingly. The feeding of the fish continued until those in any feed treatment and all its replicates attained a mean weight of at least 5.0 g. Then the experiment was terminated and all the survived fish in each treatment were harvested, counted, and their individual body weight was measured.

2.8 Determination of Performance Indicators

The mean specific growth rate (MSGR), daily mean weight gain (DMWG), mean feed intake (MFI), mean feed conversion ratio (MFCR), mean feed efficiency (MFE) and mean survival rate (MSR) were computed as follows:

i. $$\text{MSGR} = 100 \times \frac{\text{In (final mean body weight)} - \text{In (initial mean body weight)}}{\text{Number of days reared}}$$

Where In = Natural logarithm

ii. $$\text{DMWG (g day}^{-1}\text{)} = \frac{\text{Final mean body weight (g) - Initial mean body weight (g)}}{\text{Number of days reared}}$$

iii. $$\text{MFI (g fish}^{-1}\text{)} = \frac{\text{Mean total feed fed (g)}}{\text{Total number of harvested fingerlings}}$$

iv. $$\text{MFCR} = \frac{\text{Mean total feed fed (g)}}{\text{Mean total live weight gain (g)}}$$

v. $$\text{MFE (\%)} = \frac{\text{Meant total live weight gain}}{\text{Mean total feed fed}} \times 100$$

vi. $$\text{MSR (\%)} = \frac{100 \times \text{Final mean total number of fingerlings}}{\text{Initial mean total number of fry}}$$

2.9 Profitability Analysis

The profitability of the various feeds used in the tilapia fingerlings production was determined by computing the following indices:

2.9.1 Incidence Cost (IC)

$$\text{IC} = \frac{\text{Cost of feed used (GHS)}}{\text{Weight of fingerlings produced (kg)}}$$ (Anani and Agbo, 2019) [12]

$$\text{PI} = \frac{\text{Value of fingerlings produced (GHS)}}{\text{Cost of feed used (GHS)}}$$ (Anani and Agbo, 2019) [12]

The value of fingerlings produced and costs of feeds used were computed based on market prices in Ghana Cedis (GHS) and their equivalent amount in US Dollars (US$) as pertained in the study area during the study period. Only the costs of the various feeds were considered, as those of others such as hapas and labour were constant.

2.10 Data Analyses
All data on the various parameters were tested for normality using the Kolmogorov-Smirnov test and homogeneity using the Levene's test so as to determine if the data were normally distributed and the variances were homogeneous. All percentages and ratios were arcsine transformed to normalize the data before analyzes (Zar, 2010) [13]. Statistical analyses were carried out using one-way analysis of variance (ANOVA) to test differences among the various parameters of feed treatments. Tukey's honest significant difference test (Tukey's HSDT) was used to identify specific differences between pairs of treatments. Differences were regarded as significant when $P \leq 0.05$.

3. Results and Discussions
3.1 Comparison of declared and analyzed Crude Protein and Lipid Contents of the feeds
The declared and the analyzed crude protein and lipid contents of the various feeds are shown in Table 1. The figures for chemical analyses of the crude protein contents of three of the feeds (B, C and D) showed negative deviations from the expected. The mean deviation was 2.8 ± 1.9 with D (40.0% CP) showing the highest (-4.8%) whilst B (33.0% CP) showed the least (-0.6%).

Table 1: Percentage deviations of the observed from the expected crude protein and lipid contents, gross energy and prices per kilogramme of the various commercial tilapia feeds

Parameter	Attribute	Feed			
		A (30.0%)	B (33.0%)	C (38.0%)	D (40.0%)
Crude protein (%)	Declared	30.0	33.0	38.0	40.0
	Analyzed	30.6	32.8	36.5	38.1
	Deviation	+2.0	-0.6	-3.9	-4.8
Crude lipid (%)	Declared	5.0	6.0	6.0	7.0
	Analyzed	2.2	2.5	3.5	3.4
	Deviation	-56.0	-58.3	-41.7	-51.4
Gross energy (kJ g^{-1})		15.98	15.93	16.32	16.46
Price (GHS kg^{-1})		3.75	3.85	4.30	5.50

The exchange rate of the Ghana cedis (GHS) to the USA dollar (USD) in 2018, during the period of the study was on the average: GHS 4.43 = 1.00 USD

The results of this study agreed with those of Ayuba and Iorkohol (2013) [14]. In their study of analyses of crude protein contents of four commercial fish feeds (*Adolf calyx*, *Coppens*, *Dizengoff* and *Durate*), these researchers observed that all the analyzed figures on crude protein contents were less (ranging from 0.7 to 38.4%) than the producers' declared figures. On the other hand, similar analyses carried out by Opiyo *et al*. (2014)[15] revealed that three commercial fish feeds which were indicated to contain 26.0% crude protein each, feeds 1, 2 and 3 had crude protein levels of 32.7%, 16.0% and 28.0% respectively. The differences between the analyzed and declared figures were attributed to inconsistent proximate analysis of ingredients before feed formulation and production (Opiyo *et al*., 2014) [15]. Variations in nutritional value of feed ingredients could also be due to regionalism and seasonality in availability of the ingredients (Munguti *et al*., 2012) [16]. For this reason, feed producers need to carry out routine proximate analyses particularly when a new batch of fish feed ingredients is procured and more so when the sources of such ingredients varied.

In the current study, the analyzed lipid figures (2.2 to 3.5%) in all the feeds were lower than the declared figures (5.0 to 7.0%), with a mean deviation of 51.85 ± 7.35%. The recorded figures were less than the 5-6% dietary lipid levels stated by Luquet (2000) [17] as often used in commercial tilapia feeds. The gross energy contents of the feeds were similar and the figures ranged from 15.93 to 16.46 kJ g^{-1}.

A unit (1 kg) cost of the feeds ranged from 3.75 to GHS 5.50 with the least protein content feed, A (30.0% CP) being least expensive whilst that of the highest protein content, D (40.0% CP) being most expensive. These prices are highly unstable as they are affected by the exchange rate of the local currency to the USA dollar.

3.2 Water Quality
Water quality parameters recorded during the feeding trials indicated that temperature ranged from 27.2 to 33.4 °C, pH ranged from 5.61 to 7.20, DO ranged from 3.7 to 8.8 mg L^{-1}, Nitrite ranged from 0.011 to 0.016 mg L^{-1}, Total Ammonia ranged from 0.42 to 0.67 mg L^{-1} and Alkalinity from 71.0 to 89.0 mg L^{-1}. The mean figures were 30.4 ± 0.02 °C , 6.38 ± 0.28, 6.3 ± 1.2 mg L^{-1} , 0.010 ± 0.003 mg L^{-1}, 0.53 ± 0.07 mg L^{-1} and 83.0 ± 0.6 mg L^{-1} for Temperature, pH, DO, Nitrite, Total Ammonia and Alkalinity respectively. There were no significant differences (ANOVA, $P>0.05$) among measured water quality parameters within and among the various treatments and the open pond water, and all recorded figures were within the suitable ranges for *O. niloticus* (Hussain, 2004; Swann, 2007) [18, 19].

3.3 Growth performance of Nile Tilapia fry based on Crude Protein levels
The target mean weight of ≥ 5.0 g was attained at the end of the ninth week (Figure 1). Both B (33.0% CP) and D (40.0% CP) recorded mean figures greater than 5.0 g whilst those of A (30.0% CP) and C (38.0% CP) recorded less.

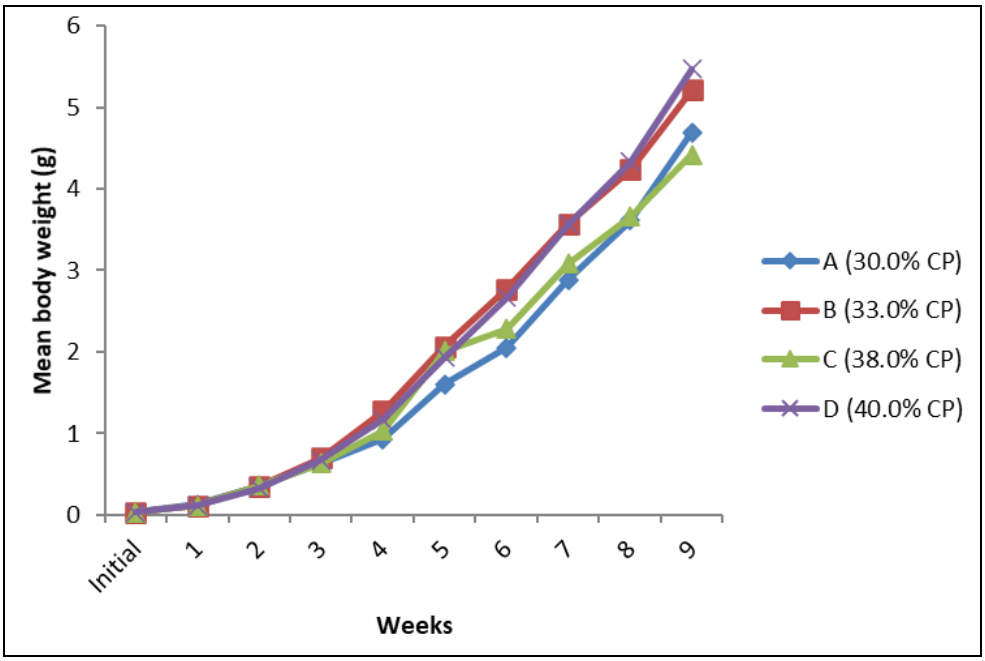

Fig 1: Growth performance of Nile tilapia fry fed with a commercial feed of four different crude protein levels for 9 weeks

Growth was slow from the first to the third week in all the feed treatments. However, growth peaked after the fourth week in all the treatments, but highest in fry fed with B and D till the ninth week. Fry fed with D recorded the highest final mean weight of 5.47 g whilst those fed with A gave the least of 4.42 g.

The computed growth performance and feed efficiency indices are shown in Table 2. The final mean weight gains were significantly higher (Tukey's HSDT, $P<0.05$) in B and D. Highest (5.44 g) mean weight gain was recorded in fingerlings fed with D whilst the least (4.39 g) was recorded in those fed with C. There were no significant differences ($P>0.05$) in feed intake, specific growth rate, mean daily weight gain, feed conversion ratio, survival rate and harvested biomass among the feeds. This suggests that these parameters were not affected by differences in crude protein levels. The results of this study disagreed with Sumi *et al*. (2011) [20], who reported that feed containing at least 35% protein level would be appropriate for the production of *O. niloticus* fingerlings.

Table 2: Growth performance of *O. niloticus* fry fed with commercial tilapia diets of varying crude protein contents for 9 weeks

Parameters	Feed			
	A (30% CP)	B (33% CP)	C (38% CP)	D (40% CP)
Initial mean weight (g)	0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00
Final mean weight (g)	4.69 ± 1.92^{a}	5.21 ± 2.11^{b}	4.42 ± 1.94^{a}	5.47 ± 2.19^{b}
Mean weight gain (g)	4.66 ± 1.92^{a}	5.18 ± 2.11^{b}	4.39 ± 1.94^{a}	5.44 ± 2.19^{b}
Mean feed intake (g fish^{-1})	17.65 ± 6.49	18.04 ± 2.42	15.61 ± 2.29	17.53 ± 1.60
Mean specific growth rate (% day^{-1})	8.04 ± 0.17	8.19 ± 0.15	8.19 ± 0.15	8.26 ± 0.11
Daily mean weight gain (g day^{-1})	0.08±0.01	0.08±0.01	0.07±0.01	0.09±0.01
Mean feed conversion ratio	3.79 ± 0.99	3.48 ± 0.17	3.56 ± 0.11	3.22 ± 0.25
Mean survival rate (%)	72.67 ± 20.03	68.00 ± 4.00	78.67 ± 19.63	72.67 ± 5.03
Mean harvested biomass (g)	170.2 ± 39.55	177.07 ± 5.72	173.53 ± 29.50	198.73 ± 0.46

Figures are means ± standard deviations of three replicates. Means within the same row with different superscripts are significantly different (Tukey's HSDT, $P<0.05$)

3.4 Profitability of using the different Crude Protein level feeds

Generally, there were no significant differences (ANOVA, $P>0.05$) in computed economic performance parameters among the feeds (Table 3). The costs of the various feeds which were based on their crude protein levels affected the price worth of the fingerlings produced and hence, the overall production costs. Incidence cost ranged from 13.90 to 15.80 GHS with the least value occurring in A (30.0% CP). The profit indices ranged from 3.14 to 4.75 with the highest recorded in A.

Table 3: Economic analyses of varying crude protein feeds fed to *Oreochromis niloticus* fry

Parameters	Feed			
	A (30.0%)	B (33.0%)	C (38.0%)	D (40.0%)
Incidence Cost (GHS kg^{-1})	13.90±6.62	15.33±0.72	15.80±0.50	15.67±1.24
Profit Index	4.75±2.07	3.38±0.46	3.83±0.56	3.14±0.29

There were no significant differences among values within each row, $P>0.05$.

The exchange rate of the Ghana cedis (GHS) to the USA dollar (USD) in 2018, during the period of the study was on the average: GHS 4.43 = 1.00 USD

4. Conclusion

The results of the current study indicated that although Nile tilapia fry fed with feeds of crude protein levels 33.0 and 40.0% attained the targeted mean weight of ≥ 5.0 g at the end of the ninth week culture period, the use of the 30.0% crude protein level of the commercial feed to produce Nile tilapia fingerlings is recommended as it gave the best economic performance in terms of production cost and profitability.

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