International Journal of Fisheries and Aquatic Research
ISSN: 2456-7248
Impact Factor: RJIF 5.44
www.fishjournals.com
Volume 3; Issue 1; January 2018; Page No. 09-15

Health condition and proximate composition of Nile tilapia (*Oreochromis niloticus* L.) fed with tilapia grower diets of commercial, farm-made and their 1:1 mixture

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Abstract
To ensure production of healthy and good quality fish, cultured fish must be fed with nutritionally balanced diet that meets the fish's nutritional requirements. Fish health condition using the health assessment indices (HAIs) and the proximate compositions of Nile tilapia, *Oreochromis niloticus* fed with a tilapia grower diet of commercial, farm-made and their 1:1 mixture in hapa-in-pond system for 140 days were investigated. The recorded HAIs were 0 for all structures examined and 0 to 1 for gut fat. There were general increases in protein and ash contents of *O. niloticus* fed with the various diets and the lipid contents of fish in all the dietary treatments were less than 5% at the end of the feeding trials. The cultured fish fed with the various diets (commercial, farm-made and their 1:1 mixture) were in good health condition and their proximate compositions were within the nutritional range required by humans.

Keywords: farm-made and commercial tilapia diets, health assessment index, health condition, nile tilapia, proximate composition

Introduction

Deficiency signs of farmed tilapia may occur when fish are fed nutrient deficient diets or raised in a low nutrient-input culture system [1]. Essential amino acid (EAA) deficiency in tilapia generally leads to loss of appetite, retarded growth, and poor feed utilization efficiency. In some fish species (e.g. rainbow trout, sockeye salmon, Atlantic salmon, chum salmon, coho salmon), lysine, methionine or tryptophan deficiency results in various signs such as scoliosis, lordosis, fin erosions and cataracts although none of these deficiency signs have been reported for tilapias [2]. Similar to EAA deficiency, the lack of essential fatty acids (EFAs) would also lead to loss of appetite and poor growth in tilapia. Other reported signs of EFA deficiencies in Nile tilapia include swollen pale and fatty livers [3].

Mineral deficiencies are difficult to assess in tilapia as most trace elements are obtained both from the dietary ingredients and from the culture water [1]. Under culture conditions, vitamin deficiency signs are not a common occurrence in tilapia [4, 5, 6]. In fact, several studies have reported on the "non-essentiality" of adding vitamin premixes to tilapia diets [4]. Vitamins obtained from natural food in fertilized ponds, endogenous vitamins present in feed ingredients used in tilapia diets and the microbial biosynthesis of some vitamins in the gut are all likely to contribute significantly to the vitamin requirements of cultured tilapia.

The main components of the edible portion of fish are water (moisture), protein, lipid (fat or oil) and ash (minerals). Chemical analyses of these basic constituents are often referred to as proximate analyses [7]. Proximate composition of fish flesh generally indicates the fish quality. Hence, information on proximate composition of fish is necessary to assess its nutritional and edible values [8, 9]. It has been well established that fishes from both fresh water and marine environments have varied proximate compositions of whole body and various body parts [10].

The nutritional composition of cultured fish is generally dependent on the diet it is fed with, although other factors such as age, feeding frequency, sex, temperature, spawning, water quality, cultured medium and the culture period may also play a role [10, 11]. There are, therefore, a number of variables that can affect the overall proximate composition of fish flesh. Visual evaluation of fish based on its general physical appearance such as size and freshness may not give appropriate nutritional information about the fish. Therefore, it is necessary for chemical analysis of fish flesh to be carried out so as to determine its nutritional value and quality [12].

Most commercial fish diets are supplemented with different supplements including growth hormones at varying inclusion levels so as to achieve optimum growth within the shortest possible time period. These, together with the type of feed ingredients and their inclusion levels in the diets may affect the health status as well as the nutritional quality of fish the diets are fed with.

The Nile tilapia, *Oreochromis niloticus* is the most widely cultured tilapia [13]. Traditionally, *O. niloticus* was cultured at low stocking densities in freshwater ponds and fed mainly with supplemental feeds such as cereal brans. However, the intensification of the fish culture practices in recent times requires the use of nutritionally balanced formulated diets [14]. Fish diet has been widely recognized as the most expensive component of the operational cost in fish farming [15, 16, 17]. Farm budget analyses show that fish diet constitutes 60-70% of total production cost of *O. niloticus* for small-scale rural farmers [18].

In many countries, where fish farming is conducted at semi-intensive culture level, more than 90% of the farmers use farm-made feeds in order to reduce production cost [19]. The use of nutritionally balanced diets constitutes an unwise use of resources and economically unsound practices in semi-intensive aquaculture where external feed input is expected to supplement natural food production [20, 21]. Hence, the development and management of fish feed play an essential part in aquaculture development, growth and expansion. Undeniably, it is the main factor that determines the profitability of aquaculture venture [22].

The major challenge facing small-scale pond fish farmers is the ability to formulate and prepare nutritionally balanced and cost-effetive farm-made fish diets using locally available feed ingredients [23]. This has resulted in most of these farmers feeding cultured fish with highly deficient nutrient feeds including raw agro-industrial by products. In an attempt to reduce cost of fish production, some small-scale pond fish farmers alternate the use of commercial fish diets with farm-made ones whilst others, in their attempt to improve upon the quality of on-farm made fish feed, mix it with an equal amount of commercial fish diet to feed cultured fish [23]. Other farmers depend on the farm-made type alone. Therefore, the objectives of the present study were to determine the health condition and proximate compositions of *O. niloticus* fed with a commercial tilapia grower diet, a farm-made diet and their 1:1 mixture.

Materials and Methods

Study area

The study was carried out at the Aquaculture Research and Development Centre (ARDEC) of Water Research Institute (WRI) of the Council for Scientific and Industrial Research (CSIR), Ghana (6^0 13′ N; 0^0 4′ E) at Akosombo in the Eastern Region of Ghana.

Experimental system

Fish growth study was carried out in nine (9) 5.0 x 2.0 x 1.2 m (i.e. length, width and height) mosquito netting hapas mounted in a 0.2 hectare earthen pond at ARDEC, Akosombo. The hapas were suspended to bamboo poles by means of nylon twine and the former were inserted in the bed of the pond. A monofilament nylon gill net of stretched mesh size 30.0 mm was sewn over the hapas as a cover and an opening was left at one end of the 2 m side so as to allow input and collection of fish during stocking, measurements and harvest [24]. The cover net was to keep predatory birds from injuring or picking the experimental fish and also to prevent the fish from jumping out as they grow bigger. The pond was supplied with water from the Volta Lake to a mean height of about 1.4 ± 0.2 m.

Each hapa was separated from others by about 6 m distance to avoid easy drifting of contents of one system into another and also to enhance easy water exchange [25]. About two-thirds (0.8 m) of the hapa heights were constantly submerged in the pond water by ensuring periodic topping up of the water when the level fell due mainly to evaporation and seepage.

Water quality parameters

Water temperature, dissolved oxygen (DO), total ammonia and pH were measured at the commencement and fortnightly both in the hapas and in the open pond water throughout the culture period. Water temperature was measured with a thermometer whilst DO was measured with oxygen meter (YIS Environmental model no: DO 200). Total ammonia was measured using a spectrophotometer (UV mini-1240) and pH with a pH meter (HANNA model no: HI 98128). All parameters were measured at mid-water-depth and measurements were carried out between 0700 to 0800 GMT.

Fish stocking, feeding, growth monitoring and harvesting

Mono sex male *O. niloticus* known as the “Akosombo Strain” developed by CSIR WRI at ARDEC, Akosombo through selective breeding was used in the study. At the commencement of the feeding trials, 3 fish were taken at random and sacrificed for their proximate composition analyses. A total number of one hundred and eighty (180) of the fish, with an initial mean weight 22.8 ± 2.1 g were randomly divided into three groups of 20 fish (three treatments in triplicate) and stocked at a density of 2 fish m^{-2} in the hapas, each of operational volume of about 8.0 m^3. The fish were fed under three dietary treatments (a commercial type, a farm-made type and their 1:1 mixture) at 4-3 % body weight three times a day (between 0800-0830, 1200-1230 and 1600-1630 GMT) throughout the week including weekends for a 140-day growth period.

The standard length (SL), total length (TL) and weight of all the fish in each hapa under each dietary treatment were measured fortnightly using fish measuring board (0.1 cm) and digital weighing balance (0.1 g) respectively. A bamboo pole was used at the opposite sides of the longer side of each hapa, starting from the bottom of the sewn end of the cover; the pole was drawn to confine the fish at the open end of the cover. All the fish were then netted and put into a large bowl containing pond water. The hapas were cleaned with pond water to ensure water circulation. The total number of fish was recorded. Each fish was gently blotted on a soft towel so as to remove excess water from the body. Then the SL and TL were measured followed by the weight. Each fish was then returned into a bowl containing fresh pond water. After measuring the lengths and weights of all the fish in each hapa, they were put back into their respective hapas.

The total weight (biomass) of fish in each hapa under each dietary treatment was determined, and then the quantity of each diet type for each fish group was adjusted accordingly. The culture period lasted for 140 days (20 weeks). The day following the 140th day, all the fish from each treatment were harvested and counted individually to determine the final survival. Fifty per cent (50%) of survived fish were selected at random from each dietary treatment for health profile assessments whilst a sample of 9 harvested fish (3 from each treatment) was taken to determine their proximate compositions.

Fish health profiles assessments

The health profiles of the randomly selected fish were assessed by examining them for external and internal abnormalities following the method by [26]. For the purpose of data analysis, the abnormalities were converted to a numerical health assessment index (HAI) based on a modification of [27, 28], and their health profiles were taken using the score sheet described in Table 1. A higher HAI represents a higher incidence and severity of abnormalities.

Table 1: Criteria and numeric ratings used at the end of the culture period for fish health assessments of Nile tilapia fed with a commercial, a farm-made and their 1:1 mixed tilapia grower diets (based on [26, 27, 28])

Structure or tissue	Rating criteria	Numeric rating
Eyes	Normal	0
	Abnormal	1
Fat	None	0
	<50 % of gut covered	1
	>50 % of gut covered	2
	100 % of gut covered	3
Fins	No erosion	0
	Light erosion	1
	Moderate erosion	2
	Severe erosion	3
Gills	Normal	0
	Clubbed, frayed or discoloured	1
Gut	Normal	0
	Slight inflammation	1
	Moderate inflammation	2
	Severe inflammation	3
Kidney	Normal	0
	Abnormal	1
Liver	Normal	0
	Abnormal	1
Pseudobranchs	Normal	0
	Abnormal	1
Opercles	Normal	0
	Short	1
Spleen	Normal	0
	Cysts or enlarged	1

Source: Adapted from [29].

Proximate composition determination

The proximate composition analyses of the fish specimen were carried out in triplicates following standard methods [30]. The protocol was applied in the determination of the percentage (%) dry matter (DM), % crude protein (CP), % ash, % crude lipid (CL) also known as ether extracts (EE) and % crude fibre (CF). Moisture content was estimated by drying samples in a thermostat oven at 105 °C for 24 hours. The difference between the initial and final weights after drying gave the moisture content whilst the final weight was that of the DM. The total nitrogen content of each sample was determined by the Kjeldahl method and a factor of 6.25 was used to convert the total nitrogen to CP contents of the fish samples. Ash was determined by burning dry samples in a muffle furnace at 550 °C for 4-5 hours. The Soxhlet extraction method was used to determine the CL contents of the samples whilst CF was determined by acid/alkaline digestion, then the dry residue was burnt at 550 °C in a muffle furnace for 4 hours. Percentage Nitrogen-free extract (% NFE) was computed using the formula: % NFE = % DM - (% CP + % Ash + % CL + % CF). The gross energy contents of the fish was computed by using the average physiological fuel values of 23.64, 39.54 and 17.15 MJ kg-1 for protein, fat and carbohydrate respectively [31].

Data analyses

All data were analyzed using the SPSS (version 21) statistical analysis program (SPSS, Chicago, Illinois). Data on water quality, health assessment and carcass traits were tested for normality using the Kolmogorov-Smirnov test and homogeneity using the Levene's test. Statistical analyses of data on carcass traits and water quality were carried out using one-way analysis of variance (ANOVA). Tukey's honest significant different test was used to identify specific differences between pairs of treatments. Health assessment data was analyzed using a Kruskal–Wallis test. Significance for all analyses was predetermined at $P \leq .05$.

Results

Water quality analyses

The values recorded for the selected water quality parameters for the various dietary treatments and the open pond water indicated that temperature ranged from 27.6 to 29.8 °C, dissolved oxygen (DO) ranged from 3.50 to 5.40 mg L^{-1}, pH ranged from 6.95 to 7.47 and total ammonia ranged from 0.51 to 0.61 mg L^{-1} (Table 2). The mean values were 28.9 ± 0.02 °C, 4.53 ± 0.15 mg L^{-1}, 7.22 ± 0.05 and 0.35 ± 0.01 mg L^{-1} for temperature, DO, pH and total ammonia respectively. There were no significant (ANOVA, $P > .05$) differences among the water quality parameters within and among the various dietary treatments and the open pond water.

Table 2: Range and mean values (± Standard Deviation, SD) of water quality parameters recorded in the various dietary treatments and the open pond water during the study period

Parameter	Range	Mean (± SD)
Temperature (°C)	27.6-29.8	28.9 ± 0.02
DO (mg L^{-1})	3.50-5.40	4.53 ± 0.15
Total ammonia (mg L^{-1})	0.51-0.61	0.35 ± 0.01
pH	6.95-7.47	7.22 ± 0.05

Health condition of *O. niloticus* fed with *Raanan*, farm-made and their 1:1 mixture diets

The health assessment indices (HAIs) of *O. niloticus* were low in all the dietary treatments. There were no abnormalities observed in the eyes, fins, gills, guts, kidneys, livers, pseudobranchs, opercles or spleens in any of the fish fed with the various diets (Table 3). Abdominal fat covered less than half of the viscera in almost all the fish examined in the various dietary treatments and the values ranged from 0.33 to 0.93. Generally, the least gut fat content was observed in the fish fed with the mixed diet and the mean value obtained was significantly lower (Tukey's HSDT, $P < 0.05$) than that of the commercial and the farm-made diets.

Table 3: Fish health assessments of Nile tilapia fed with a commercial, a farm-made and their 1:1 mixed diets

Variables	Diet		
	Commercial	Farm-Made	Mixture
Eyes	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Fat	0.9 ± 0.4^{a}	0.9 ± 0.7^{a}	0.3 ± 0.5^{b}
Fins	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Gills	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Gut	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Kidney	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Liver	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Pseudobranchs	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Opercles	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Spleen	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

Means with different letters across a row are significantly different ($P < 0.05$) whilst absence of letters indicates no significant difference ($P > 0.05$)

Proximate composition of *O. niloticus* fed with a commercial, a farm-made and their 1:1 mixture diets

The results of the whole body proximate compositions of *O. niloticus* at the commencement and end of the culture period showed that there was no significant (ANOVA, *P* >. 05) differences in whole body moisture contents among all the dietary treatments (Table 4). The observed values ranged from 75.61 to 76.26%, and they were lower than the initial whole body moisture composition of the experimental fish. There were general increases in protein, ash and energy contents of the flesh of *O. niloticus* at the end of the feeding trials.

Table 4: Initial and final whole body proximate composition (% mean ± SD) of cultured Nile tilapia

Constituent	Initial	Commercial	Farm-made	Mixture
Moisture	81.21 ± 0.16	75.65 ± 0.60[a]	75.61 ± 1.06[a]	76.26 ± 0.23[a]
Protein	12.49 ± 0.42	17.87 ± 2.96[a]	16.37 ± 5.18[a]	16.20 ± 4.63[a]
Fat	3.51 ± 0.06	3.14 ± 0.40[a]	4.20 ± 0.37[b]	3.04 ± 0.59[a]
Carbohydrate	0.94 ± 0.63	1.42 ± 2.94[a]	1.73 ± 5.22[a]	2.53 ± 4.33[b]
Ash	0.75 ± 0.36	1.85 ± 0.28[a]	1.96 ± 0.26[b]	1.90 ± 0.28[b]
Gross Energy	4.50 ± 0.03	5.71 ± 0.12[a]	5.83 ± 0.31[a]	5.47 ± 0.21[a]

Values are means ± SDs of three replicates. Values within the same row with dissimilar letters are significantly different (Tukey's HSDT, *P* <. 05)

The various constituents of Nile tilapia for each dietary treatment are compared in Figures 1 to 6.

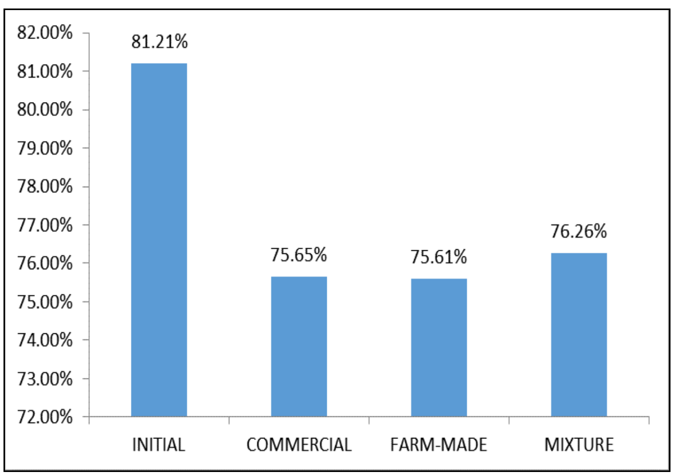

Fig 1: Moisture contents of Nile tilapia fed with the various diets

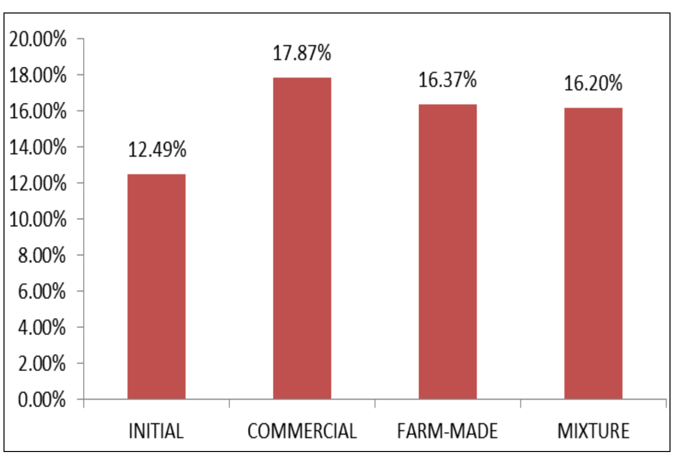

Fig 2: Protein contents of Nile tilapia fed with the various diets

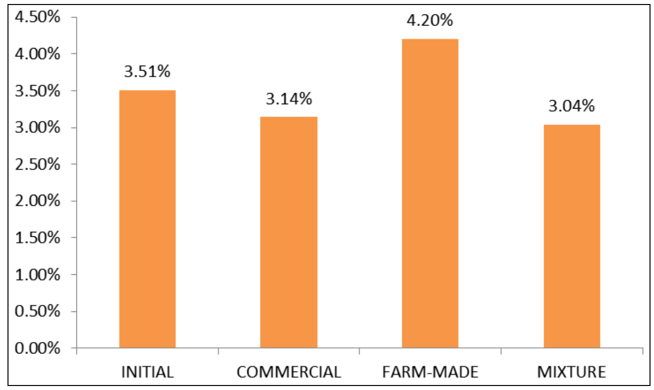

Fig 3: Fat contents of Nile tilapia fed with the various diets

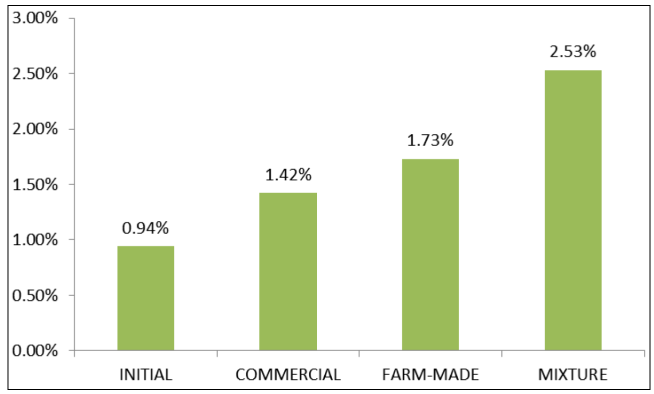

Fig 4: Carbohydrate contents of Nile tilapia fed with the various diets

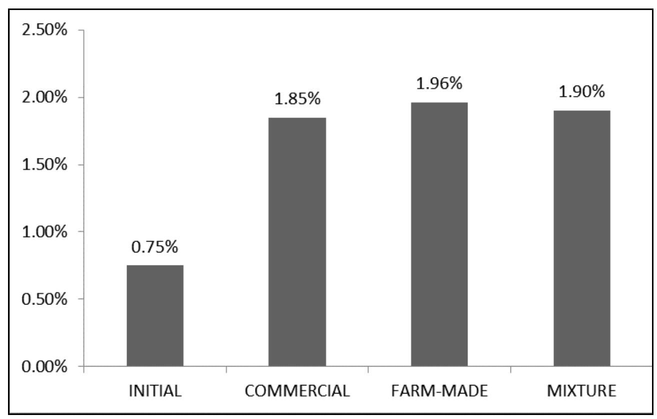

Fig 5: Ash contents of Nile tilapia fed with the various diets

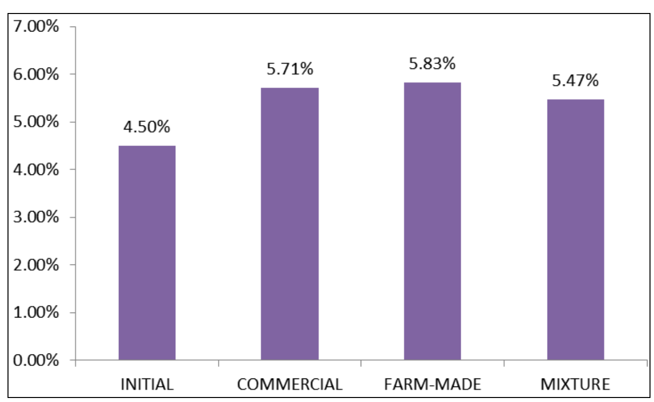

Fig 6: Gross energy contents of Nile tilapia fed with the various diets

Discussion
Water quality and fish health condition
All recorded values for water quality parameters in the present study were within the suitable ranges for *O. niloticus* [32, 33]. The expected impact of uneaten diet and waste from fish excreta caused no any noticeable water deterioration during the study. Hence, dietary treatment did not impact negatively on the quality of water in the culture systems as values observed were comparable with those of the open pond water.
An elevated health assessment index (HAI) has been related to contaminant exposure and associated decreased growth and condition in other studies [27, 34]. In the present study, the observed HAIs for *O. niloticus* were zero (0), indicating normality in structures examined, except for gut fat that recorded 0 and 1 in all the dietary treatments. The good water quality parameters recorded in all the dietary treatments coupled with the good nutritional quality of the experimental diets could account for the low HAIs observed. This observation agreed with findings of [24]. A study carried out by these researchers on the length-weight relationship and the condition factor of *O. niloticus* fed with a farm-made tilapia grower diet (*Ardecfeed*) and two commercial types (*Raanan* and *Coppens*) indicated that all the diets were suitable for commercial production of *O. niloticus* as the cultured fish were found to be in good condition [24].
Deficiency signs of farmed tilapia may occur when fish are fed nutrient deficient diets or raised in a low nutrient-input culture system [1]. Since no deficiency signs were observed in any of the fish of the various dietary treatments, it suggests that all the diets (the commercial, the farm-made and their 1:1 mixture) used in the current study were not deficient in nutrients.
Absence of both external and internal abnormalities in *O. niloticus* in all the dietary treatments could also be attributed to the quality control measures that were applied to the diets which prevented them from being infested with aflatoxin. A study showed that *O. niloticus* fingerlings were able to tolerate immediate effect of aflatoxin but later the fish developed external and internal abnormalities [35]. External manifestations of abnormality in fish fed with aflatoxin contaminated diets were eye opacity leading to cataract and blindness, lesions on the body surface, fin and tail rot, yellowing of the body surface of the fish, abnormal swimming, feeble and stationary on one place, and reduced appetite [35]. These manifestations became more intense as aflatoxin level in the diet increased. Observed manifestations of aflatoxin in the liver of fish were abnormal enlargement and yellowing as well as collapsed liver in newly dead fish [36, 37].

Proximate compositions
The proximate compositions of *O. niloticus* in all the dietary treatments in the current study were in the range of values reported by [38] when the fish was fed with different feed types. The results of their study indicated that proximate compositions of *O. niloticus* were affected by the diet it was fed with. This agrees with the findings of [39] that the composition of fish flesh is dependent on the composition of the feed the fish feeds on as well as the environmental conditions.
The range of moisture contents (75.61-76.26%) recorded in *O. niloticus* fed with the various diets in this study fell within values 70-80% being the general live weight whole body moisture composition of fish [40]. The results of this study agreed with the observations made by [41] that larger fish contain lower amount of moisture than those of smaller ones since the initial moisture content (81.21%) of the experimental *O. niloticus* before the feeding trials was higher than values recorded in any of the dietary treatments after the study. This suggests that moisture contents in the fish decreased as the fish grew larger to produce more dry matter resulting in increase in the various nutrients, particularly protein and ash as observed in the current study. The range of moisture content values observed in the current study were also in conformity with those (72.18-83.65%) recorded for twenty seven (27) freshwater fish species [42].
In the current study, there was significant increase in protein contents of *O. niloticus* in all the dietary treatments in comparison with that of the initial content of the experimental fish. This indicated that the protein to energy ratio for each diet was appropriate as sufficient amount of protein was spared for growth. Similar results were reported by [43] in *T. zillii*, [44] in rohu, [45] in Nile tilapia. The range of protein contents (16.20-17.87%) recorded in all the dietary treatments in this study agreed with that of others [46]. Reported a range of 13- 20%, [47] recorded a range of 15-18% in freshwater fish species whilst [48] also observed a range of 9-25% protein contents in freshwater and marine fish species.
In the present study, the percentages of fat in all the dietary treatments were less than 5%. This suggests that the *O. niloticus* produced in all the dietary treatments were lean based on the 5% fat composition criteria for discriminating lean fish from fatty one [49]. The low fat contents (3.04-4.20%) observed in the body compositions of *O. niloticus* in the various dietary treatments were also supported by the low HAIs (0.3-0.9) recorded for the gut fat contents in all the dietary treatments. The observed value range was similar to 3.46 - 4.12% recorded by [50] when *O. niloticus* was fed with a farm-made diet, commercial diet and live feed. The low fat contents might be as a result of the combined effects of the culture environment, species and the type of diets the fish were fed with.
The ash content of a food item indicates the presence of various minerals such as calcium, phosphorus, potassium, zinc, iron and magnesium [51, 52, 53]. Hence, the range (1.85-1.96%) of ash contents which were more than twice the initial value (0.75%) of the experimental fish before commencement of the feeding trials, suggests that the cultured fish in all the dietary treatments were good source of minerals.

Conclusion
The use of the commercial, the farm-made and their 1:1 mixed tilapia grower diets to feed *O. niloticus* did not result in any noticeable negative health condition in the present study. The harvested fish were in good health and condition. The nutritional compositions of the cultured fish were within the nutritional range required by humans. Hence, all the diets were appropriate for the production of *O. niloticus*.

Acknowledgement
The authors are most grateful to Bernard Akpakli and

Elizabeth Akoto, National Service personnel as well as all the farmhands at the CSIR WRI, Aquaculture Research and Development Centre (ARDEC), Akosombo, Ghana, for their immeasurable support during the study.

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