



Growth Performance and Nutrient Utilization of Nile Tilapia (*Oreochromis niloticus*) Fed Processed Duckweed (*Lemna paucicostata*) Meal as Protein Source

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Abstract

Growth performance and nutrient utilization of Nile tilapia (*Oreochromis niloticus*) fed processed duckweed (*Lemna paucicostata*) meal were evaluated. Blanching and sun-drying were employed as the processing methods. The blanched and sun-dried duckweed meals were used to replace toasted soybean meal in the diets of Nile tilapia at 25%, 50%, 75%, and 100% each. Nine iso-proteinous diets were formulated using the least cost feed formulation software. The feeding trials were conducted in 27 Hapa nets measuring 1m² each for 24 weeks. Ten fingerlings of Nile tilapia were stocked per Hapa and fed three times daily at 5% biomass. The fish fed 75% blanched duckweed meal had the best mean weight gain (460.59g), feed conversion ratio (1.82) and protein efficiency ratio (12.67) while the fish fed 100% inclusion level of sun-dried duckweed meal and 100% of blanched duckweed meal diet had the poor mean weight gain, feed conversion ratio and protein efficiency ratio of 401.69g and 394.03g, 2.06 and 2.10, 11.05 and 10.37, respectively. This study revealed that blanched duckweed meal can replace toasted soybean meal in the diet of Nile tilapia at 75% without any unpropitious effect on the growth performance and nutrient utilization.

Keywords: Duckweed Meal; Specific Growth Rate; Protein Efficiency Ratio; *Lemna paucicostata*; *Oreochromis niloticus*

Abbreviations: SBM: Soybean Meal; BDM: Blanched Duckweed Meal; SDM: Sun-Dried Duckweed Meal; NFE: Nitrogen Free Extract; CRD: Completely Randomized Design; VSI: Viscerosomatic Index; HSI: Hepatosomatic Index; PER: Protein Efficiency Ratio; FCR: Feed Conversion Ratio; ANPU: Apparent Net Protein Utilization; NNR: Net Nitrogen Retention; PPV: Protein Productive Value; GSI: Gonadosomatic Index; SSI: Spleenosomatic Index.

Introduction

Aquaculture production retained its growth trend in 2020 amidst the worldwide escalation of the COVID-19 pandemic, even though with differences among regions and among producing countries within each region [1]. African aquaculture (excluding algae) suffered from a superficial contraction in its annual production with about 1.2 percent decreased in 2020 when compared to 2019, mainly the result

of the drop in production in Egypt, Africa's major producer. In Nigeria, the largest producer in sub-Saharan Africa, the declining trend since 2016 worsened in 2020 with a sharp decrease of 9.6 percent [1].

The high cost of quality fish feed is one of the problems militating against the development of aquaculture [2]. This might not be unconnected to the scarcity and high cost of some conventional protein feedstuffs like soybean meal due to an ever-increasing demand as a staple food for man, raw material in industries and feed ingredients in farm animals [3]. However, the major problems confronting the fish farming industry are the increasing cost of feed ingredients in the local market [4].

The use of plant protein sources such as soybeans in the fish diet may not be profitable because it is very expensive being that it serves as a good source of protein for humans. FAO [5] reported that the shortage of soybeans in Nigeria caused a hike in its price by up to 193%. Expensive fish feed ingredients will significantly increase the cost of production and in return reduce profitability. Thus, there is an urgent need to identify other protein-rich plant sources that could substitute soybean meal in the fish diet.

Duckweed (*Lemna paucicostata*) is a small, free-floating aquatic plant that grows well in static and nutrient-rich freshwater or a brackish aquatic medium [6]. Its biomass doubles in 2 to 3 days under ideal conditions of nutrient availability, sunlight, pH (6.5-7.5), and temperature (20°C to 30°C) [7]. There are about 40 duckweed plant species worldwide the major ones are of the four genera; *Spirodela*, *Lemna*, *Wolffiella* and *Wolffia* [8]. This plant is very rich in nutrients. Different authors reported varying amounts of nutrients in duckweed [9]. The plant is rich in both macro and micro minerals such as calcium and chlorine. Generally, duckweed contains 6.8 to 45% crude protein, 1.8 to 9.2% crude lipid, 5.7 to 16.2% crude fibre, 12 to 27.6% ash, and the carbohydrate content is in the range of 14.1- 43.6% on a dry matter basis [7]. The nutrient composition in each duckweed species varies depending on the condition of the water environment [10]. Duckweed is suitable for animal consumption and is rich in invaluable nutrients [11]. Fresh duckweed has been successfully used as feedstuffs for common carp, silver carp and tilapia [8]. Other non-conventional plant-based proteins such as duckweed can be cultured easily and has the nutritional potential of replacing soybean meal in the diets but possess a variety of antinutritional factors which are known to decrease the availability of nutrients and become increasingly toxic with increasing amounts ingested, although processing, such as sun-drying and blanching can reduce the anti-nutritional content in the feed ingredients [6]. Therefore, these processing methods were employed to reduce the levels

of antinutrients. The use of duckweed meal as a fish feed ingredient in the diets of *Oreochromis niloticus* has not been fully explored. Thus, this study aimed to evaluate the effects of blanched and sun-dried duckweed (*Lemna paucicostata*) meal as protein sources in complete replacement for soybean meal on growth performance and nutrient utilization of Nile tilapia.

Materials and Methods

Experimental Site

The experiment was conducted outdoors, in concrete ponds of the Department of Fisheries and Aquaculture, Faculty of Agriculture, Ahmadu Bello University, Zaria which falls within latitude 11° 17'North and longitude 7° 63'East in the northern guinea savannah zone of Nigeria [12].

Procurement of Experimental Fish

Three hundred fingerlings of *Oreochromis niloticus* with an initial mean weight of 7.46g were procured from Kuka Farm, Gabasawa, Kano State and transported in an oxygenated polythene bag placed in 50 litres "Jerry-can".

Collection and Culture Duckweed (*Lemna paucicostata*)

Fresh duckweed was collected during raining season from a burrow pit at Hanwa Low-cost, Kwangila, Zaria, Kaduna State, with a hand net and transported in nylon bags. The fresh *Lemna paucicostata* was cultured for two months in concrete ponds at the Department of Fisheries and Aquaculture, Faculty of Agriculture, Ahmadu Bello University, Zaria. The cultured *Lemna paucicostata* was used for the experiment.

Processing of Duckweed Meal and Soybean Meal

Blanching and sun-drying methods were used to process the cultured duckweed samples while toasting was used to process the soybean meal. Blanching was done by boiling duckweed in water for 5 minutes at 100°C as described by Abdullahi AI, et al. [10]. The blanched *L. paucicostata* were milled into a fine powder and sieved through a 0.5 mm mesh screen and their samples were analyzed for their proximate composition, amino acids profile, and mineral and antinutrients contents. The second treatment involved sun drying duckweed under hygienic conditions for three (3) days [10]. After which the sun-dried *L. paucicostata* were then milled into a fine powder and sieved through a 0.5 mm mesh screen and their samples were analyzed for proximate composition, amino acid profile, and mineral and antinutrients contents.

Proximate Composition of the Experimental Diet

The proximate composition (moisture, crude protein, lipid crude fibre, ash and nitrogen-free extracts) of the experimental diets was determined using the methods of the Association of Official Analytical Chemists [13].

Gross Energy Values

The gross energy values in kilo-calories of the leaf samples and feed were calculated as described by Pauzenga [14].

GE = (Crude protein x 37) + (ether extract x 81.8) + (nitrogen-

free extract x 35) Kcal.

Experimental Diets

Nine iso-nitrogenous diets (D1-D9) were formulated using least cost feed formulation software (Feed Solution Software version 2022) which took into consideration the cost and the nutritive value of the ingredients. The soybean meal which serves as the control in the diets was replaced by blanched duckweed meal and sun-dried duckweed meal at 25%, 50%, 75% and 100% each. All the feed ingredients were integrated into computing, at the required quantities to make up a 100-unit quantity of the feed. Ingredient compositions of the experimental diets are resented in Table 1.

Ingredients	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
Soybean meal	23.74	17.81	11.87	5.93	0	17.81	11.87	5.93	0
Blanched <i>L. paucicostata</i>	0	5.93	11.87	17.81	23.74	-	-	-	-
Sun-dried <i>L. paucicostata</i>	-	-	-	-	-	5.93	11.87	17.81	23.74
Fish meal	11.87	11.87	11.87	11.87	11.87	11.87	11.87	11.87	11.87
Groundnut cake	35.61	35.61	35.61	35.61	35.61	35.61	35.61	35.61	35.61
Maize	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39
Wheat bran	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39	9.39
Palm oil	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Pre-mix	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
DL-Methionine	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
L-Lysine	2	2	2	2	2	2	2	2	2
Klinofeed	1	1	1	1	1	1	1	1	1
Proximate composition of diets (% DM basis)									
Moisture	11.45	10.12	10.5	10.46	11.52	10.54	9.36	10.03	9.21
Crude protein	38.02	35.54	35.49	36.33	37.98	35.56	37.55	38	36.35
Ether extract	12.59	10.06	11.54	10.83	10.49	10.11	11.55	10.53	10.02
Ash	14.95	15.81	16.32	15.92	16.81	15.34	15.95	16.4	16.86
Crude fibre	6.98	7.01	7.04	6.96	6.85	7.05	6.94	6.88	6.89
NFE	16.01	21.46	19.11	19.5	16.35	21.4	18.65	18.16	20.67
Gross energy (Kcal)	2996	2861.3	2926	2912.6	2836	2891.7	2986.9	2903	2888

D1 - 100% SBM (Control diet)

D2 - 75% SBM, 25% BDM

D3 - 50% SBM, and BDM

D4 - 25% SBM, 75% BDM

D5 - 100% BDM D9 - 100% SLP

D6 - 75% SBM, 25% SDM

D7 - 50% SBM, and SDM

D8 - 25% SBM, 75% SDM

Table 1: Feed formulation of the different experimental diets.

Experimental Set-Up

A completely Randomized Design (CRD) was employed in this research. The experiment consisted of eight treatments (D2, D3, D4, D5, D6, D7, D8, D9) and one control (D1) with three replications each. A semi flow through system was used. A group of 270 fingerlings of *Oreochromis niloticus* was acclimatized for 14 days. After the period of acclimatization, 10 fish were randomly assigned to a 1m² Hapa net. A total of 27 Hapa nets were used in outdoor concrete ponds of 5m × 3.5m (l × b) and depth of 1.5m each (Plate I and II) and nine formulated diets were fed to the experimental fish at 5% biomass three times daily.

Monitoring of Water Quality Parameters of Experimental Ponds

Water quality parameters were determined weekly, before feeding the fish. The dissolved oxygen level of the water was measured using a digital water dissolved oxygen meter (Smart Sensor AR8210 model) while pH and temperature were measured using a digital pH/Temperature meter (HI-98127 model).

Determination of Growth Performance and Nutrient Utilization Parameters

The data obtained on the growth performance and nutrient utilization of *O. niloticus* fed on the formulated diets were determined as following the methods of Abdullahi et al. [12]:

➤ Mean Weight Gain (MWG) (g)

Mean Weight Gain (MWG) = $\frac{W_2 - W_1}{T}$
Where W1 = Initial mean weight (g)
W2 = Final mean weight (g)

➤ Daily Weight Gain (g/day)

$$\text{Daily Weight Gain (DWG)} = \frac{FMW - IMW}{T}$$

Where FMW = Final mean weight (g)
IMW = Initial mean weight (g)
T = Feeding trial period in days

➤ Percentage Weight Gain (%)

$$\text{Percentage weight gain (PWG \%)} = \frac{FMW - IMW}{IMW} \times 100$$

Where FMW = Final mean weight (g)
IMW = Initial mean weight (g)

➤ Specific Growth Rate (SGR %/day)

$$\text{SGR \%} = \frac{\log \text{ of } W_2 - \log \text{ of } W_1}{T_2 - T_1} \times 100$$

Where W1 = Initial mean weight (g)

W2 = Final mean weight (g)

T1 = Initial time (g)

T2 = Final time (g)

➤ Condition Factor (CF)

$$CF = \frac{100 (\text{Weight gain})(g)}{(\text{Final Length})^3 (cm)}$$

➤ Survival Rate (%)

$$SR = \frac{\text{Number of fish that remain at the end of the experiment}}{\text{The initial number of fish stocked}} \times 100$$

Daily Feed Intake (g)

$$\text{Daily Feed intake (DFI)} = \frac{\text{Quantity of feed fed (g)}}{\text{Number of days}}$$

➤ Protein Efficiency Ratio (PER)

$$PER = \frac{\text{Total weight gain (g)}}{\text{Crude protein fed (g)}}$$

➤ Feed Conversion Ratio (FCR)

$$FCR = \frac{\text{Total weight of diet fed (g)}}{\text{Total weight of fish (g)}}$$

➤ Apparent Net Protein Utilization (ANPU)

$$ANPU = \frac{\text{Final carcass protein (g)} - \text{Initial carcass protein (g)}}{\text{Protein fed (g)}} \times 100$$

➤ Net Nitrogen Retention (NNR)

$$NNR = \frac{\text{Initial body protein (g)}}{\text{Final body protein (g)}} \times 100$$

➤ Mortality

$$M = \frac{\text{Number of fish dead at the end of experiment}}{\text{The initial number of fish stocked}} \times 100$$

Somatic Indices

Somatic indices were used to know the condition of the experimental fish by determining the Viscerosomatic index (VSI) and Hepatosomatic index (HSI) according to Kubiriza et al. [15] as follows:

$$\text{Viscerosomatic Index (VSI)} = \frac{\text{FVM}}{\text{FBM}} \times 100$$

Where FVM = Fish visceral mass (g)
FBM = fish body mass (g)

$$\text{Hepatosomatic Index (HSI)} = \frac{\text{LM}}{\text{BM}} \times 100$$

Where LM = liver mass (g)
BM = body mass (g).

Data Analysis

All data collected from the experiment were subjected to one-way analysis of variance to test for significant differences among treatment means using XLSTAT version 2022, followed by Duncan pairwise comparisons which was used to separate significantly different means at a confidence interval of 95%. The level of significance set for treatments was $P \leq 0.05$. The growth and nutrient utilization parameters were subjected to trend analysis to determine their patterns at different inclusion levels.

Results

Water Quality Parameters of the Experimental Ponds

The mean dissolved oxygen, mean hydrogen ion concentration and mean temperature in the experimental ponds are presented in Table 2. There was no significant difference in the water quality parameters among all the treatments and the control ($P > 0.05$). All the parameters recorded were within the recommended range. The DO ranged from 5.20 to 5.23, the pH ranged from 6.50 to 6.52 and the temperature ranged from 28.00°C to 28.40°C.

Growth Performance of *Oreochromis niloticus* Fed Experimental Diets

The growth performance and survival of *Oreochromis niloticus* fed experimental diets are presented in Table 3. There was no significant difference ($P > 0.05$) in the initial weight and initial length among all the treatments and the control. The fish-fed diet containing 75% blanched duckweed meal (D4) recorded significantly highest ($P \leq 0.05$) mean final weight of 468.01g followed by the fish fed with 50% blanched *L. paucicostata* (D3) with 453.68g then the fish fed diet containing 25% sun-dried duckweed meal (D6) with a value of 443.77g. The fish-fed diet containing 100% blanched duckweed meal (D5) recorded significantly lowest

($P \leq 0.05$) value of 401.54g. There was significant difference in the mean final weight among all the treatments and the control ($P \leq 0.05$) diet. The monthly increase in weight of *Oreochromis niloticus* fed experimental diets is presented in Figure 1. There was no significant difference ($P > 0.05$) in the condition factor among all the treatments and the control. The survival rate of the experimental fish showed significant difference ($P \leq 0.05$). The fish fed diet containing 50% blanched duckweed meal (D3), 25% sun-dried duckweed meal (D6), 50% sun-dried duckweed meal (D7) and 100% sun-dried duckweed meal (D9) recorded 100% survival rate while the fish fed with 100% soybean meal (D1), 25% blanched duckweed meal (D2), 75% blanched duckweed meal (D4), 100% blanched duckweed meal (D5) and 75% sun-dried duckweed meal (D8) recorded 96.66% survival rate.

The result of the trend analysis for the growth parameters is presented in Figures 1-4. The trend line for mean weight gain, daily weight gain and specific growth rate of *Oreochromis niloticus* fed experimental diets displayed an increasing trend as the inclusion levels of blanched duckweed meal increased upto 75% while decreasing as inclusion levels of sun-dried duckweed meal increased upto 100% inclusion.

Nutrient Utilization and Somatic Indices

The results of nutrient utilization and somatic indices in terms of protein efficiency ratio (PER), feed conversion ratio (FCR), apparent net protein utilization (ANPU), net nitrogen retention (NNR), protein productive value (PPV), viscerosomatic index (VSI) and Hepatosomatic index (HSI) *Oreochromis niloticus* fed experimental diets are presented in Table 4. There was significant difference ($P \leq 0.05$) in the feed intake, protein efficiency ratio, feed conversion ratio, protein productive value, viscerosomatic index and Hepatosomatic index among all the treatments and the control.

The result of the trend analysis for the nutrient utilization parameters is presented in Figures 5 and 6. The trend line for protein efficiency ratio of *Oreochromis niloticus* fed experimental diets displayed an increasing trend as the inclusion levels of blanched duckweed meal increased upto 75% while decreasing as inclusion levels of sun-dried duckweed meal increased upto 100% inclusion. While the trend line for the feed conversion ratio displayed a decreasing trend as the inclusion levels of blanched duckweed meal increased upto 75% while increasing as inclusion levels of sun-dried duckweed meal increased upto 100% inclusion (Tables 2-4) and (Figures 7 & 8).

Treatments	DO (mg/l)	pH	T (°C)
D ₁	5.20±0.01 ^a	6.52±0.02 ^a	28.04±0.93 ^a
D ₂	5.20±0.01 ^a	6.51±0.02 ^a	28.10±0.93 ^a
D ₃	5.22±0.01 ^a	6.52±0.02 ^a	28.00±0.93 ^a
D ₄	5.21±0.01 ^a	6.51±0.02 ^a	28.16±0.93 ^a
D ₅	5.20±0.01 ^a	6.51±0.02 ^a	28.30±0.93 ^a
D ₆	5.22±0.01 ^a	6.51±0.02 ^a	28.12±0.93 ^a
D ₇	5.21±0.01 ^a	6.51±0.02 ^a	28.05±0.93 ^a
D ₈	5.21±0.01 ^a	6.50±0.02 ^a	28.40±0.93 ^a
D ₉	5.23±0.01 ^a	6.52±0.02 ^a	28.30±0.93 ^a
P values	0.24	0.95	1

Means with the same superscript along the same column are not significantly different (P>0.05)

D1 - 100% SBM (Control diet)

D2 - 75% SBM, 25% BDM D6 - 75% SBM, 25% SDM

D3 - 50% SBM, and BDM D7 - 50% SBM, and SDM

D4 - 25% SBM, 75% BDM D8 - 25% SBM, 75% SDM

D5 - 100% BDM D9 - 100% SLP

Table 2: Mean weekly water quality parameters of the experimental ponds.

Parameters	Treatments								
	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
IW (g)	7.48±0.06 ^a	7.43±0.06 ^a	7.50±0.06 ^a	7.42±0.06 ^a	7.51±0.06 ^a	7.47±0.06 ^a	7.45±0.06 ^a	7.41±0.06 ^a	7.51±0.06 ^a
IL (cm)	7.79±0.07 ^a	7.75±0.07 ^a	7.87±0.07 ^a	7.78±0.07 ^a	7.86±0.07 ^a	7.75±0.07 ^a	7.77±0.07 ^a	7.75±0.07 ^a	7.85±0.07 ^a
FW (g)	416.88±56.90 ^c	425.57±56.90 ^b	453.68±56.90 ^{ab}	468.01±56.90 ^a	401.54±56.90 ^d	443.77±56.90 ^{ab}	432.54±56.90 ^b	426.33±56.90 ^b	409.20±56.90 ^c
FL (cm)	27.07±0.43 ^a	27.19±0.43 ^a	27.68±0.43 ^a	27.72±0.43 ^a	26.72±0.43 ^b	27.41±0.43 ^a	27.21±0.43 ^a	27.50±0.43 ^a	26.75±0.43 ^b
MWG (g)	409.40±56.92 ^c	418.14±56.92 ^b	446.18±56.92 ^{ab}	460.59±56.92 ^a	394.03±56.92 ^d	436.30±56.92 ^{ab}	425.09±56.92 ^b	418.92±56.92 ^b	401.69±56.92 ^c
DWG (g)	2.27±0.31 ^c	2.32±0.31 ^b	2.48±0.31 ^{ab}	2.55±0.31 ^a	2.19±0.31 ^d	2.42±0.31 ^{ab}	2.36±0.31 ^b	2.32±0.31 ^b	2.23±0.31 ^c
PWG (%)	98.17±0.27 ^b	98.25±0.27 ^{ab}	98.31±0.27 ^a	98.33±0.27 ^a	98.12±0.27 ^b	98.20±0.27 ^{ab}	97.98±0.27 ^b	98.26±0.27 ^{ab}	98.09±0.27 ^b
SGR (%)	0.97±0.03 ^{ab}	0.97±0.03 ^{ab}	0.98±0.03 ^a	0.99±0.03 ^a	0.96±0.03 ^b	0.98±0.03 ^a	0.96±0.03 ^b	0.97±0.03 ^{ab}	0.96±0.03 ^b
CF	2.10±0.24 ^a	2.12±0.24 ^a	2.13±0.24 ^a	2.18±0.24 ^a	2.10±0.24 ^a	2.12±0.24 ^a	2.10±0.24 ^a	2.06±0.24 ^a	2.11±0.24 ^a
SR	96.66±2.48 ^b	96.66±0.24 ^b	100.00±0.24 ^a	96.66±0.24 ^b	96.66±0.24 ^b	100.00±0.24 ^a	100.00±0.24 ^a	96.66±0.24 ^b	100.00±0.24 ^a

Means with the same superscript across the same row were not significantly different (P>0.05)

D1 - 100% SBM (Control diet) D4 - 25% SBM, 75% BDM D7 - 50% SBM, and SDM

D2 - 75% SBM, 25% BDM D5 - 100% BDM D8 - 25% SBM, 75% SDM

D3 - 50% SBM, and BDM D6 - 75% SBM, 25% SDM D9 - 100% SDM

Table 3: Growth performance and survival of *Oreochromis niloticus* fed experimental diets.

Parameters	Treatments								
	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇	D ₈	D ₉
DFI (g)	42.11±4.12 ^{ab}	42.61±4.12 ^{ab}	44.17±4.12 ^a	44.44±4.12 ^a	41.67±4.12 ^b	43.33±4.12 ^a	43.06±4.12 ^a	42.52±4.12 ^{ab}	41.83±4.12 ^b
PER	10.77±1.55 ^b	11.76±1.55 ^b	12.57±1.55 ^a	12.67±1.55 ^a	10.37±1.55 ^b	12.26±1.55 ^a	11.31±1.55 ^b	11.08±1.55 ^b	11.05±1.55 ^b
FCR	1.99±0.19 ^a	1.91±0.19 ^{ab}	1.82±0.19 ^b	1.82±0.19 ^b	2.10±0.19 ^a	1.84±0.19 ^b	1.88±0.19 ^b	1.91±0.19 ^{ab}	2.06±0.19 ^a
ANPU	34.96±1.27 ^c	39.08±1.27 ^b	43.14±1.27 ^a	44.23±1.27 ^a	33.65±1.27 ^c	43.14±1.27 ^a	39.25±1.27 ^b	35.68±1.27 ^{ab}	33.98±1.27 ^c
NNR	77.09±1.10 ^b	76.31±1.10 ^b	74.50±1.10 ^{bc}	73.57±1.10 ^c	77.78±1.10 ^{ab}	74.46±1.10 ^{bc}	75.21±1.10 ^b	76.24±1.10 ^b	78.36±1.10 ^a
PPV	1.53±0.43 ^c	1.65±0.43 ^b	1.69±0.43 ^b	1.66±0.43 ^b	1.51±0.43 ^c	1.68±0.43 ^b	1.58±0.43 ^c	1.80±0.43 ^a	1.57±0.43 ^c
VSI	7.21±1.12 ^b	7.48±1.12 ^b	9.77±1.12 ^a	9.90±1.12 ^a	6.99±1.12 ^b	9.35±1.12 ^a	8.91±1.12 ^{ab}	7.62±1.12 ^b	7.14±1.12 ^b
HIS	0.65±0.11 ^b	0.68±0.11 ^b	0.88±0.11 ^a	0.95±0.11 ^a	0.63±0.11 ^b	0.85±0.11 ^a	0.81±0.11 ^{ab}	0.68±0.11 ^b	0.65±0.11 ^b

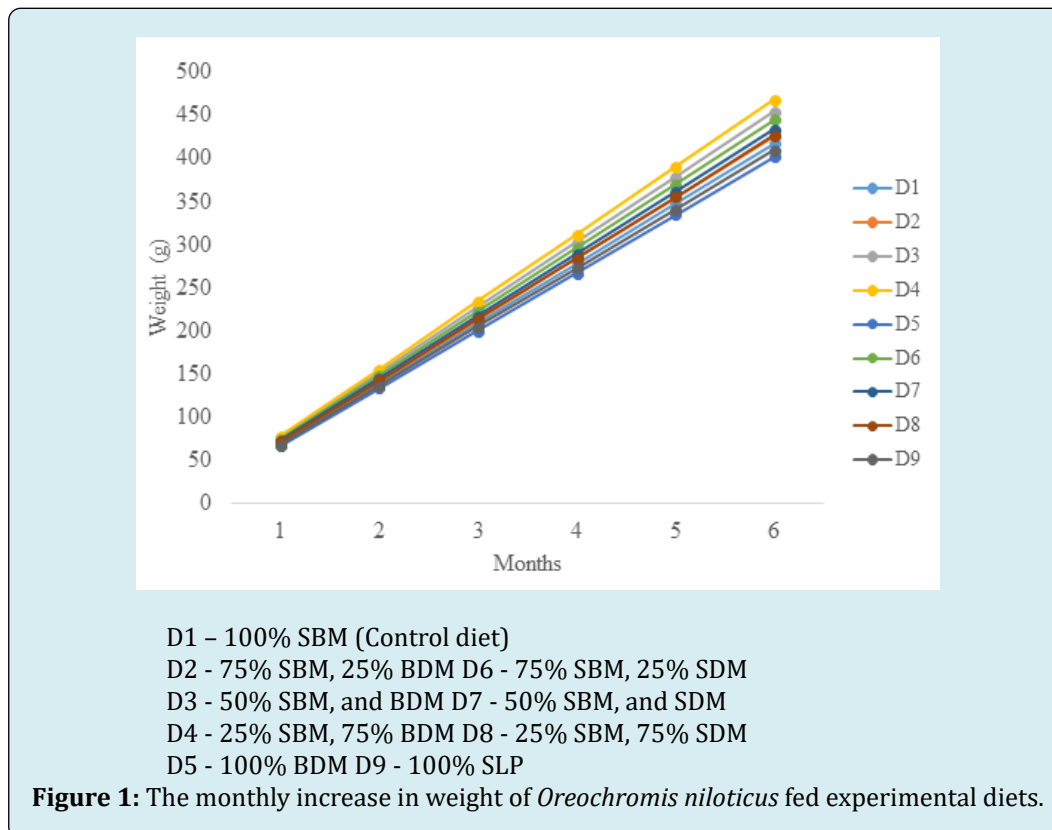
Means with the same superscript within the same row were not significantly different ($P>0.05$)

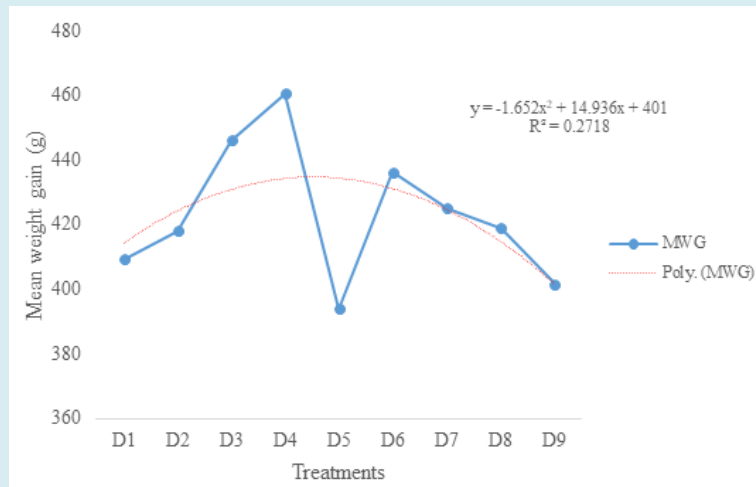
D1 - 100% SBM (Control diet) D4 - 25% SBM, 75% BDM D7 - 50% SBM, and SDM

D2 - 75% SBM, 25% BDM D5 - 100% BDM D8 - 25% SBM, 75% SDM

D3 - 50% SBM, and BDM D6 - 75% SBM, 25% SDM D9 - 100% SDM

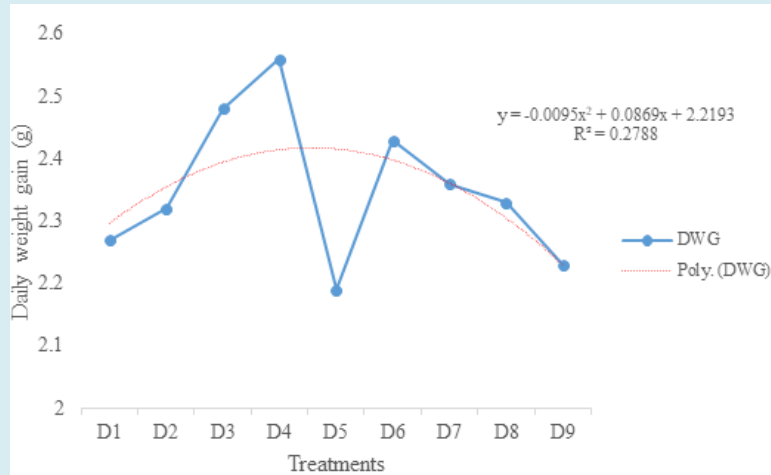
Table 4: Nutrients utilization and somatic indices of *Oreochromis niloticus* fed experimental diets.





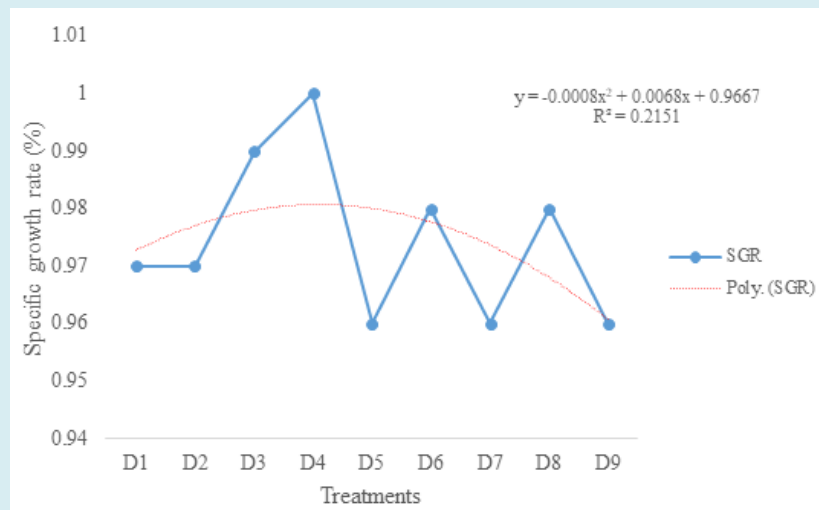
D1 - 100% SBM (Control diet)
 D2 - 75% SBM, 25% BDM D6 - 75% SBM, 25% SDM
 D3 - 50% SBM, and BDM D7 - 50% SBM, and SDM
 D4 - 25% SBM, 75% BDM D8 - 25% SBM, 75% SDM
 D5 - 100% BDM D9 - 100% SLP

Figure 2: Trend line for the mean weight gain of *Oreochromis niloticus* fed experimental diets.



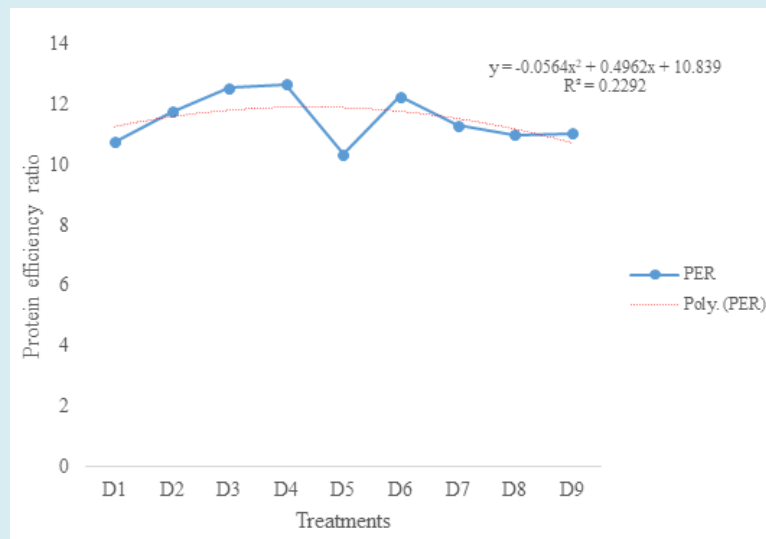
D1 - 100% SBM (Control diet)
 D2 - 75% SBM, 25% BDM D6 - 75% SBM, 25% SDM
 D3 - 50% SBM, and BDM D7 - 50% SBM, and SDM
 D4 - 25% SBM, 75% BDM D8 - 25% SBM, 75% SDM
 D5 - 100% BDM D9 - 100% SLP

Figure 3: Trend line for the daily weight gain of *Oreochromis niloticus* fed experimental diets.



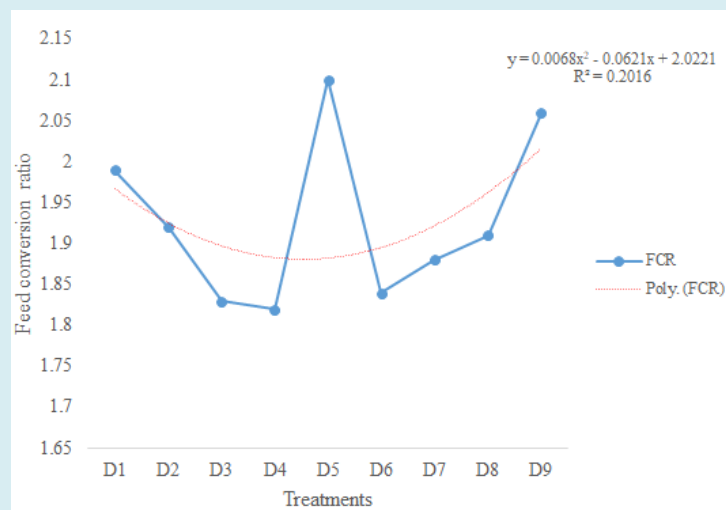
D1 - 100% SBM (Control diet)
 D2 - 75% SBM, 25% BDM D6 - 75% SBM, 25% SDM
 D3 - 50% SBM, and BDM D7 - 50% SBM, and SDM
 D4 - 25% SBM, 75% BDM D8 - 25% SBM, 75% SDM
 D5 - 100% BDM D9 - 100% SLP

Figure 4: Trend line for the specific growth rate of *Oreochromis niloticus* fed experimental diets.



D1-100% SBM (Control diet)
 D2 - 75% SBM, 25% BDM D6 - 75% SBM, 25% SDM
 D3 - 50% SBM, and BDM D7 - 50% SBM, and SDM
 D4 - 25% SBM, 75% BDM D8 - 25% SBM, 75% SDM
 D5 - 100% BDM D9 - 100% SLP

Figure 5: Trend line for the protein efficiency ratio of *Oreochromis niloticus* fed experimental diets.



D1-100% SBM (Control diet)
 D2 - 75% SBM, 25% BDM D6 - 75% SBM, 25% SDM
 D3 - 50% SBM, and BDM D7 - 50% SBM, and SDM
 D4 - 25% SBM, 75% BDM D8 - 25% SBM, 75% SDM
 D5 - 100% BDM D9 - 100% SLP

Figure 6: Trend line for the feed conversion ratio of *Oreochromis niloticus* fed experimental diets.



Figure 7: Longitudinal view of the experimental set-up.



Figure 8: Side view of the experimental set-up.

Discussion

The water quality parameters (temperature, dissolved oxygen and potential of hydrogen or hydrogen ion concentration) monitored during the experimental period were not affected by the forms of the experimental diets, all the parameters measured did not differ significantly ($P > 0.05$)

among the treatments and the control. The dissolved oxygen ranged from 5.20-5.23mg/l, hydrogen ion concentration (pH) ranged from 6.50-6.52 while the temperature ranged from 28.00oC – 28.40oC. Ayoola and Fedrick [16] stated that 3-8mg/L of dissolved oxygen is recommended for freshwater fish culture. The physicochemical parameters of water used for the culture of *Oreochromis niloticus* during the experimental period were within the range recommended for Nile tilapia culture [17].

The growth performance of Nile tilapia fed varying inclusion levels of blanched and sun-dried duckweed meal as a replacement for toasted soybean indicated that the initial mean weight (7.41g -7.51g) and initial mean length (7.75cm-7.87cm) were not significantly different ($P > 0.05$) among the experimental treatments and the control showing uniformity in their sizes at onset of the experiment which in turn indicating the accuracy of randomization process among the experimental treatments and the control. The high mean weight gain observed in the D4 (75% blanched duckweed meal) and D3 (50% blanched duckweed meal) was an indication that the fish were able to utilize the diet more efficiently than the other treatments and the control diet. While the low mean weight gain obtained in D5 (100% blanched duckweed meal) and D9 (100% sun-dried duckweed meal) could be due to low feed consumption as a result of less palatability of the diet. Since it was observed that the fish were not actively responding to the diet during feeding when compared to the response in the other treatments and

the control. The decrease in mean weight gain as a result of less palatability of the diet had been reported by Welker et al. [18]. Daily weight gain, percentage weight gain and specific growth rate also revealed a similar trend with the mean weight gain. The best growth performance was observed in the fish fed diet containing 75% blanched duckweed meal in this study contradicts the findings of Effiong et al. [19] who reported that the inclusion of duckweed at 10% in the diet of *Heterobranchius longifilis* fingerlings gives better results as compared to diets containing duckweed at 20% and 30%. Olaniyi and Oladunjoye [20] reported that the substitution of duckweed meal for 25% fish meal promotes higher growth performance than feeding only fish meal as the main source of protein in the Nile tilapia fish. These authors added that the growth performance of the fish that were fed the control diet was higher than those that received 50%, 75% and 100% duckweed meal. However, Oyas et al. [21] replaced duckweed with fish meal in the diet of common carp (*Cyprinus carpio*) fingerling at 0%, 15%, 30% and 45% inclusion levels and concluded that duckweed inclusion level at a lower level (15%) gives better results compared with higher inclusion levels (30% and 45%). The discrepancy observed between the results of this study and those of the above-referenced authors could be due to the differences in experimental fish in relation to species, type of duckweed species used, processing methods used in treating antinutrients in the duckweed, the ingredient that was replaced in the diet, culture system (indoor or outdoor) used for the experiment, age and stage of the fish development and water quality management. Condition factor is a useful index for monitoring feeding intensity, age and growth rates in fish [22]. It also provides information relating to the physiological condition of the fish, welfare, health and well-being of the fish. It is based on the hypothesis that heavier fish of a particular length is in a better physiological condition [22]. The condition factors (2.06 – 2.18) observed in this study were not significantly different among the treatments and the control indicating that all the experimental fish were in good condition. The survival rate of Nile tilapia fingerlings fed the experimental diets showed similar performance (96.66% - 100.00%) among the experimental treatments and the control as no significant difference was observed. The trend line for mean weight gain, daily weight gain and specific growth rate of Nile tilapia fed experimental diets displayed a decreasing trend as the inclusion levels of duckweed meal increased. While the trend line for the survival rate increased as duckweed meal increased in the experimental diets. Ramezani [23] and Sotolu [24]; had earlier stated that a high feeding rate of quality feed is directly related to fish growth performance hence, the trend of growth observed in the study is an indication that the energy quality of D4 (75% blanched duckweed meal) is better utilized in the diet of Nile tilapia fingerlings compared to the other treatments and the control.

The nutrient utilization of Nile tilapia fed diets containing different dietary levels of blanched and sun-dried duckweed meal show significant differences ($P \leq 0.05$) in protein efficiency ratio, feed conversion ratio and protein productive value among the experimental diets and the control. The lowest feed conversion ratio (1.82) observed in the fish fed D3 (50% blanched duckweed meal) and D4 (75% blanched duckweed meal) could be a result of the activation of digestive enzymes by the high mineral concentrations present in the duckweed. The best feed conversion ratio obtained in this research is in line with the findings of Sogbesan et al. [25] and Ibrahim et al. [26] who reported best feed conversion ratios of 1.85 and 1.95, respectively. Apparent net protein utilization differed significantly ($P < 0.05$) among the experimental fish and the control. The highest ANPU (44.23) was recorded in the fish fed D4 (75% blanched duckweed meal) while the least ANPU of 33.65 was obtained in the fish fed D5 (100% blanched duckweed meal), this could be due high weight gain (460.59g) obtained in the fish fed D4 (75% blanched duckweed meal) and least weight gain (394.03g) obtained in the fish fed D5 (100% blanched duckweed meal) this observation revealed that high ANPU value will be obtained if the weight gain is high. The assessment of nutrient utilization and biochemical composition in the diets can be carried out using the morphometric characterization of the fish as described by Vatandoust et al. [27] using organ and tissue indices of a particular fish. The organ indices commonly used are the Viscerosomatic Index (VSI), Hepatosomatic Index (HSI), Gonadosomatic Index (GSI) and Splenosomatic Index (SSI) as cited by Sudaporn et al. [28]. Babalola et al. [29] described viscerosomatic and hepatosomatic indices as the ratio of organs to body weight measured in relation to body mass which can be used as indices of changes in nutritional and energy status. According to Gumus and Ikiz [30], the assessment of viscerosomatic and hepatosomatic (organosomatic indices) plays a significant role in the secretion of digestive enzymes, digestion and absorption of food items as well as metabolism in fishes. The mean viscerosomatic index (6.99g - 9.90g) and hepatosomatic index (0.63g - 0.95g) of Nile tilapia fed with the experimental diets observed in this study, increase with the increase in mean weight gain, feed intake, protein efficiency ratio and protein productive value among the treatments and the control, this indicated that the fish were able to make use of the dietary duckweed meal in the diet by converting it into muscle tissues or carcass as reported by Marroh and Ekelemu [31].

Conclusions

The growth performance, nutrient utilization and protein efficiency ratio of the experimental fish increased with the increased of inclusion levels of blanched duckweed meal up to the maximum of 75% while decreasing with the

increase of inclusion levels of sun-dried duckweed meal up to 100%. The fish fed 75% blanched duckweed meal had the best mean weight gain (460.59g), feed conversion ratio (1.82) and protein efficiency ratio (12.67) while the fish fed 100% inclusion level of sun-dried duckweed meal and 100% of blanched duckweed meal diet had the poor mean weight gain, feed conversion ratio and protein efficiency ratio of 401.69g and 394.03g, 2.06 and 2.10, 11.05 and 10.37, respectively. This study revealed that blanched duckweed meal can replace toasted soybean meal in the diet of Nile tilapia at 75% without any unpropitious effect on the growth performance and nutrient utilization.

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