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Growth Performance and Nutrient Digestibility of *Clarias gariepinus* (Burchell 1822) Fed Diets Fortified with *Tamarindus indica* Pulp and Leaf Meal

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Abstract

The global disapproval on the adverse effects of synthetic drugs necessitated research into efficacious alternatives that will enhance growth of food fish. This study was conducted to examine the growth performance of *Clarias gariepinus* (Burchell 1822) fingerlings on diets fortified with tamarind pulp and leaf. The fingerlings (n = 900, 5.73±0.1 g) were randomly distributed into 10 groups of 100 L tanks with borehole water in a static renewal system. Fish were fed test diets fortified with 0.0 % (positive control), 2 g oxytetracycline kg^{-1} diet (negative control) and four varying levels (5, 10, 15, 20 $g.kg^{-1}$ diets) each of tamarind pulp or leaf meal at 3 % body weight daily for 84 days. Fortification of the diets with tamarind significantly enhanced ($P<0.05$) weight gain, specific growth rate, feed conversion ratio, nitrogen metabolism and survival rate, with the best performance at 20 g pulp and 10 g leaf. The highest apparent nutrient digestibility, profit index and benefit cost ratio were also obtained at these two treatments. Feed conversion ratio was significantly reduced ($P<0.05$) while protein efficiency ratio increased in fish fed tamarind-fortified diets. Thus, inclusion of tamarind pulp and leaf promoted digestibility of nutrients, and consequently the growth performance, in *Clarias gariepinus*.

Keywords: *Clarias gariepinus*, tamarind, synthetic antibiotic, fish growth, nutrient digestibility

Introduction

Fish and fishery products represent affordable source of animal protein that may not only be cheaper than other animal protein sources but is also a preferred part of local and traditional recipes

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valued for diversified benefits including health benefits. Fish provides high value protein and a wide range of essential micronutrients, including vitamins, mineral salts and polyunsaturated omega-3 fatty acids, while most fish are low in saturated fats, carbohydrates and cholesterol (FAO 2012). The dietary contribution of fish is more significant in terms of animal proteins, as a portion of 150 g of fish provides about 50–60 % of the daily protein requirement for an adult (FAO 2012).

The demand for fish as a source of readily digestible animal protein for human consumption is very high and will continue to rise in the coming decades as a result of population growth and urbanisation (FAO 2010). The United Nations' Population Division projected that the world population would exceed 9 billion by 2050 while most of the growth was expected to occur in developing countries (FAO 2010). This increasing demand for fish to meet the needs of the growing human population, as well as for animal feed production, requires higher production levels.

The growth in aquaculture in recent decades has resulted in the use of synthetic antibiotics as chemotherapeutics and growth promoters. The global criticism of the adverse effects of these synthetic drugs necessitates research into efficient alternatives to ensure production of healthy fish and fish products which are safe for consumption. Useful bioactive compounds for enhancing growth, feed efficiency and health of animals as well as food safety and quality are now being investigated from plants and research on growth-promoting effects of phytobiotics is increasing (Dada and Ikuerowo 2009; Sanchez et al. 2009; Aly and Mohamed 2010; Bello et al. 2012; Sotolu et al. 2014; Dada 2015).

Tamarind, *Tamarindus indica*, a multi-purpose tropical tree, has been recognised for its medicinal importance (Kumar and Bhattacharya 2008). *Tamarindus indica* contains many active compounds such as carvacrol, cinnamaldehyde, limonene, linalool, lupeol, epicatechin and tartaric acid among others (Bala 2006; Shehla et al. 2007; Samina et al. 2008). Tamarind has antioxidant, antifungal, antibacterial, antiviral, laxative and carminative properties and its use traditionally to control constipation has been reported (Bhadoriya et al. 2011; Gupta et al. 2012, Adeniyi et al. 2017). It has been demonstrated that polyphenolic compounds extracted from tamarind seed coat improved growth performance of broilers (Aengwanich et al. 2009).

The positive *in vitro* antimicrobial property of tamarind reported in our previous study (Adeniyi et al. 2017) and its use traditionally to control constipation justifies further research into the mode of action to achieve optimal growth performance in fish nutrition. Therefore, the aim of this study was to examine the growth performance and apparent nutrient digestibility of *Clarias gariepinus* (Burchell 1822) fed diets supplemented with air-dried tamarind pulp and leaf meal as dietary additives.

Materials and Methods

Diet formulation and preparation

Tamarind leaves and fruits were obtained from the environment of Teaching and Research Farm, College of Agriculture, Kwara State University, Malete, Nigeria. The fruit husk was carefully removed and the pulp scraped from the seeds. The leaves and pulp were air-dried under shade and then ground into meals. Ten experimental diets with similar basal diet as shown in Table 1 were formulated. The tamarind pulp (TP) and leaves (TL) meals were added to the basal diets at 5, 10, 15 and 20 $g.kg^{-1}$ diets each with two controls: the negative control containing no test ingredient and the positive control containing 2 g (as recommended by the manufacturer) oxytetracycline (OXY 200 WSP, Holland).

All ingredients were thoroughly mixed to ensure homogeneity. Cassava starch was prepared with hot water and added as binder. Chromic oxide was used as an inert marker (indicator) to estimate apparent nutrient digestibility of the diets. The resultant dough was formed into pellets using a pelleting machine (Shuangying, SYSLJ-1, China) with 2 mm die size. The pellets were sun-dried and hand crumbled into smaller sizes, after which they were packed in separate airtight polythene bags, labelled and stored in a dry environment at room temperature throughout the experimental period. All formulated feeds contained 40 % crude protein. Samples of diets were analysed for proximate composition using AOAC (2005) method. Gross energy ($kcal.g^{-1}$) was calculated using 5.65, 9.45, 4.11 $kcal.g^{-1}$ for protein, lipid, and carbohydrate respectively (Ahmad and Abdel-Tawwab 2011)

Experimental set-up and feeding

Clarias gariepinus fingerlings were obtained from a fish farm in Ilorin, Nigeria and transported to the Teaching and Research Farm of College of Agriculture, Kwara State University, Malete, Nigeria. The fingerlings were acclimatised in indoor tanks for 2 weeks during which they were fed with commercial floating feeds. Fish (n=900, 5.75±0.1 g) were randomly distributed into treatments using 100-L circular plastic tanks containing 60 L of water. Each treatment had three replicates with 30 fingerlings per replicate, in a static renewal culture system. The fish were starved 24 h prior to feeding with the experimental diets to enhance their appetite. Thereafter, they were fed daily with the experimental diets at 3 % body weight for 84 days. The daily feed rations were divided into two equal portions, half of which was offered to the fish in the morning hours (between 08.30 h and 09.30 h) and the second half in the evening hours (between 16.30 h and 17.30 h). The feed ration was adjusted fortnightly as the fish increased in weight. Water temperature was measured daily using mercury-in-glass thermometer while dissolved oxygen and pH were determined weekly with AMSTAT dissolved oxygen meter (DO-Temp., AMT07; C.V. Java Multi Mandiri, Indonesia) and Hanna pH meter (pHep, HI98107, USA), respectively.

Table 1. Gross composition (g.kg^{-1} dry matter) of experimental diets (40 % crude protein) at varying inclusion of tamarind pulp and leaf meal.

Ingredients	Diets									
	-C	+C	5P	10P	15P	20P	5L	10L	15L	20L
Fish meal	241.1	241.1	241.1	241.1	241.1	241.1	241.1	241.1	241.1	241.1
SBM	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
GNC	255.0	255.0	255.0	255.0	255.0	255.0	255.0	255.0	255.0	255.0
Maize	108.9	108.9	108.9	108.9	108.9	108.9	108.9	108.9	108.9	108.9
Soy oil	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Salt	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Bone meal	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
O. shell	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Premix*	20.0	20.0	20.0	20.0	20.0	20 0	20.0	20.0	20.0	20.0
Cr_2O_3	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Starch	35.0	33.0	30.0	25.0	20.0	15.0	30.0	25.0	20.0	15.0
Tamarind	-	-	5.0	10.0	15.0	20.0	05.0	10.0	15.0	20.0
OTC	-	2.0	-	-	-	-	-	-	-	-
Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Proximate composition (%)										
Moisture	7.87	7.87	7.42	7.38	7.29	7.55	7.68	7.50	7.51	7.72
Crude P.	40 01	40.01	40.02	40.03	40.05	40.05	40.02	40.03	40.04	40.05
Ether	6.63	6.41	6.68	6.75	6.95	6.97	7.00	7.01	7.03	7.04
Crude F.	10.05	10.05	10.10	10.18	10.21	10.26	10.08	10.27	10.89	11.06
Ash	11.54	11.57	11.95	11.96	12.06	12.15	12.36	12.61	12.80	12.89
NFE	23.90	24.09	23.81	23.71	23.45	23.02	22.86	22.50	22.73	21.24
GE	386.97	385.5	387.1	387.3	387.2	386.0	386.0	385.24	382.01	380.04
		6	2	7	8	5	5			

C = Control; T = Pulp**; L= Leaf***; SBM = Soybean meal; GNC = Groundnut cake; O. shell = Oyster shell; OTC = Oxytetracycline; P= Protein; F = Fibre; NFE = Nitrogen free extract; GE = Gross energy (kcal.g^{-1}).

Premix*: Vitamin A = 20,500.00 IU, Vitamin B1 = 20,000.00 mg, Vitamin B2 = 15,000.00 mg, Vitamin B3 = 90,000 mg, Vitamin B4 = 4,000.00 mcg, Vitamin B5 = 40.00 mg, Vitamin B6 = 20,000.00 mg, Vitamin B7 = 500.00 mcg, Vitamin B12 = 15.00 mcg, Vitamin C = 350,000.00 mg, Vitamin D3 = 4,250,000.00 IU, Vitamin E = 250,000.00 IU, Vitamin K = 8,000.00 mg, Copper sulphate = 4,000.00 mg, Potassium iodine = 2,000.00 mg, Inositol = 50,000.00 mg, Methionine = 50,000.00 mg, Choline chloride = 600,000.00 mg, Ferrous sulphate = 40,000.00 mg, Manganese oxide = 30,000.00 mg, Magnesium = 60,000.00 mcg, Molybdenum = 100.00 mg, Antioxidant = 125,000.00 mg, Lysine = 50,000.00 mg, Cobalt = 750.00 mg, Sodium selenite = 200.00 mcg, Zinc oxide = 40,000.00 mg. **Moisture = 15.74, Crude protein = 8.08, Ether extract = 6.20, Crude fibre = 9.62, Ash = 11.95, NFE = 48.41, GE = 237.93 ***Moisture = 10.63, Crude protein = 9.67, Ether extract = 7.60, Crude fibre = 11.21, Ash = 12.05, NFE = 48.84, GE = 179.29.

The range of water temperature, pH and dissolved oxygen were 24.7 to 27.2 ^oC, 6.9 to 7.2 and 4.75 to 5.85 $mg.L^{-1}$, respectively. The fish were monitored daily for mortality. Dead fish were removed, counted and recorded. Four fish were taken randomly from each tank before feeding fortnightly and weighed to access their growth rates. Weight gain, average daily growth, specific growth rate, feed intake, feed conversion ratio, feed efficiency ratio, nitrogen metabolism, survival and economic indices were calculated from the data obtained.

Collection of faeces

Faecal collection commenced 4 days after changing to experimental diets to allow evacuation of the previous feeds. The culture water was drained completely from all tanks and replaced one hour after the last meal for the day, to ensure proper cleaning and avoid contamination of faeces with uneaten feeds.

The settled faeces and surrounding water were gently siphoned from the base of the experimental tanks for all treatment groups after 14–16 h of feeding (Bureau and Cho 1999; Belal 2005; Koprucu and Ozdemir 2005). Faecal samples were dried and together with the diets were analysed for crude protein, ether extract, nitrogen free extract (AOAC 2005), energy (Ahmad and Abdel-Tawwab 2011) and the digestion indicator (Furukawa and Tsukahara 1966).

Performance indices

Weight gain (WG, g) = Final weight (FW) - Initial weight (IW)
Average daily growth (ADC, g) = WG/Duration of experiment (days)
Specific growth rate (SGR, % per day) = (Log FW-Log IW)/Duration of experiment (days) x 100
Percentage survival (%) = Number of fish at the end of experiment/Initial number of fish x 100
Feed conversion ratio (FCR) = Feed intake/Weight gain
Protein efficiency ratio (PER) = Weight gain/Protein intake
Nitrogen metabolism (Nm) = Duration of experiment (0.549) x (Initial weight + Final weight)/2
Protein productive value (PPV, %) = Protein gained in fish/Protein in feed x100
Apparent nutrient digestibility = 100 x (1 – (F/D) x (D_1/F_1)
(D = % nutrient of diet; F = % nutrient of faeces; D_1 = % marker (Cr_2O_3) in diet; F_1 = % marker [Cr_2O_3] in faeces)
Total cost of feed (TCF) = Feed cost (kg) x Feed intake (kg)
Total investment cost (TIC) = Cost of feeding (₦) + Cost of fingerlings stocked (₦)
Value of fish produced (VF) = Cost of fish (₦) x Final weight (kg)
Economic conversion ratio (ECR) = FCR x Cost of feed/kg (₦)
Profit index (PI) = VF/TCF
Benefit cost ratio (BCR) = VF/TIC

Statistical analysis

One-way analysis of variance (ANOVA) was used to analyse the data. Duncan multiple range test was used to compare differences among means while polynomial regression analysis of weight gain was also done at 5 % probability level using statistical software SAS (Statistical Analysis System, 2010).

Results

Effects of dietary tamarind pulp and leaf meal on growth performance

The results on growth performance of *C. gariepinus* fed with varying inclusion of TP and TL as dietary additives showed that there were no significant differences (P>0.05) between the weight gain (WG), average daily growth (ADG), and specific growth rate (SGR) of the fish fed with the control diets (Table 2). However, all the groups of fish fed diet fortified with TP and TL had significantly higher (P<0.05) WG than the control diets. The WG, ADG, and SGR of fish fed with diets treated with TP increased with the increasing levels of inclusion with significantly higher (P<0.05) values at 20 g.kg^{-1}. The WG, ADG and SGR of fish fed diets containing 5–10 g TL followed the same pattern after which it declined.

The best percentage survival (PS) was obtained in fish fed pulp at 20 g.kg^{-1} diet. The polynomial regression shows the optimum inclusion of 3.02 % pulp (30.2 g.kg^{-1} diet) and 1.72 % leaf (17.2 g.kg^{-1} diet) with respect to WG (Fig. 1). Fish fed diets treated with TP and TL had significantly lower (P<0.05) feed conversion ratio (FCR) than those fed the control diets (Table 2). The FCR of fish fed with diets treated with TP and TL did not differ significantly (P>0.05). However, the FCR of the group fed with 10 g TL.kg^{-1} diet differed significantly (P<0.05) from the group on 5 gTL.kg^{-1} diet. Protein efficiency ratio (PER) of fish fed tamarind-treated diets were significantly enhanced (P<0.05) compared to those fed with the control diets. Nitrogen metabolism (Nm) of the experimental fish fed with the control diets was significantly lower (P<0.05) than those fed with diets containing 10–20 g TP and TL.

Best Nm was obtained from the fish fed with diet containing 20 g TP.kg^{-1} diet. Treating the diets of *C. gariepinus* with TP and TL had significant effects on protein productive value (PPV). The PPV of the fish fed with diets treated with TP and TL was significantly higher (P<0.05) than those fed the control diets. However, increasing levels of inclusion of TP and TL reduced PPV. Treating the diets of *C. gariepinus* with tamarind significantly improved (P<0.05) Nm and PPV of the fish.

Table 2. Growth performance and nutrient utilisation of *Clarias gariepinus* fed varying tamarind pulp and leaf meal as feed additives for 84 days

Diets ($g.kg^{-1}$)	Parameters								
	FW (g)	WG (g)	ADG (g)	SGR ($\%.day^{-1}$)	PS (%)	FI ($g.fish^{-1}$)	FCR	Nm	PPV (%)
0.0	30.72±3.77^{d}	24.97±3.79^{d}	0.30±0.05^{d}	0.87±0.06^{d}	88.89±5.09^{c}	45.26±2.83^{d}	1.82±0.07^{a}	840.84±54.91^{d}	19.01±1.73^{d}
2.0 O	30.09±1.26^{d}	24.34±1.28^{d}	0.29±0.02^{d}	0.86±0.02^{d}	90.03±5.77^{c}	44.16±1.95^{d}	1.81±0.07^{a}	826.32±28.95^{d}	20.24±1.43^{d}
5.0P	34.65±2.21^{c}	28.90±2.21^{c}	0.34±0.01^{c}	0.93±0.01^{c}	91.11±1.92^{bc}	46.54±3.02^{cd}	1.61±0.03^{b}	931.62±22.42^{c}	42.78±1.58^{a}
10.0P	41.03±0.97^{b}	35.29±0.97^{b}	0.42±0.03^{b}	1.02±0.03^{b}	93.33±0.00^{abc}	53.16±2.78^{b}	1.51±0.07^{bc}	1078.65±51.03^{b}	36.99±0.08^{b}
15.0P	42.57±1.58^{b}	36.80±1.58^{b}	0.44±0.02^{b}	1.04±0.02^{ab}	95.56±1.92^{abc}	55.60±1.83^{b}	1.52±0.02^{bc}	1114.01±36.50^{b}	34.75±0.38^{b}
20.0P	45.86±1.25^{a}	40.11±1.22^{a}	0.48±0.01^{a}	1.08±0.01^{a}	98.89±1.92^{a}	61.04±0.82^{a}	1.52±0.03^{bc}	1190.18±29.62^{a}	30.50±4.23^{c}
5.0L	34.44±2.42^{c}	28.69±2.42^{c}	0.34±0.03^{c}	0.92±0.03^{c}	93.33±3.33^{abc}	46.09±3.80^{cd}	1.61±0.05^{b}	926.62±56.11^{c}	42.27±0.25^{a}
10.0L	42.48±1.94^{b}	36.72±1.92^{b}	0.44±0.02^{b}	1.03±0.02^{ab}	97.78±3.85^{ab}	55.14±2.22^{b}	1.50±0.02^{c}	1112.24±45.14^{b}	37.84±4.51^{b}
15.0L	37.28±3.08^{c}	31.53±3.07^{c}	0.38±0.04^{c}	0.96±0.04^{c}	94.45±3.85^{abc}	50.39±4.54^{bc}	1.60±0.09^{bc}	992.19±71.24^{c}	35.03±0.58^{b}
20.0L	41.46±1.13^{b}	35.71±1.12^{b}	0.43±0.01^{b}	1.02±0.01^{b}	94.44±5.09^{abc}	54.16±1.82^{b}	1.52±0.02^{bc}	1088.64±26.23^{b}	34.58±1.39^{b}

Means with the same letter on the same column are not significantly different at $P<0.05$

O = Oxytetracycline; FW = Final weight; WG = Weight gain; ADG = Average daily growth; SGR = Specific growth rate; P = Pulp; L = Leaf; PS = Percentage survival; FI = Feed intake; FCR = Feed conversion ratio; PER = Protein efficiency ratio; Nm = Nitrogen metabolism; PPV = Protein productive value

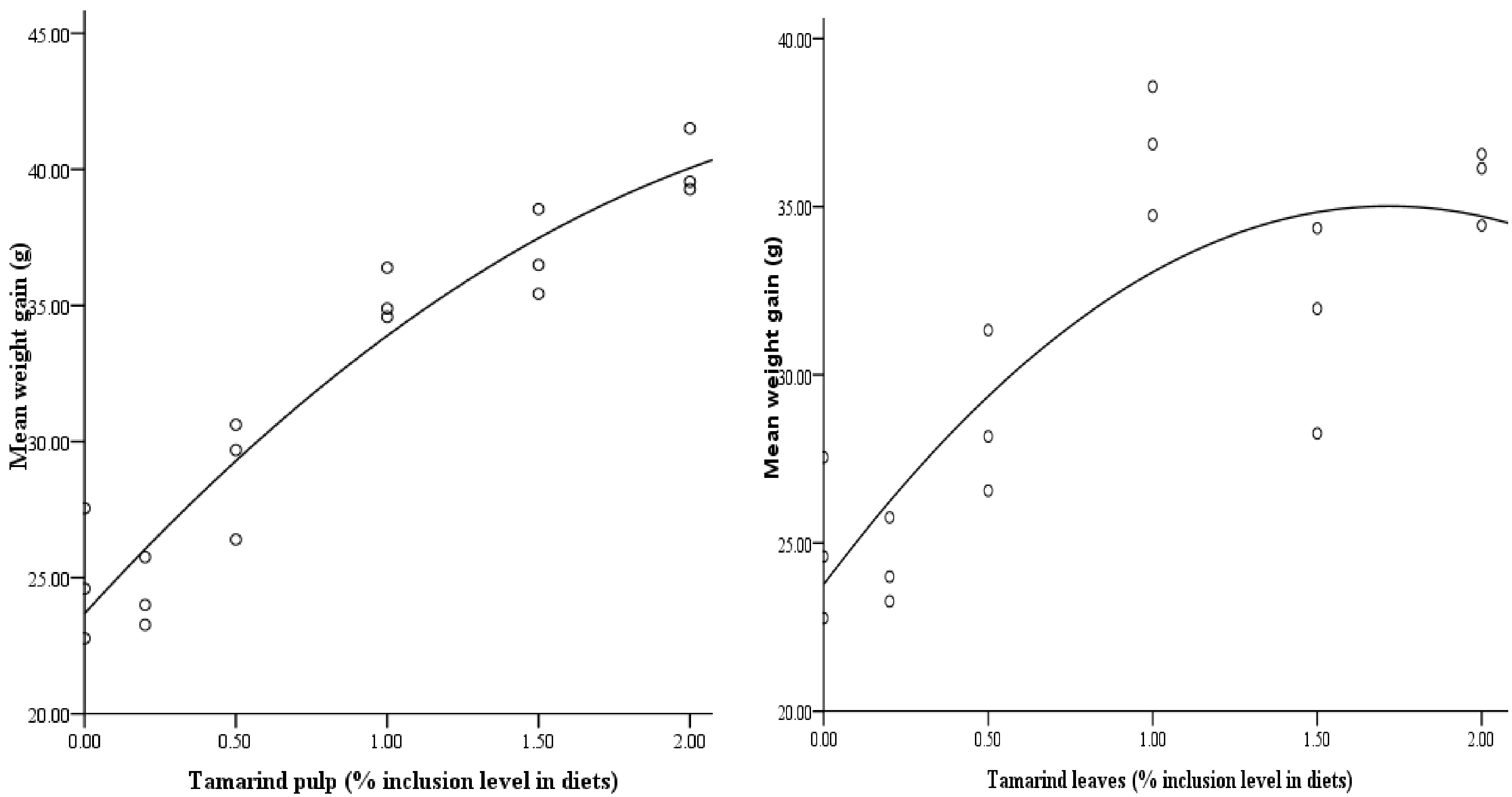

Fig.1. Relationship between levels of inclusion of dietary tamarind and weight gain of *Clarias gariepinus*

Apparent nutrient digestibility

Apparent nutrient digestibility of crude protein of diets was significantly (P<0.05) enhanced with all TP-treated groups and 10–20 g TL.kg^{-1} diet than both the OTC-treated and untreated control diets (Table 3). The highest apparent nutrient digestibility of crude lipid was obtained for the diet containing 20 g TP, followed by 10 g TL diet. Groups of *C. gariepinus* on 15–20 g TP and 10–20 g TL diets showed significantly higher (P<0.05) apparent nutrient digestibility of energy, compared to those on untreated control diet.

Table 3. Apparent nutrient digestibility (%) of *Clarias gariepinus* fed diets treated with tamarind pulp and leaves as dietary additive for 84 days

Diet (g.kg^{-1})	Parameters		
	Crude protein (%)	Crude lipid (%)	Gross energy (%)
0.00	52.98±6.54^{e}	32.17±1.92^{e}	16.05±3.02^{f}
2.0 OTC	62.83±0.11^{d}	35.97±1.76^{de}	18.00±3.55^{def}
5.0 Pulp	58.54±1.31^{d}	43.38±5.33^{cd}	17.31±0.70^{ef}
10.0 Pulp	61.68±0.99^{d}	51.22±2.92^{bc}	19.23±0.74^{cdef}
15.0 Pulp	68.51±3.09^{c}	51.22±7.85^{bc}	21.20±1.37^{bcd}
20.0 Pulp	83.09±2.44^{a}	65.58±3.28^{a}	25.80±0.38^{a}
5.0 Leaves	53.57±6.09^{e}	37.19±5.60^{de}	16.42±0.39^{ef}
10.0 Leaves	78.89±1.03^{a}	57.69±5.42^{ab}	23.04±1.16^{ab}
15.0 Leaves	68.52±1.03^{c}	53.80±3.43^{bc}	19.99±0.47^{bcde}
20.0 Leaves	73.83±2.31^{b}	43.60±7.96^{cd}	21.71±6.542.62^{bc}

Means with the same letter on the same column are not significantly different at P<0.05; OTC = Oxytetracycline

Economic analysis

There were significant differences in the total cost of feeding (TCF), investment cost (IC), value of fish (VF), economic conversion ratio (ECR), profit index (PI) and benefit cost ratio (BCR), among the treatments (Table 4). The TCF of *C. gariepinus* fed with diets treated with 10–20 g TP and TL were significantly higher (P<0.05) than those fed diets treated with 5 g inclusion level and the control diets. The GP, PI and BCR of fish on diets treated with TP and TL was significantly higher (P<0.05) than those of the control diets. Treating the diets of *C. gariepinus* with TP and TL significantly reduced ECR.

Table 4. Economic analysis of *Clarias gariepinus* fed diets ($g.kg^{-1}$) treated with tamarind pulp and leaves as dietary additive for 84 days

Diets	Parameters						
	FC.kg (₦)	TCF (₦)*	TIC (₦)	VF (₦)**	ECR	PI	BCR
0.0	180.10 ± 0.00^{f}	214.37 ± 9.19^{d}	574.52 ± 9.19^{d}	484.35 ± 19.56^{e}	327.18 ± 13.39^{a}	2.26 ± 0.06^{b}	0.86 ± 0.02^{e}
2.0OTC	183.00 ± 0.00^{a}	215.52 ± 12.77^{d}	575.52 ± 12.77^{d}	481.01 ± 14.63^{e}	332.26 ± 12.49^{a}	2.23 ± 0.07^{b}	0.84 ± 0.01^{e}
5.0P	180.40 ± 0.00^{e}	229.75 ± 15.98^{d}	592.75 ± 15.98^{d}	575.75 ± 48.17^{d}	290.64 ± 5.69^{b}	2.51 ± 0.04^{a}	0.98 ± 0.05^{d}
10.0P	180.60 ± 0.00^{d}	265.55 ± 12.43^{bc}	625.55 ± 12.43^{bc}	673.17 ± 30.22^{bc}	272.13 ± 13.52^{bc}	2.54 ± 0.08^{a}	1.08 ± 0.03^{bc}
15.0P	180.90 ± 0.00^{c}	288.38 ± 14.81^{b}	648.38 ± 14.81^{b}	732.42 ± 39.46^{ab}	273.19 ± 3.40^{bc}	2.54 ± 0.02^{a}	1.13 ± 0.03^{ab}
20.0P	181.10 ± 0.00^{b}	327.99 ± 7.18^{a}	687.99 ± 7.18^{a}	816.48 ± 32.17^{a}	275.75 ± 5.55^{bc}	2.49 ± 0.04^{a}	1.19 ± 0.03^{a}
5.0L	180.40 ± 0.00^{e}	232.25 ± 20.78^{d}	592.75 ± 20.78^{d}	578.86 ± 50.83^{d}	289.90 ± 8.54^{bc}	2.46 ± 0.07^{a}	0.98 ± 0.05^{d}
10.0L	180.60 ± 0.00^{d}	292.16 ± 16.61^{b}	652.16 ± 16.61^{b}	747.60 ± 44.37^{ab}	271.33 ± 3.41^{c}	2.56 ± 0.01^{a}	1.15 ± 0.04^{ab}
15.0L	180.90 ± 0.00^{c}	257.80 ± 18.13^{c}	617.80 ± 18.13^{c}	633.59 ± 56.80^{c}	289.47 ± 15.92^{bc}	2.46 ± 0.13^{a}	1.02 ± 0.07^{cd}
20.0L	181.10 ± 0.00^{b}	278.24 ± 23.37^{bc}	638.92 ± 23.37^{bc}	705.31 ± 51.86^{bc}	274.68 ± 3.68^{bc}	2.54 ± 0.03^{a}	1.10 ± 0.04^{b}

Means with the same letter on the same column are not significantly different at $P<0.05$. FC = Feed cost; TCF = Total cost of feeding; TIC = Total investment cost; VF = Value of fish; ECR = Economic conversion ratio; PI = Profit index; BCR = Benefit cost ratio

*Prices of feed ingredients at the prevailing market price in Nigeria

**Value of 1kg fish = ₦600, 1US S = ₦198.23 (in October 2015)

Discussion

The results from this study demonstrated better nutrient digestibility with consequent growth promotion in the *C. gariepinus* fed diets fortified with tamarind pulp and leaf compared to the control groups. The enhanced digestibility of nutrients in fish on tamarind-fortified diets further elucidates the digestive properties of these phytogenics. The improved growth performance might have been because tamarind pulp and leaf stimulated digestibility of nutrients due to the presence of polyphenolic compounds in these additives. The results of this study coincided with results of some other researchers demonstrating the beneficial effects of supplementing fish diets with phytobiotics. Dada and Ikuerowo (2009) reported significant increase in growth performance of *C. gariepinus* broodstock fed diets supplemented with ethanolic extract of bitter kola at the rate of 0.25–2.0 $g.kg^{-1}$ compared to the control group. Sanchez et al. (2009) similarly reported improved growth performance of shrimp fed with herbal extract. Aly and Mohamed (2010) also reported significantly higher body weight gain of *Oreochromis niloticus* (Linnaeus 1758) fed diets supplemented with *Echinacea purpurea* and *Allium sativum* than those fed with diets treated with oxytetracycline and the negative control. Similar improved growth performance of *C. gariepinus* juveniles fed diets supplemented with residue of walnut leaf and onion bulb (Bello et al. 2012), date palm seed (Sotolu et al. 2014), and fluted pumpkin leaf powder (Dada 2015) was reported.

Similar results on improved growth performance of Nile tilapia diets treated with ginseng herb (Ashraf and Goda 2008), green tea (Abdel-Tawwab et al. 2010) and caraway seed (Ahmad and Abdel-Tawwab 2011) meal as phytogenic additives were reported. Sturgeon fed garlic powder (Dong-Hoon et al. 2014) and *Clarias batrachus* (Linnaeus 1758) fed diets containing *Ocimum gratissimum* leaf extract (Gayatri and Rajani 2014) also exhibited improved growth performance. Also, sea bass fed diets containing garlic and onion powder had better growth performance and nutrient utilisation when compared to the control groups (Saleh et al. 2014).

In contrast to the present study, Pongsak and Parichat (2009) did not observe significant differences ($p<0.05$) in weight gain, feed conversion ratio and specific growth rate of *Oreochromis niloticus* fed varying inclusions of Chinese chive oil compared to 0.01 % (100 $mg.kg^{-1}$ diet) oxytetracycline; although the researchers fed the fish for only 2 weeks. Pakravan et al. (2011) and Bahrami et al. (2015) did not obtain significant difference in the specific growth rate and feed conversion ratio of carp fed diets containing willow herb and wood betony extracts. Oxytetracycline, a broad-spectrum antibiotic, is one of the FDA approved antibiotics usually applied through medicated feed in aquaculture (Romero et al. 2012).

Previous studies showed growth-promoting effect of OTC-treated diet in channel catfish (Sanchez-Martinez et al. 2008) and Nile tilapia (Reda et al. 2013) when compared to the non-treated diet. Supplementing the diets of *C. gariepinus* fingerlings with oxytetracycline did not enhance growth and nutrient utilisation when compared to TP and TL treated groups.

Growth and utilisation of *C. gariepinus* improved with increase in the inclusion levels of tamarind pulp and leaf except at 15 $g.kg^{-1}$ TL treatment: the reason for the decrease at that level (although significantly higher than the control), is not clear. Dada and Ikuerowo (2009) also reported reduction in the growth performance of the experimental fish at 2.0 g bitter kola per kg diet, the value of which was still better than the control diet. The PS in all groups of the fish fed with the diets treated with tamarind increased compared with the control diets. This increase might be indicative of the efficiency of the tested tamarind products to improve the health and physiological status of fish.

The economic conversion ratio (ECR) also known as incidence of cost shows the cost of feed for producing 1 kg of fish flesh: hence, the lower the value of ECR, the better for the fish farmer. Inclusion of tamarind in the diets of *C. gariepinus* in this study reduced ECR while PI and BCR were increased. The BCR is more than 1 at inclusion levels $\geq$ 10 $g.kg^{-1}$ diet, indicating profitability of the investment in the production of this fish at these levels. El-Dakar et al. (2008) obtained similar results on incidence cost (also known as ECR) and profit index of hybrid tilapia fed diets incorporated with basil leaf powder compared to the control fish. Improved economic efficiency in the production of *C. gariepinus* fed with diets treated with onion and walnut leaf (Bello et al. 2012) and roselle and bitter leaf (Adeyemo 2014, Adeyemo 2015) were also reported. Higher net profit and percentage economic efficiency were similarly obtained from the production of Nile tilapia when fed with diets containing black cumin seeds, green tea and propolis extraction (Wafaa et al. 2014).

It could be concluded that tamarind pulp and leaf-fortified diets stimulated nutrient digestibility and consequently enhanced the growth performance, survival rate and economy of production of *Clarias gariepinus*. Therefore, 20 g pulp and 10 g leaf of tamarind per kg diet is recommended as a suitable alternative to synthetic antibiotic for optimum growth performance and economic efficiency.

References

Abdel-Tawwab M., M.H. Ahmad., E.A. Medhat and F.M. Saleh. 2010. Use of green tea, *Camellia sinensis* L. in practical diet for growth and protection of Nile tilapia, *Oreochromis niloticus* (L) against *Aeromonas hydrophila* infection. Journal of the World Aquaculture Society 41:203–213.

Adeniyi O.V., F. E. Olaifa, B.O. Emikpe and S.T. Ogunbanwo. 2017. Phytochemical components and antibacterial activity of *Tamarindus indica* Linn extracts against some pathogens. Biotechnology Journal International 17:1–9.

Adeyemo M.A. 2014. Effects of roselle as dietary additive on growth performance and production economy of *Clarias gariepinus*. Journal of Emerging Trends in Engineering and Applied Sciences 5:1–8.

Adeyemo M.A. 2015. Production economy of bitter leaf (*Vernonia amygdalina*) as dietary additive fed to *Clarias gariepinus*. Journal of Emerging Trends in Engineering and Applied Sciences 6:267–275.

AOAC. 2005: Official Methods of Analysis of AOAC International, 18th Edition, Arlington, VA, USA. 68 pp.

Aengwanich W., M. Suttajit, P. Chaleeri, P. Thangklang, S. Kapan, T. Srikhun and T. Boonsorn. 2009. Antibiotic effect of polyphenolic compound extracted from tamarind (*Tamarindus indica* L.) seed coat on productive performance of broilers. International Journal of Applied Research Veterinary Medicine 7:112–115.

Ahmad M.H. and M. Abdel-Tawwab. 2011. The use of caraway seed meal as a feed additive in fish diets: Growth performance, feed utilization and whole body composition of Nile tilapia, *Oreochromis niloticus* (L) fingerlings. Aquaculture 314:110–114.

Aly S.M. and M.F. Mohamed. 2010. *Echinacea purpurea* and *Allium sativum* as immunostimulants in fish culture using Nile tilapia (*Orechromis niloticus*). Journal of Animal Physiology and Animal Nutrition 94:e31–e39.

Ashraf M.A. and S. Goda. 2008. Effect of dietary Ginseng herb (Ginsana^R G115) supplementation on growth, feed utilization and haematological indices of Nile tilapia, *Oreochromis niloticus* (L) fingerlings. Journal of the World Aquaculture Society 39:205–214.

Bahrami B.S., H.F Paykan, S. Dorafshan, S.N. Mahboobi. and M.R. Vahabi. 2015. Effect of dietary wood betony, *Stachys lanvandulifolia* extract on growth performance, haematological and biochemical parameters of common carp, *Cyprinus carpio*. Iranian Journal of Fisheries Sciences 14:805–817.

Bala S.A. 2006. Some ethnomedical plants of the savanna regions of West Africa; description and phytochemicals. Triumph Publishing Limited, Kano, Nigeria. 266 pp.

Belal I.E.H. 2005. A review of some fish nutrition methodologies. Bioresource Technology 96: 395–402.

Bello O.S., F.E. Olaifa and B.O. Emikpe. 2012. The effect of walnut (*Tetracarpidium conophorum*) leaf and onion bulb residues on the growth performance and nutrient utilization of *Clarias gariepinus* juveniles. Journal of Agricultural Science 4:205–213.

Bhadoriya S.S., A. Ganeshpurkar, J. Narwaria, G. Rai and A.P. Jain. 2011. *Tamarindus indica*: Extent of explored potential. Phamacognosy Review 5:73–81.

Bureau D.P. and C.Y. Cho. 1999. Measuring digestibility in fish. UG/OMNR Fish Nutrition Research Laboratory Technical Document, University of Guelph, Ontario Canada, pp 1–9.

Dada A.A. and M. Ikuerowo. 2009. Effects of ethanolic extracts of *Garcinia kola* seeds on growth and haematology of catfish (*Clarias gariepinus*) brood stock. African Journal of Agricultural Research 4:344–347.

Dada A.A. 2015. Use of fluted pumpkin (*Telfairia occidentalis*) leaf powder as feed additive in African catfish (*Clarias gariepinus*) fingerlings. International Journal of Biological and Chemical Sciences 9:301–307.

Dong-Hoon L., L. Seong-Ryul, H. Jung-Jo, L. Sang-Woo, R. Chang-six and K. Jeong-Dae. 2014. Effect of dietary garlic powder on growth, feed utilization and whole body composition changes in fingerling sterlet sturgeon, Asian-Australasian Journal of Animal Sciences 27: 1303–1310.

El-Dakar A.Y., G.D. Hassanien, S.S. Gad and S.E. Sakr. 2008. Use of dried leaves as a feeding attractant for hybrid tilapia (*Oreochromis niloticus* x *Oreochromis aureus*) fingerlings. Mediterranean Aquaculture 1: 35–44.

FAO. 2010. The State of World Fisheries and Aquaculture. World Review of Fisheries and Aquaculture, Rome.89 pp.

FAO. 2012. The State of World Fisheries and Aquaculture. World Review of Fisheries and Aquaculture, Rome. 26 pp.

Furukawa A. and H. Tsukahara. 1966. Acid digestion method for the determination of chromic oxide as an index substance in the study of digestibility of fish feed. Bulletin of the Japanese Society of Scientific Fisheries 32: 502–504.

Gayatri N. and K.S. Rajani. 2014. Immunomodulatory effect of *Ocimum gratissimum* Linn leaf extract on a common fish, *Clarias batrachus* Linn. International Journal of Drug Delivery 6:268–278.

Gupta A., M. Naraniwal. and V. Kothari. 2012. Modern extraction methods for preparation of bioactive plant extracts. International Journal of Pure and Natural Sciences 1:8–26.

Koprucu K. and Y. Ozdemir. 2005. Apparent digestibility of selected feed ingredients for Nile tilapia (*Oreochromis niloticus*). Aquaculture 250:308–316.

Kumar C.S. and S. Bhattacharya. 2008. Tamarind seed: Properties, processing and utilization. Food Science and Nutrition 48:1–20.

Pakravan S., A. Hajimoradloo and R. Ghorbani. 2011. Effect of dietary willow herb, *Epilobium hirsutum*, extract on growth performance, body composition, haematological parameters and *Aeromonas hydrophila* challenge on common carp, *Cyprinus carpio*. Aquaculture Research 42: 1–9.

Pongsak R. and P. Parichat. 2009. Potential of Chinese chive oil as a natural antimicrobial for controlling *Flavobacterium columnare* infection in Nile tilapia, *Oreochromis niloticus*. Aquaculture 75:1431–1437.

Reda R.M., R.E. Ibrahim, E.G. Ahmed and Z.M. El-Bouhy. 2013. Effect of oxytetracycline and florfenicol as growth promoters on the health status of cultured *Oreochromis niloticus*. Egyptian Journal of Aquatic Research 39:241–248.

Romero J., C.G. Feijoo and P. Navarrete. 2012. Antibiotics in aquaculture – use, abuse and alternatives. In: Health and environment in aquaculture (eds. D.C. Edmir, S.D. Gianmarco and J.S. Reinaldo), pp 15–198. InTech, Croatia.

Saleh N.E., F.R. Michael and M.M. Toutou. 2014. Evaluation of garlic and onion powder as phytoadditives. Egyptian Journal of Aquatic Research 41:211–217.

Samina K.K., W. Shaikh, S. Shahzadi, T.G. Kazi, K. Usmanghani, A. Kabir. and T.H. Sheerazi 2008. Chemical constituents of *Tamarindus indica,* medicinal plant in Sindh. Pakistan Journal of Botany 40:2553–2559.

Sanchez J.A.O., A.C. Flores and J.R.O. Hernandez. 2009. The effects of herbal growth promoter feed additives on shrimp performance. Research Journal of Biological Sciences 4:1022–1024.

Sanchez-Martinez J.G., R. Perez-Castaneda, J.L. Rabago-Castro, G. Aguire-Guzman and M.L. Vazqnez-Sauceda. 2008. Preliminary study on the effects on growth, condition and feeding indices in channel catfish, *Ictalurus punctatus*, after the prophylactic use of potassium permanganate and oxytetracycline. Journal of the World Aquaculture Society 39:664–670.

Shehla I., M. Azhar, M. Hasan, M.S. Ali and S.W. Ahmed. 2007. Two triterpenes lupanone and lupeol isolated and identified from *Tamarindus indica* Linn. Pakistan Journal of Pharmaceutical Sciences 20:125–127.

Sotolu A, A.A. Kigbu and A.J. Oshiowo. 2014. Supplementation of date palm (*Phoenix dactylifera*) seed as feed additive in the diets of juvenile African catfish (Buchell, 1822). Journal of Fisheries and Aquatic Science 9:359–365.

Wafaa E., I. Doaa, A. El-murr and R. Mahmoud. 2014. Effects of dietary inclusion of black cumin seeds, green tea and propolis extraction on growth parameters, body composition and economic efficiency of Nile tilapia, *Oreochromis niloticus*. World Journal of Fish and Marine Sciences 6:447–452.

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