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Phytase as a Feed Additive: Impact on Growth, Nutrient Digestibility and Carcass Composition of *Catla catla* Fingerlings Fed on Different Plant By-Products Based Diets

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Key words
Plant by-products, Phytase, *Catla catla*, Nutrients digestibility, Carcass composition, Growth performance

ABSTRACT

Owing to existence of anti-nutritional factors (ANFs) such as phytate in diets based on plant by-products, fish show poor growth and nutrition retention in their bodies because less minerals and nutrients are available to them. To overcome this problem, phytase was supplemented with different plant by-products based diets and impact was checked on digestibility of nutrients, growth performance and carcass composition of *Catla catla* fingerlings (average weight= 6.10±0.01 g), in a feeding trial lasting seventy days. The fingerlings were fed a variety of diets that were based on different plant by-products with phytase supplementation at levels of 0, 250 and 500 FTU Kg^{-1}, in three-factorial configurations with a completely random design in triplicates. Chromium oxide was added to test diets at a concentration of 1% as an inert marker. Diets were served twice a day, @ 4% of body weight of fingerlings. Feces from every fish tank were gathered twice a day to measure nutrients digestion. Phytase supplementation into the test diets considerably ($p<0.05$) enhanced the growth rate, nutrient digestibility (including crude protein, crude fat, and gross energy), and carcass composition of *C. catla*. The findings showed that the test diet with 50% MOLM and 500 FTU Kg^{-1} phytase exhibited the best growth performance, nutrient digestibility, and carcass composition. Additionally, it was discovered that phytase supplementation lowered the nutrient discharge via feces, hence reducing the amount of contaminants in the water. In conclusion, adding phytase at a level of 500 FTU Kg^{-1} was favorable for using with different plant by-products to create an inexpensive and ecologically friendly fish diet.

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INTRODUCTION

It is estimated that by 2030, there will be almost 8.5 billion people on the earth and global food security and sustainable development will be considerably supported by aquaculture, which is estimated to supply roughly 53% of the seafood consumed worldwide (FAO, 2022; UN DESA, 2023). By 2025, the world's aquaculture output of fed species is expected to be 58.9 million tons, and the demand for aqua feed is expected to reach 69.5

million tons (Tacon *et al*., 2022). In order to facilitate this expansion, the sector must look at cutting-edge ways to get sustainable ingredients for raising aqua feed output (Hua *et al*., 2019). Since past two decades, reducing reliance on fishmeal (FM) by switching to plant based by-products has proved very challenging (Gatlin *et al*., 2007; Hussain *et al*., 2024). Plant-based proteins are beneficial to fish in terms of nutrition, nutrient utilization, growth, protein retention, digestibility, nutrient bioavailability, biochemical changes, meat quality, strength, and stress response (Shahzad *et al*., 2020).

Moringa oleifera is a fast-growing plant that is abundant in macro and micronutrients, including proteins, minerals (iron, potassium, calcium, phosphorus), carbohydrates, vitamins, and many other bioactive compounds (Sahay *et al*., 2017). Its leaves contain 260 g of crude protein per kilogram of leaf, which is significantly more than the amount found in many other legumes i.e. soybean seeds (Ferreira *et al*., 2008; Hussain *et al*., 2024). Sunflower meal (SFM) is another promising substitute of FM to be used in aqua feed due to its high protein amount, palatability and low content of anti-nutritional factors (ANFs) (Saleh *et al*., 2021). It is utilized in formulations of feed because it contains natural proteolytic enzymes that aid in protein digestion in fish (Kocher *et al*., 2000; Soltan *et al*., 2023). After soybean meal, canola meal (CM) is rich source of protein and has higher concentrations of important amino acids like cysteine and methionine. CM is often utilized instead to FM in aquaculture feed (Hussain *et al*., 2022). Guar meal (GM) has rich protein value with better amino acid composition and is less expensive per unit of generated protein. Additionally, because guar gum is used less frequently as a binder, guar meal has improved digestibility and higher pellet quality (Hardy, 1999; Brinker and Friedrich, 2012).

In fish nutrition, plant proteins are a feasible sources of protein. However, presence of a number of ANFs in plants decrease their use in aqua feed. In addition to other significant ANFs such as fiber, tannins, glucosinolates, protease inhibitors, or saponins, one of the most common ANFs in plant feed sources is phytic acid or phytate (inositol hexakisphosphate, IP6) (Francis *et al*., 2001; Serra *et al*., 2024). One of the main issues with phytate in aqua feed is its detrimental impacts on growth, energy and nutrient utilization, and minerals uptake. The enzyme phytase have a critical role in increasing the discharge of minerals, such as phosphorus, that are bound to phytic acid, increasing their bioavailability for animal assimilation. The aqua feed sector has been using phytase for the past ten years to improve fish growth and nutrient utilization as well as to lower P pollution in the aquatic environment (Kumar *et al*., 2015; Negm *et al*., 2024).

Catla catla is the sixth-most recognized fish species in all known fish species of the world, making up roughly 5.6% of total output. *C. catla*, often called Thaila, is a surface feeder. The best source of human protein among all fish species is *C. catla*, which is also the cheapest. It is characterized by a high concentration of excellent quality nutrients, including vitamins, minerals, fatty acids and a balanced amino acid content (Khan *et al*., 2012; FAO, 2020). Thus, the goal of present research was to ascertain the impacts of phytase on growth, nutrient digestibility and carcass composition of *C. catla* fingerlings given different plant by-products based diets.

MATERIALS AND METHODS

This study was designed to check the impact of supplemented phytase on growth, nutrient digestibility and carcass composition of *C. catla* fingerlings fed on different plant by products based test diets. The trial was held in Fish Nutrition Lab, Department of Life Sciences, KFUEIT, Rahim Yar Khan.

Conditions of trial and fish

C. catla fish (average weight= 6.10±0.01 g) was taken from Fish Seed Hatchery, Rahim Yar Khan and looked after in glass aquarium (especially designed to collect feces) for 15 days to acclimatize them to trial conditions. The fingerlings were treated with NaCl (5 g L^{-1}) solution before start of trial in order to avoid any fungal infections. The fingerlings were fed on basal diet throughout this acclimation stage. Water quality indicators i.e. dissolved O_2 (4-6 mg L^{-1}), temperature (26-28°C) and pH (6.7-7.5) were checked on daily basis.

Test diets formulation

Four different plant by-products including MOLM, SFM, CM and GM were used to replace FM in test diets, in which phytase was added at the level of 250 and 500 FTU Kg^{-1}, except control diet (FM based) with 0 FTU Kg^{-1} phytase supplementation. All feed ingredients (Table I) were sourced from a commercial feed mill, and recognized methods were used to analyze their chemical composition (AOAC, 2005), before formulation of diets. To get the required particle size to pass through a 0.5 mm filter, all ingredients were ground and sieved.

The fish oil was slowly mixed with the mixture by blending in the blender for 5 min. About 10 to 15% water was included to produce a suitable paste. Then, granulator turned the already prepared dough into food granules. To assess digestibility, 1% chromium oxide was included in the test meals as an inert marker. Two grams of phytase were dissolved in 1000ml of purified water. According to

Table I. Ingredients composition (%) of test diets.

Ingredients	T_1 (control)	T_2 (MOLM)	T_3 (MOLM)	T_4 (SFM)	T_5 (SFM)	T_6 (CM)	T_7 (CM)	T_8 (GM)	T_9 (GM)
Fishmeal	50	35	50	35	50	35	50	35	50
		15		15		15		15	
Soybean meal	15	15	15	15	15	15	15	15	15
Wheat flour	17	17	17	17	17	17	17	17	17
Rice polish	8	8	8	8	8	8	8	8	8
Fish oil	6	6	6	6	6	6	6	6	6
Vitamin premix	1	1	1	1	1	1	1	1	1
Mineral premix	1	1	1	1	1	1	1	1	1
Ascorbic acid	1	1	1	1	1	1	1	1	1
Chromic oxide	1	1	1	1	1	1	1	1	1
Phytase (FTU Kg^{-1})	0	250	500	250	500	250	500	250	500

MOLM, *M. oleifera* leaf meal; SFM, Sunflower meal; CM, Canola meal; GM, Guar meal; Phytase inclusion was by the substitution of wheat flour.

Robinson *et al*. (2002) test diets were sprayed with the recommended concentrations of phytase. One test diet without phytase (T_1) and eight test diets (T_2, T_3, T_4, T_5, T_6, T_7, T_8, and T_9) with varying levels of phytase (250 and 500 FTU Kg^{-1}) were formulated.

Feeding protocol and sampling

In a completely randomized design, nine fish groups (N = 405) were created in triplicates having 15 fingerlings in each group. Test diets were fed to fish about 5 % of their body mass twice per day. Following the feeding period, unused feed was taken out of fish tanks in order to gauge feed intake. Fecal matter was collected after 2 h of feeding via the tanks' fecal collection tubes. After being dried, the feces were preserved for chemical examination.

Growth analysis

The fingerlings of each tank were bulk weighed at the beginning and end the trial to check growth performance. Growth features including weight gain percentage (WG%), feed conversion ratio (FCR), and specific growth rate (SGR%) were determined by following standard formulae:

$$\text{WG\%} = \frac{\text{Final weight} - \text{initial weight}}{\text{Initial weight}} \times 100$$

$$\text{FCR} = \frac{\text{Total dry feed intake (g)}}{\text{Wet weight gain (g)}}$$

$$\text{SGR\%} = \frac{(\text{ln. final weight of fish} - \text{ln. initial weight of fish})}{\text{Days of trial}} \times 100$$

Feed, feces and carcass chemical analysis

The feed, feces and carcass samples were homogenized separately by using pestle and motor and then chemically checked by using conventional methods (AOAC, 2005). Moisture content was evaluated by oven drying at 105℃ for about 12 h. Crude protein (N×6.25) was measured with a micro-Kjeldahl apparatus. A Soxtec HT2 1045 system was used to extract crude fat by ether extraction method; calcination at 650°C for about 12 h. at constant weight was used to determine crude ash content. Bomb calorimeter was utilized to measure the gross energy of samples.

Chromic oxide estimation

The content of chromic oxide (Cr_2O_3) was gauged by acid digestion method as described by Divakaran *et al*. (2002) following oxidation of ash samples of feed and feces by using reagent $HClO_4$.

Nutrient digestibility calculations

The nutrient digestibility of experimental diets was determined by calculating apparent digestibility coefficients (ADC%) by utilizing following standard formula:

$$\text{ADC\%} = 100 - \left(\frac{\%\ Cr_2O_3\ in\ diet}{\%\ Cr_2O_3\ in\ diet}\right)\left(\frac{\%\ \text{nutrient in feces}}{\%\ \text{nutrient in diet}}\right) \times 100$$

Statistical assay

Utilizing one-way ANOVA, the data of feed digestibility, growth, mineral absorption, and overall body composition was analyzed (Steel and Torrie, 1996). Using Tukey's Honesty Significant Difference Test, differences between means were contrasted. According to Snedecor and Cochran (1989), when comparing variances across means, a significance threshold of $p<0.05$ was taken into account. For this aim, the Co-stat computer program was employed.

RESULTS

This study explored the effects of phytase as a supplement on the growth performance, carcass composition, and nutrient digestibility of *C. catla*

Table II. Growth indices of *C. catla* fingerlings fed diets based on different plant by-products supplemented with phytase.

Test diets	Fishmeal protein replacement levels (%)	Plant by products	Plant by products replacement levels (%)	Phytase (FTU Kg-^{1})	Initial weight (g)	Final weight (g)	Weight gain (g)	Weight gain (%)	Weight gain (fish^{-1} day^{-1}) g	Feed Intake (fish^{-1}day^{-1})g	FCR	SGR
T_1	50	MOLM	0	0	6.10±0.01^{i}	9.6±0.12^{i}	3.5±0.10^{i}	57.1±1.6^{i}	0.05±0.001^{i}	0.31±0.06^{i}	6.22±0.14^{i}	0.65±0.01^{i}
T_2	35		15	250	6.11±0.02^{c}	18.6±0.18^{c}	12.5±0.2^{c}	204.9±3.98^{c}	0.17±0.002^{c}	0.30±0.007^{c}	1.70±0.06^{c}	1.59±0.02^{c}
T_3	0		50	500	6.11±0.02^{a}	22.7±0.31^{a}	16.6±0.33^{a}	271.1±6.49^{a}	0.23±0.004^{a}	0.34±0.005^{a}	1.46±0.03^{a}	1.87±0.03^{a}
T_4	35	SFM	15	250	6.09±0.01^{f}	15.7±0.31^{f}	9.6±0.30^{f}	157.5±5.00^{f}	0.14±0.004^{f}	0.3±0.006^{f}	2.13±0.07^{f}	1.35±0.03^{f}
T_5	0		50	500	6.10±0.02^{e}	16.6±0.23^{e}	10.5±0.21^{e}	172.7±3.13^{e}	0.15±0.003^{e}	0.29±0.005^{e}	1.94±0.06^{e}	1.43±0.02^{e}
T_6	35	CM	15	250	6.11±0.03^{d}	17.4±0.13^{d}	11.3±0.107^{d}	185.7±1.03^{d}	0.16±0.001^{d}	0.29±0.004^{d}	1.78±0.03^{d}	1.50±0.01^{d}
T_7	0		50	500	6.12±0.02^{b}	20.6±0.18^{b}	14.5±0.16^{b}	236.7±1.85^{b}	0.21±0.002^{b}	0.29±0.004^{b}	1.39±0.02^{b}	1.73±0.01^{b}
T_8	35	GM	15	250	6.07±0.03^{h}	12.39±0.28^{h}	6.32±0.31^{h}	104.1±5.6^{h}	0.09±0.004^{h}	0.29±0.004^{h}	3.20±0.14^{h}	1.02±0.04^{h}
T_9	0		50	500	6.09±0.01^{g}	14.45±0.13^{g}	8.37±0.12^{g}	137.5±1.7^{g}	0.12±0.001^{g}	0.29±0.004^{g}	2.41±0.05^{g}	1.24±0.01^{g}

Data is mean ± standard deviation (N=3). Within columns, means having distinct superscripts differ significantly ($p<0.05$); FCR, feed conversion ratio; SGR, specific growth rate

Table III. Analyzed nutrient compositions in diets based on different plant by-products supplemented with phytase.

Test diets	Fishmeal protein replacement levels (%)	Plant by products	Plant by-products replacement levels (%)	Phytase (FTU Kg^{-1})	Crude protein	Crude fat	Gross energy
T_1	50	MOLM	0	0	30.63±0.02	8.22±0.01	3.53±0.02
T_2	35		15	250	30.55±0.04	8.23±0.02	3.53±0.01
T_3	0		50	500	30.67±0.03	8.24±0.01	3.54±0.02
T_4	35	SFM	15	250	30.53±0.03	8.24±0.02	3.52±0.01
T_5	0		50	500	30.53±0.02	8.25±0.02	3.53±0.02
T_6	35	CM	15	250	30.66±0.02	8.24±0.03	3.53±0.02
T_7	0		50	500	30.65±0.02	8.24±0.03	3.53±0.02
T_8	35	GM	15	250	30.56±0.02	8.21±0.01	3.53±0.02
T_9	0		50	500	30.45±0.02	8.22±0.01	3.53±0.02

Data is mean ± standard deviation (N=3). In columns, means with distinct superscripts differ significantly ($p<0.05$).

fingerlings given different plant by product based diets. MOLM, SFM, CM, and GM plant by-products were the basic ingredients to replace FM. The current study's findings are as follows:

Growth performance

The growth indices of *C. catla* fingerlings fed phytase supplemented diets based on different plant by-products are shown in Table II. It was recorded that T_3 diet; having 50% MOLM with 500 FTU Kg^{-1} phytase showed maximum WG% (271.1%), SGR (1.87%), and lowest FCR (1.46). The second best values were observed when fish were given diet T_7; in which 50% CM with 500 FTU Kg^{-1} phytase resulted in the WG% (236.7%) and SGR (1.73%) with FCR (1.39), respectively. The minimum values of WG% (57.1%), SGR (0.65%) and highest FCR (6.22) were resulted from T_1 test diet with 0 FTU Kg^{-1} phytase. The results of growth performance showed that MOLM and CM with phytase inclusion are better alternatives of protein for fish diets in place of costly FM.

Nutrient digestibility

Tables III and IV show the nutrients percentage in test diets and feces of *C. catla*, while Table V shows their digestibility values. In different plant by-product based diets, the phytase as a supplement improved the nutrients digestibility by decomposing phytate. The test diet T_3 (50% MOLM with 500 FTU Kg^{-1} phytase) resulted in the highest ADCs (CP: 73.45%, CF: 77.94%, and GE: 75.79%), while the control test diet T_1 gave the lowest values of ADCs (CP: 40.46%, CF: 43.74%, and GE: 31.64%). Second highest ADC% of CP, CF, and GE were resulted by T_7 (50% CM with 500 FTU Kg^{-1} phytase) with values 68.22%, 75.93%, and 72.95%, correspondingly.

Table IV. Analyzed nutrient compositions in feces of *C. catla* fed diets based on different plant by products supplemented with phytase.

Test diets	Fishmeal protein replacement levels (%)	Plant by products	Plant by-products replacement levels (%)	Phytase (FTU Kg-^{1})	Crude protein	Crude fat	Gross energy
T_1	50	MOLM	0	0	24.73±0.26^{i}	6.27±0.16^{i}	2.95±0.03^{i}
T_2	35		15	250	14.50±0.51^{c}	2.94±0.04$_{c}$	1.38±0.09^{c}
T_3	0		50	500	10.18±0.08^{a}	2.27±0.08^{a}	1.04±0.01^{a}
T_4	35	SFM	15	250	19.07±0.05^{e}	4.86±0.03^{e}	1.94±0.02^{e}
T_5	0		50	500	20.54±0.33^{f}	4.12±0.01^{f}	1.66±0.03^{f}
T_6	35	CM	15	250	16.22±0.32^{d}	3.86±0.03^{d}	1.56±0.05^{d}
T_7	0		50	500	12.54±0.33^{b}	2.56±0.03^{b}	1.16±0.04^{b}
T_8	35	GM	15	250	23.22±0.32^{h}	5.96±0.03^{h}	2.25±0.03^{h}
T_9	0		50	500	21.54±0.33^{g}	5.36±0.03^{g}	2.06±0.04^{g}

Data is mean ± standard deviation (N=3). In columns, means with distinct superscripts differ significantly ($p<0.05$).

Table V. Apparent digestibility coefficients (ADC%) of nutrients for *C. catla* fingerlings fed diets based on different plant by- products supplemented with phytase.

Test diets	Fishmeal protein replacement levels (%)	Plant by-products	Plant by-products replacement levels (%)	Phytase (FTU Kg-^{1})	Crude protein	Crude fat	Gross energy
T_1	50	MOLM	0	0	40.46±0.58^{i}	43.74±2.45^{i}	31.64±2.06^{i}
T_2	35		15	250	60.65±2.06^{d}	66.31±0.64^{d}	63.34±2.46^{d}
T_3	0		50	500	73.45±0.92^{a}	77.94±1.43^{a}	75.79±0.38^{a}
T_4	35	SFM	15	250	47.27±2.23^{f}	51.01±1.56^{f}	54.23±1.63^{f}
T_5	0		50	500	54.16±0.70^{e}	65.98±0.84^{e}	61.89±0.36^{e}
T_6	35	CM	15	250	61.89±1.59^{c}	70.84±0.05^{c}	68.02±3.19^{c}
T_7	0		50	500	68.22±1.20^{b}	75.93±0.30^{b}	72.95±1.06^{b}
T_8	35	GM	15	250	46.41±2.35^{g}	49.40±0.76^{g}	52.17±2.34^{g}
T_9	0		50	500	45.07±1.58^{h}	47.73±0.98^{h}	47.20±1.27^{h}

Data is mean ± standard deviation (N=3). In columns, means with distinct superscripts differ significantly ($p<0.05$).

Table VI. Analyzed body composition of *C. catla* fingerlings fed diets based on different plant by-products supplemented with phytase.

Test diets	Fishmeal protein replacement levels (%)	Plant by products	Plant by-products replacement levels (%)	Phytase (FTU Kg-^{1})	Protein	Fat	Ash	Moisture
T_1	50		0	0	14.75±0.03^{i}	12.81±0.04^{i}	1.00±0.01^{i}	71.44±0.02^{a}
T_2	35	MOLM	15	250	17.18±0.01^{c}	5.22±0.02^{c}	2.33±0.03^{c}	75.27±0.01^{g}
T_3	0		50	500	18.05±0.03^{a}	2.97±0.01^{a}	2.49±0.02^{a}	76.50±0.00^{h}
T_4	35	SFM	15	250	16.03±0.02^{f}	8.75±0.04^{f}	1.48±0.01^{f}	73.74±0.02^{d}
T_5	0		50	500	16.27±0.02^{e}	7.98±0.04^{e}	1.68±0.01^{e}	74.07±0.01^{e}
T_6	35	CM	15	250	16.87±0.02^{d}	6.13±0.04^{d}	2.03±0.03^{d}	74.97±0.01^{f}
T_7	0		50	500	17.84±0.05^{b}	3.03±0.02^{b}	2.47±0.00^{b}	76.67±0.06^{i}

T_8	35	GM	15	250	15.38±0.55^h	10.82±0.54^h	1.05±0.02^h	72.74±0.02^b
T_9	0		50	500	15.78±0.55^g	10.10±0.55^g	1.08±0.01^g	73.04±0.02^c

Data is mean ± standard deviation (N=3). In columns, means with distinct superscripts differ significantly ($p<0.05$).

Carcass composition

The body composition of *C. catla* given diets based on different plant by-products supplemented with phytase is displayed in Table VI. The body composition of fingerlings of different groups varied significantly ($p<0.05$). The T_3 diet resulted in the highest level of crude protein (18.05%), ash (2.49%) and lowest value of crude fat (2.97%). In contrast, the T_7 diet, had a second higher value of crude protein (17.84%), ash (2.47%) and second lowest value of crude fat (3.03%). Highest value (76.67%) of moisture was recorded at T_7 diet and the second higher value (76.50%) was observed at T_3 diet. The lowest value (71.44%) of moisture was observed from T_1 diet.

DISCUSSION

The substitution of FM, a protein source, in fish feed is needed in these days, owing to its uncertain availability and high price. Since FM is the primary source of protein, replacing another protein source for FM must not reduce the feed's nutritional value. One of the best substitutes is plant by-products. But plant ingredients utilization is hampered by the existence of ANFs such phytic acid, having a number of negative impacts including reduced fish growth rates (Punia and Singh, 2024). To reduce these negative impacts, a number of strategies are being used. In a current study, phytase was supplemented with plant by-products based diets and efficacy was observed on growth, nutrients digestibility and carcass composition of *C. catla*.

In this study, it was recorded that phytase supplementation improves growth performance. Phytase efficacy was maximum at T_3 diet (50% MOLM with 500 FTU Kg^{-1} phytase), in contrast to T_1 diet (50% FM with 0 FTU Kg^{-1} phytase). Same growth improvements were recorded for fishes fed phytase supplemented diets; i.e. phytase inclusion at 1500 to 2000 UF kg^{-1} for *Oreochromis niloticus* (Rodrigues *et al*., 2022), at 300 to 1500 FTU Kg^{-1} with MOSM for *C. catla* (Hussain *et al*., 2017) and up to 1000 FTU Kg^{-1} with rice protein concentrate for *Labeo rohita* (Khizar *et al*., 2024) enhanced the growth parameters including WG and SGR, increased the feed intake and reduced the FCR. This improvement can be attributed to the phytase, which effectively broke down the complex phytate and released the nutrients, resulting in an increase in feed palatability (Maas *et al*., 2020; Rodrigues *et al*., 2022). Similarly, Adeshina *et al*. (2023) recorded that dietary phytase improved the growth of African catfish fed SBM based diet and stimulated feed intake and Maas *et al*. (2019) noticed an increase in the growth rate of Nile tilapia given SFM based diets having phytase level 1000 FTU Kg^{-1}. In contrast, Adeoye *et al*. (2016), found that adding phytase to juvenile tilapia had no statistically significant influence on growth parameters.

The results of current study demonstrated that phytase inclusion to plant by-products based diets significantly raised the nutrients digestion when compared to diet without phytase and these findings are consistent with previous findings. The maximum ADC% of CP, CF and GE values were recorded by T_3 diet (50% MOLM with 500 FTU Kg^{-1} phytase). Hussain *et al*. (2017), using MOSM based diet having 900 FTU Kg^{-1} phytase, observed maximum increase in digestibility in *C. catla* fingerlings. Phytase-fed fish groups showed improved digestibility, which could potentially be related to increased protease production, which is linked to protein digestibility (Morales *et al*., 2016). The results demonstrated that, phytase inclusion to plant based diets decreased the amount of nutrients excreted into the water through feces, thereby improving nutrient digestibility in contrast to a diet with 0 FTU Kg^{-1} phytase. Reducing pollution in the aquatic environment is greatly helped by fish bodies by using maximum nutrients of diet and releasing less pollutants into the water (Kumar *et al*., 2015). Hussain *et al*. (2017) observed that feeding *Cirrhinus mrigala* fingerlings a test diet based on SFM supplemented with phytase resulted increase in CP, CF and GE digestibility. On the other hand, adding dietary phytase to the diets of several fish species did not demonstrate any impact on the ADC of nutrients (Maas *et al*., 2020). Several factors, including the type of fish, feed composition (especially basic plant ingredients having different levels of phytate), enzyme source, inclusion method and other response characteristics, might affect the activity of phytase (Debnath *et al*., 2005).

According to current findings, plant by-products based diets with phytase as a supplement improved the nutritional composition of body of *C. catla* fingerlings. The best carcass composition was observed by T_3 (50% MOLM with 500 FTU Kg^{-1} phytase) in comparison to T_1 diet (50% FM without phytase). Consistent with these findings, Shahzad *et al*. (2021) found improvement in carcass composition of Nile tilapia fed on moringa based diets with phytase inclusion in a range 500 to 1250 FTU Kg^{-1}. In contrast, Akpoilih (2015) found no significant improvement in crude protein by phytase when compared to non phytase diets fed to *C. gariepinus*. In line with current findings, Naseem *et al*. (2021) observed increase in body protein, ash and fat of *L. rohita* fingerlings by phytase supplementation.

CONCLUSION

In this study, effects of phytase were checked systematically on the growth, nutrients digestibility and carcass composition of *C. catla* fingerlings fed different plant by-products based diets. The findings showed that dietary supplementation of phytase boosted the growth rate of *C. catla* fingerlings. These positive outcomes might be related to improved nutrient availability, digestibility and nutrient retention. Best results were recorded for diet having 50% MOLM with 500 FTU Kg^{-1} phytase, in contrast to diet with 50% FM and without phytase. Conclusively, phytase supplementation with different plant by-products based diets is beneficial to produce low cost, highly nutritive and environmentally friendly fish diets. Future research must focus on more economical and eco-friendly aqua-feeds.

DECLARATIONS

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IRB approval

All applicable institutional, national and international guidelines for the care and use of animals were followed.

Ethical statement

All the procedures and methods used in this study followed the ethical guidelines provided by Government College University, Faisalabad.

Statement of conflict of interest

The authors have declared no conflict of interest.

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