IMPACT OF DIETARY TURMERIC FORTIFICATION ON GROWTH PERFORMANCE, HEMATO-BIOCHEMICAL AND ENZYMETIC PROFILE OF PANGUS (*PANGASIUS HYPOPHTHALMUS*)

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Abstract - There is a growing demand to find alternatives to antibiotics in aquafeed, and there is now a strong emphasis on promoting the use of safe substances to ensure sustainable practices in aquaculture. Turmeric is considered a versatile dietary supplement and is typically used for its promising effects on the growth of fish and its ability to boost their immune system. The objective of this research was to evaluate the impact of incorporating turmeric into the diet of *Pangasius hypophthalmus* juvenile fish. Four distinct diets were prepared, each containing varying amounts of turmeric (0%, 2%, 4%, and 6%). 240 *P. hypophthalmus* fingerlings were distributed into four equally sized groups, with each group consisting of 60 fish. Within each group, there were three replicates, each containing 20 fish. These groups were categorized as the control group and three turmeric-treated groups, with turmeric levels at 2% (T1), 4% (T2), and 6% (T3) in their diets, and the study spanned over an 8-week period. Following a 60-day feeding trial, various factors were measured, which encompassed growth performance, body composition, hematological measures (such as WBCs and RBCs, HB levels, and HCT), as well as the activities of digestive and antioxidant enzymes. Fish that were fed a diet containing 4% turmeric (T2) exhibited the most substantial growth performance, demonstrating a significant improvement ($P \leq 0.05$) in comparison to the control group across all growth performance parameters, including NWG, PWG(%), FCR(%), SGR(%), FE, HSI(%) and VSI(%).The hematological measurements fell within the healthy range for fish. However, dietary turmeric notably elevated levels of hematocrit, hemoglobin, RBCs, and WBCs, with the highest improvements observed in the group T2 (4% Turmeric). Noticeably increased levels of digestive enzyme activity were detected in all groups that received turmeric additives in their diets when compared to the control group. The most significant ($P \leq 0.05$) enhancements were observed in the T2 group. In addition, the T2 group showed notably higher ($P \leq 0.05$) levels of antioxidant enzyme activities. The levels of biochemical blood markers associated with liver function (ALP, AST, ALT), kidney function (urea), and total cholesterol were all within the normal range. The presence of turmeric in the diets led to a significant improvement in serum glucose, triglyceride levels, and the overall body composition. The results obtained for all the parameters indicated that T2 was the most effective treatment, demonstrating significant differences when compared to all the other experimental groups, including the control group. Incorporating turmeric at a 4% rate enhanced the growth and overall health of *P. hypophthalmus*. Therefore, based on the findings of this study, it can be inferred that incorporating turmeric at a 4% inclusion level can be beneficial in enhancing the growth, hematological parameters, digestive and antioxidant enzyme activities, as well as the overall health of *Pangasius hypophthalmus* fingerlings.

Index Terms - *Pangasius hypophthalmus,* Turmeric, Growth Performance, Body Composition, Hematological Measures, Liver Function

I. INTRODUCTION

Over the last 40 years, there has been a swift expansion in the global output of fish through aquaculture, making a substantial addition to the worldwide fish supply for people to consume [1]. Aquaculture ranks among the most rapidly expanding sources of animal protein on a global scale, with around 50% of the overall production relying on external feeds [2]. Utilizing top-quality artificial fish feed is essential, particularly as intensive fish farming becomes more prevalent. In this method, fish are densely stocked, and the primary source of nutrition for these organisms is the artificial feeds [3]. To boost fish growth and overall production, a combination of feeds enriched with chemical fertilizers, various organic substances, as well as additional components like proteins, minerals, and antibiotics, is being employed [4]. A diverse array of feed supplements is utilized to address nutritional needs, aiming to promote the well-being, efficient feed utilization, and resilience to stress in aquatic species raised through aquaculture [5]. Feed additives are characterized as ingredients or components within feed formulations that do not contribute to the nutritional content but are added to influence the physical or chemical characteristics of the diet, or to impact the performance and quality of aquatic animals and their products [6]. The purpose of employing these feed supplements in aquaculture is to improve the quality of fish while also safeguarding the health of consumers from any potential negative impacts [7, 8]. Over recent decades, aquaculture facilities have employed a variety of antibiotics, chlorides, and similar substances that have had adverse effects on the environment. [9].

Turmeric (*Curcuma longa*) is a medicinal and aromatic plant belonging to the Zingiberaceae family, originally cultivated in tropical regions. This plant, along with its active compound, displays a broad spectrum of pharmacological effects within the field of aquaculture, including anti-inflammatory, growth-enhancing, liver-protecting, immune-modulating, stress-alleviating, antioxidative, and antimicrobial properties. Research has demonstrated that these substances can influence growth performance when administered at precise dosages, with the added benefit of improving fish quality while ensuring no adverse effects on consumers' health. [10, 11 and 12]

The Asian catfish, scientifically known as *Pangasius hypophthalmus*, is a prominent inland fish species in the Far Eastern Asia region [13]. Consumers highly favor this fish because it lacks intramuscular bones [14]. Considering the growing global and national demand for the production and consumption of striped catfish (*P. hypophthalmus*). Pangus is among the rapidly growing fish species with significant potential for increasing production and export opportunities [15] Pangus is distinguished by its rapid growth, allowing it to reach a profitable size in just a few months, and it can withstand higher stocking densities in comparison to other species [16]. Therefore, it has become one of the most important species for fish producers worldwide. Therefore, this study has been designed to diagnose the growth promoting, anti-oxidant and hemato-biochemical effects of turmeric on Pangus (*Pangasius hypophthalmus*).

II. MATERIALS AND METHODS

The Diets

Four types of iso-nitrogrnous (30% CP) diets were formulated adding varying amount of turmeric powder 0% (T0), 2% (T1), 4% (T2) and 6% (T3) according to the table: 1. Turmeric was obtained from a nearby store and finely ground before being incorporated into the feed ingredients. The feed components were meticulously mixed, and sufficient water was introduced to transform them into a paste. A meat grinder was used to create pellets out of the mixture, which was then dried at room temperature in front of a fan.

Fish & Feeding

P. hypophthalmus weighing approximately 15.16±0.17g were obtained from a local farm and subsequently transported to the laboratory. Prior to being placed in 12 separate 50-liter aquariums, the fish were carefully inspected for any visible signs of disease or injury. Each aquarium was stocked with 15 fish.

Following a one-week acclimation period during which the fish were fed the control diet, they were subsequently provided with the control diet (0%), T1 diet (2%), T2 diet (4%), and T3 diet (6%) for a duration of 8 weeks. Three separate groups, each corresponding to a specific treatment (diet), were established. During the acclimation and feeding phases, aeration was consistently provided in every aquarium, and half of the water was refreshed on a daily basis. Water quality parameters were monitored daily to ensure they met the established standard values.

Growth Parameters

At the start and end of the feeding experiment, five fish were randomly selected from each tank after they had finished the experimental feeding. These fish were collectively weighed to determine the growth parameters. The evaluation of growth performance included parameters such as the IBW, FBW, NWG, PWG, FCR, SGR, feed efficiency (FE), survival rate, HSI, and VSI.

WG (g) = Final weight (g) – Initial weight (g)
Weight gain % = 100 [Final weight (g) – Initial weight (g)] / Initial weight (g)
FE = Weight gain (g) / Feed given (g)
SGR (%g/day) = 100 (Ln (Final weight) – Ln (Initial weight) / No of days)
FCR = Feed intake (g) / Weight gain (g)
HSI (%) = Weight of liver ÷ Weight of fish × 100
VSI (%) = Weight of viscera ÷ Weight of fish × 100

Table 1: Proximate Analysis of Diets Containing Graded Levels of Turmeric

Ingredients	**T_0**	**T_1**	**T_2**	**T_3**
Fish meal	25	25	25	25
Soybean Meal	20	20	20	20
Corn Gluten	20	20	20	20
Rice Polish	15	13	11	09
Wheat flour	10	10	10	10
Fish oil	5.5	5.5	5.5	5.5
Vitamin premix	2	2	2	2
Mineral mixture	2	2	2	2
Turmeric Powder	0	2	4	6
Total	100	100	100	100

Proximate Analysis

After concluding the experiment, three fish from each experimental group were chosen for the evaluation of their proximate composition, and the entire body of each fish was utilized for this analysis. Dry matter was obtained by exposing the samples to an oven set at 105°C until a stable weight was achieved. The ash content was calculated by placing the samples in a muffle furnace and incinerating them at 450°C for a period of 4 hours. Lipid content was evaluated through the ether extraction technique, and crude protein content was ascertained using the Kjeldahl method, which involves multiplying the nitrogen content by a factor of 6.25. [17]

Digestive Enzymes

At the conclusion of the experiment, the digestive systems of two fish from each experimental group (total of 6 per treatment) were dissected and immediately frozen using liquid nitrogen, followed by storage at a temperature of -20°C. Subsequently, these samples were thawed, homogenized in ice-cold distilled water (at a ratio of 1:8, weight to volume) utilizing a tissue-tearor homogenizer for 2.5 minutes, including 5 cycles of 30 seconds for cooling purposes, and were then subjected to centrifugation at 20,817 g (utilizing an Eppendorf 5804 R centrifuge) for a duration of 15 minutes at 4°C. The liquid portion (supernatant) was employed to assess the activities of proteases, amylase, and lipase. The measurement of protease activity was conducted following the described method [18]. A single unit of protease activity (U/mg protein) was defined as the quantity that released 1 gram of tyrosine while breaking down casein during a 1-minute period at 37°C. The assessment of amylase activity was conducted following the procedure outlined by [19]. One unit of amylase activity (U/mg protein) was calculated as the quantity that generated 1 milligram of glucose by breaking down starch within a 1-minute duration at 40°C. Lipase activities were assessed following the procedure outlined [20]

Ant-Oxidant Enzymes

SOD and CAT levels were quantified using a commercially available kit (Zellbio Co.; Hinter den Garten ̈ 56; 89,173 Lonsee, Deutschland) with a microplate reader.

The measurement of SOD activity was carried out using the xanthine/xanthine oxidase method, which relies on the generation of O2− that oxidizes hydroxylamine, resulting in the formation of nitrites. In the presence of chromogenic agents, this reaction produces a purplish-red color. The catalase (CAT) mediated breakdown of H2O2 is promptly halted by the addition of ammonium molybdate. The residual H2O2 forms a yellow complex with ammonium molybdate, and its change in concentration is assessed at 405 nm to determine CAT activity. The assessment of Peroxidase enzyme (POD) activity was conducted in accordance with the methodology as described [21]. A single unit of SOD activity was defined as the quantity of protein necessary to reduce the reference rate to 50% of the maximum inhibition. Enzyme activity was quantified as units per gram or milligram of protein. A single unit of CAT (catalase) activity was defined as the amount of the enzyme required to decompose 1 μM of H2O2 per minute.

Blood Parameters

Following the feeding phase, blood samples were collected from all experimental groups. Subsequently, the fish were placed in plastic bags and had their blood drawn again after a 3-hour period. Six fish were selected at random from each tank with the specified diet, and their blood was obtained by puncturing the caudal vein using disposable syringes that contained heparin. Moreover, blood samples for serum analysis were gathered using disposable syringes without heparin. To anesthetize the fish, 0.1 ml per liter of clove oil was administered. Blood samples, measuring 1 milliliter, were drawn from the caudal vein of the fish and placed into plastic micro tubes that included an anticoagulant (EDTA) to maintain the samples for subsequent use in the hematological analysis. A volume of 1 mL of blood was extracted from each sample and placed into micro tubes devoid of an anticoagulant. Subsequently, the samples were subjected to centrifugation at 2500×g for a duration of 10 minutes to isolate the serum, which was then analyzed in the biochemical assay.

RBCs, HCT, PLT, HGB, MCV, MCH, MCHC and leukocytes were enumerated using an automated hemo-cytometer XE 2100 (Advia 2120 & Sysmex, Siemens). The assessment of total protein (TP) and plasma chemical parameters, including total albumin, globulin, glucose, SGOT, SGPT, BUN, triglycerides, and total cholesterol, was performed using a spectrophotometer with an automated analyzer (SPOTCHEM™ EZ model SP4430, Arkray, Inc., Kyoto, Japan).

III. RESULTS

Growth Performance

The table 2 presents the growth, feed performance, and body indices of Pangus fish when subjected to varying levels of dietary turmeric. The inclusion of turmeric in the diet had a significant impact on growth performance. The inclusion of dietary turmeric resulted in a significant increase in FBW and WG (Table 2). Fish fed 4% turmeric had the highest ($p < 0.05$) FBW (39.60±0.33) and NWG (24.46±0.08), and fish fed a turmeric-free diet showed the lowest FBW (112.56 ± 0.65) and NWG (21.12±0.15). Fish fed turmeric at 4% had a higher SGR (1.60±0.005) than fish fed the 0, 2, and 6% levels of turmeric ($p < 0.05$) followed by PWG % and Feed Efficiency (FE). The turmeric significantly ($p < 0.05$) improved the FCR and the best value was observed in the group offered 4% turmeric (1.24±0.003) as compared to other groups. The HSI was markedly increased by the addition of turmeric and the 4% additions of turmeric showed the highest value (3.22±0.04), compared to other groups ($p < 0.05$). Additionally, fish subjected to the 4% treatment exhibited an increased VSI of 7.44±0.05 compared to fish in the 0% treatment group (Table 2).

Table 2: Impact of Dietary Turmeric on Growth Performance

Parameters	T0	T1	T2	T3
Initial Body Weight (g)	15.09±0.14^a	15.19±0.10^a	15.14±0.17^a	15.21±0.22^a
Final Body Weight (g)	36.21±0.24^a	37.25±0.15^b	39.60±0.33^d	38.34±0.27^c
Net Weight Gain (g)	21.12±0.15^a	22.06±0.22^b	24.46±0.08^d	23.13±0.18^c
PWG %	139.96±0.54^a	145.23±0.95^b	161.56±0.66^d	152.07±0.89^c
FE	0.69±0.003^a	0.72±0.002^b	0.80±0.006^d	0.76±0.005^c
FCR	1.45±0.005^d	1.40±0.009^c	1.24±0.003^a	1.32±0.005^b
SGR (%/Day)	1.46±0.003^a	1.50±0.001^b	1.60±0.005^d	1.54±0.004^c
Survival Rate (%)	100±0.00^a	100±0.00^a	100±0.00^a	100±0.00^a
HSI %	3.05±0.03^a	3.14±0.0^b	3.22±0.04^d	3.17±0.04^c
VSI %	7.25±0.03^a	7.34±0.06^b	7.44±0.05^d	7.38±0.06^c

Abbreviations: HSI, Hepatosomatic Index; VSI, Viscerosomatic Index; PWG, Percentage Weight Gain; FCR, Feed Conversion Ratio; FE, Feed Efficiency; SGR, Specific Growth Rate

Body Composition

The body composition analysis of the fish fed by turmeric supplementation showed a significant improvement as compared to non-supplemented group (control). The concentration of crude protein in the fish increased significantly by increasing turmeric (except 6%) as the highest values were obtained by using 4% supplementation of dietary turmeric and the lowest were seen in the control group followed by crude fat and crude ash. (Table 3).

Table 3: Impact of Dietary Turmeric Fortification on Proximate Analysis

Parameters	T0	T1	T2	T3
Moisture	76.90±0.03[d]	76.39±0.10[c]	74.35±0.39[a]	75.69±0.05[b]
Dry Matter	23.09±0.03[a]	23.60±101[b]	25.65±0.39[d]	24.30±0.05[c]
Crude Fat	3.61±0.00[a]	3.80±0.02[b]	4.09±0.01[d]	3.97±0.02[d]
Ash Contents	3.88±0.02[a]	3.79±0.03[b]	4.12±0.03[c]	3.82±0.02[d]
Crude Protein	15.59±0.28[a]	16.04±0.48[b]	16.56±04[d]	16.14±0.31[c]

Hematological Indices

Turmeric addition in the feed significantly improved the hematological parameters of Pangus. Results indicate that Hemoglobin, RBCs, WBCs, PCV/HCT, Platelets count and MPV were significantly improved by turmeric supplementation. The afore-mentioned parameters showed an increasing trend with an increase of turmeric inclusion in the diets except the 6% turmeric (T3) and best values were recorded in the group fed by 4% turmeric in the feed. While the values of MCV, MCH, and MCHC showed a relatively opposite trend the values of parameters decreased with an increase in the concentration of turmeric in the diet except the MCV which showed a slightly different trend as the highest numbers were recorded highest in the group fed by 6% turmeric in the feed.

Table 4: Impact of Dietary Turmeric on Hematology

Parameters	T0	T1	T2	T3
Hemoglobin (g/Dl)	7.23±0.03[a]	7.56±0.02[c]	7.93±0.04[d]	7.44±0.03[b]
Total RBCs (10^12/L)	1.41±0.03[a]	1.53±0.02[c]	1.72±0.03[d]	1.46±0.02[b]
WBCs (10^9/L)	4.23±0.03[a]	4.44±0.04[b]	4.62±0.02[d]	4.53±0.01[c]
PCV/HCT (%)	29.11±0.02[a]	30.21±0.04[b]	32.48±0.11[d]	31.12±0.03[c]
MCV (fl)	206.57±0.06[c]	197.57±0.28[b]	188.68±0.39[a]	210.51±0.20[d]
MCH (pg)	51.55±0.09[d]	49.49±0.23[b]	45.98±0.16[a]	50.35±0.25[c]
MCHC (%)	25.12±0.03[d]	24.88±0.02[c]	24.35±0.04[b]	23.94±0.03[a]
Platelets (10^9/L)	75.55±0.04[a]	76.77±0.10[b]	78.66±0.05[d]	77.01±1.13[c]
MPV (fL)	6.58±0.01[a]	6.62±0.01[b]	6.75±0.02[d]	6.67±0.03[c]

Abbreviations: WBCs, White Blood Cells; MCV, Mean Corpuscular Volume; MCH, Mean Corpuscular Hemoglobin; PCV/HCT, Packed Cell Volume Test/ Hematocrit; MPV, Mean Platelet Volume; MCHC, Mean Corpuscular Hemoglobin Concentration.

Blood Biochemical Indices

The results indicate that dietary turmeric has a convincing effect on the blood biochemical indices of the fish (Pangus). In comparison to the control group, dietary turmeric had a significant and positive effect ($P < 0.05$) on the serum total protein (TP) levels in Pangus. The highest TP value (4.16±0.12) was recorded in the T2 group, followed by Albumin and globulin which were recorded significantly higher in T2 (1.61±0.03 and 3.08±0.04) respectively. The blood urea nitrogen (BUN) was seen significantly affected by turmeric as increase in turmeric concentration boosted the levels of BUN in the fish, the highest levels were observed in T2 (4% turmeric) and lowest levels were found in control diet. Serum glucose, triglyceride and cholesterol levels showed a relatively contrast trend as the levels decreased with the increase of turmeric in the diet, the highest levels were obtained in the control while the lower levels were seen in the groups fed by 2%, 6% and 4% respectively. The dietary turmeric had an impact on the activities of metabolic enzymes (AST and ALT) in the blood of the tested fish. A noteworthy reduction ($P < 0.05$) in the activities of AST and ALT was observed in the groups where the turmeric concentration increased, with the highest levels detected in the control group. Nonetheless, the ALP exhibited an upward trend as the turmeric concentration in the diets increased. The highest values were observed in T2 (4% turmeric), in contrast to the control group.

Table 5: Impact of Dietary Turmeric on Serum Biochemical Analysis

Parameters	T0	T1	T2	T3
SGPT(U/L)	44.44±0.04^{d}	43.57±0.03^{c}	42.76±0.05^{a}	43.24±0.04^{b}
SGOT (U/L)	58.34±0.04^{d}	57.84±0.03^{c}	55.39±0.05^{a}	56.25±0.04^{b}
ALP (U/L)	37.44±0.03^{a}	39.31±0.08^{b}	41.56±0.07^{d}	40.61±0.05^{c}
Total Cholesterol (mg/dL)	114.30±0.14^{d}	112.39±0.15^{b}	109.43±0.09^{a}	113.71±0.11^{c}
Blood Glucose (mg/dL)	56.24±0.04^{d}	54.36±0.06^{c}	52.17±0.05^{a}	53.78±0.08^{b}
Triglycerides (mg/dL)	185.12±0.18^{d}	161.17±0.28^{c}	139.51±0.44^{a}	156±0.43^{b}
BUN (mg/dL)	2.73±0.04^{a}	2.88±0.03^{b}	3.14±0.07^{c}	2.96±0.01^{b}
Total Protein (g/dL)	3.45±0.04^{a}	3.76±0.03^{b}	4.16±0.12^{c}	3.88±0.04^{b}
Albumin (g/dL)	1.40±0.02^{a}	1.50±0.02^{b}	1.61±0.03^{c}	1.55±0.01^{b}
Globulin (g/dL)	2.72±0.03^{a}	2.87±0.01^{b}	3.08±0.04^{c}	2.91±0.01^{b}
A/G	0.51±0.00^{a}	0.52±0.01^{a}	0.52±0.01^{a}	0.53±0.00^{a}

Abbreviations: SGPT, Serum Glutamic-Pyruvic Transaminase; A/G, Albumin/Globulin; SGOT, Serum Glutamic-Oxalacetic Transaminase; ALP, Alkaline Phosphate; BUN, Blood Urea Nitrogen.

Digestive Enzymes

At the conclusion of the feeding trial, the digestive enzyme activities were assessed, revealing that the addition of dietary turmeric significantly influenced the activities of digestive enzymes. The amylase activity increased by increasing turmeric (except 6%) in the diet, reaching its maximum (748.45±0.78) at 4% supplementation of turmeric as compared to control, protease activity was also increased by the addition turmeric and the highest tendency (5.66±0.07) was observed with 4% supplementation of turmeric followed by the lipase activity and the highest numbers (704.65±0.49) were obtained with 6% turmeric (Table 5).

Table 6: Impact of Dietary Turmeric on Digestive Enzymes Activity

Parameters	T0	T1	T2	T3
Protease (U/mg protein)	4.33±0.03^{a}	4.97±0.06^{b}	5.66±0.07^{d}	5.13±0.04^{c}
Lipase (U/g protein)	634.45±0.64^{a}	667.14±0.51^{b}	704.65±0.49^{d}	681.18±0.77^{c}
Amylase (U/g protein)	648.34±0.56^{a}	693.21±0.43^{b}	748.45±0.78^{d}	721.29±0.67^{c}

Antioxidative Enzymes

Dietary turmeric had a notable impact on the activities of antioxidant enzymes, including SOD, CAT, and peroxidase, in Pangus (Table 6). The greatest ($P < 0.05$) SOD activity was observed in the fish from the T2 (4%) group when compared to the control. The pattern of CAT activity followed a similar trend to that of SOD activity. Nonetheless, the T2 (4%) group displayed the highest and the control group had the lowest ($P < 0.05$) CAT activity. Additionally, turmeric had a beneficial effect on peroxidase activity, with the highest values being recorded in the T2 (4%) group in comparison to the control group.

Table 7: Impact of Dietary Turmeric on Antioxidant Enzymes

Parameters	T0	T1	T2	T3
Peroxides (U/mg)	89.17±0.06^{a}	93.31±0.09^{b}	98.44±0.03^{d}	95.32±0.08^{c}
Catalase (U/mg)	71.43±0.12^{a}	76.76±0.08^{b}	84.13±0.10^{d}	81.56±0.06^{c}
Superoxide Dismutase (mU/mg)	6.40±0.05^{a}	6.95±0.04^{b}	7.56±0.03^{d}	7.23±0.06^{c}

IV. DISCUSSION

The incorporation of dietary nutraceuticals into fish feed is a crucial approach to promote sustainability in the aquaculture industry [22, 23]. Numerous medicinal herbs have been utilized in aquaculture and confirmed to serve as growth-enhancing and immune-boosting agents (23, 25]. The findings indicate the necessity to explore medicinal supplements tailored to the specific needs of each species. Turmeric and its active compound display a broad spectrum of pharmacological effects within aquaculture, including anti-inflammatory, growth-enhancing, liver-protective, immune-modulating, stress-reducing, antioxidant, and antimicrobial properties [10, 11, and 12]. Therefore, this current investigation was crafted to assess the impact of diets enriched with turmeric on the growth, body composition, blood parameters, digestive enzymes, and antioxidant enzymes of pangasius fish (*Pangasius hypophthalmus*). The findings demonstrated that incorporating turmeric into the fish's diet had a noteworthy positive impact on the growth performance, SGR, FCR, and other growth-related characteristics of pangasius (*Pangasius hypophthalmus*), aligning with prior research findings. The addition of curcumin has led to improved growth performance in Nile tilapia (*Oreochromis niloticus*), [12], common carp (*Cyprinus carpio*) [26], and grass carp (*Ctenopharyngodon idellus*) [27], Crucian carp (*Carassius auratus*) [28], rainbow trout (*Oncorhynchus mykiss*) [29, 30] and large yellow croaker (*Pseudosciaena crocea*) [31]. The ultimate weight exhibited a noteworthy difference ($P<0.05$) among the groups, with the most favorable outcomes observed in T2, where a 4% turmeric supplementation resulted in the highest average body weight gain and overall body weight increase. These findings align with the results reported by [32] but are in contrast to the findings of [33]. The SGR of various fish exhibited a notable difference ($P<0.05$) among the treatment groups, with the most favorable outcomes observed in T2, where a 4% turmeric supplementation led to improved results. Turmeric enhances the immune response, reducing vulnerability to diseases, and thereby contributing to improved weight gain in fish, as demonstrated by [34]. The most important parameter for assessing the efficiency of feed consumption by fish and, consequently, their overall growth performance is the feed conversion ratio [35]. The mean FCR of the fish exhibited a notable difference ($P<0.05$) among the treatment groups. Among the four distinct treatments, the most favorable FCR (1.24±0.003) was observed in T2, where a 4% turmeric supplementation was applied. Turmeric enhances the efficiency of feed utilization by fish, resulting in improved feed efficiency and a more favorable FCR. Additionally, turmeric supplementation tends to increase the length of intestinal villi and has a pH-reducing effect, as indicated by studies conducted by [36, 37]. The latest findings suggest that there was improved growth in the group that received 4% turmeric supplementation, possibly attributable to curcumin, a component found in turmeric known for its appealing flavor, which may enhance the taste of the feed. This, in turn, could lead to increased feed consumption and better feed utilization, as proposed by [38]. Incorporating dietary TP (Total Phosphorus) into the fish's diet has the potential to boost the digestion of the diet and the digestibility of nutrients, ultimately resulting in better nutrient utilization. This, in turn, can contribute to enhanced fish growth and more efficient feed utilization.

Blood parameters play a critical role in assessing the health of fish. The findings confirmed that the blood indices underscore the positive impact of turmeric on Pangus. Assessing hematological indices is a dependable method for understanding the influence of nutraceuticals on health. Hematocrit (Hct) and hemoglobin (Hb) levels serve as diagnostic indicators to confirm the absence of anemia in the fish's blood [39]. The findings revealed elevated levels of hemoglobin Hb, Hct, RBCs, and WBCs in fish that were fed turmeric. This suggests that turmeric has a positive impact on the metabolism and nutrient availability within the blood of Pangus. The findings demonstrated an enhanced white blood cell (WBC) count in Pangus that received dietary turmeric, implying a strong and improved immune response. These findings are consistent with previous research, such as in the case of common carp [30] and rainbow trout [40], where curcumin supplementation resulted in elevated WBCs. According to [41] they found that including curcumin in the diet led to an increase in WBCs. RBCs have the primary function of transporting oxygen from the gills to the cells and tissues of the body to support various metabolic processes, as highlighted by [42]. The outcomes were consistent with the observations made by [43, 40] both of whom documented higher HCT, Hb, and RBCs counts in Gilthead Seabream (*Sparus aurata*) and rainbow trout (*O. mykiss*) when they were fed diets containing curcumin. The increase in RBCs, HCT, and Hb levels suggests effective blood formation and red blood cell production, which is likely a result of preventing malnutrition and anemia [44]. In this research, the parameters MCH, MCV, and MCHC exhibited a decline as the turmeric concentration increased among the groups. This indicates that the addition of turmeric up to 4% in the diet led to a reduction in anemic characteristics in Pangus. In the blood of rainbow trout fed dietary curcumin, [30] noted that there were no alterations in MCH, MCV, and MCHC values when compared to the control group. The rise in the counts of total white blood cells is due to the consumption of a herbal diet underscores the infection-fighting attributes of traditional herbs [45]. The potential for turmeric (curcumin) to modulate the immune system is likely linked to its ability to stimulate neutrophils and macrophages, prompting them to release reactive oxygen species [46].

Fish groups that were fed a diet supplemented with turmeric displayed a notable reduction in the activity of AST and ALT enzymes, while the activity of ALP increased. The findings suggest that elevating the concentration of turmeric up to 4% led to a significant decrease in AST and ALT levels in the blood of Pangus, while ALP concentrations increased. These results align with the research conducted by [47], where they observed a similar decreasing pattern in the levels of ALT and AST and an increasing concentration of ALP in the blood of common carp that were fed a diet containing turmeric supplementation. These results are consistent with the observations made by [32] who documented a decrease in ALT and AST levels and an increase in ALP levels in fish when they were exposed to turmeric treatment. The positive impact of adding turmeric to the diet on the plasma activities of ALT and AST in this study could be attributed to its hepatoprotective properties [48]. The rise in ALP concentration in the bloodstream of Pangus may be attributed to the heightened phosphatase activity, signifying an increased breakdown of energy reserves used for fish growth and survival [49]. Curcumin, a key component of turmeric, has the potential to enhance liver function by stimulating the regeneration of liver cells and safeguarding them against harmful compounds [50]. Cholesterol plays an important role in the absorption of fatty acids from the intestines and their subsequent transportation in the bloodstream or hemolymph. The reduction in cholesterol levels in our study aligns with the findings of [51], who documented a decrease in serum cholesterol levels when turmeric was added to the diet of *Clarias gariepinus*. In the current research, a decrease in serum glucose and triglyceride levels was noted as the amount of turmeric supplementation in the diet increased. This suggests the efficient utilization of non-protein energy sources for energy production, likely facilitated by the combined effects of bioactive compounds present in these herbal ingredients.

The activity of digestive enzymes serves as a measure of the digestive efficiency in animals, including fish. Consequently, higher digestive enzyme activity is associated with improved breakdown and absorption of complex nutrients in animals [52, 53]. Digestive enzymes have a critical function in nutrient digestion, and their levels are a direct reflection of an organism's digestive capability, which, in turn, influences the rate of fish growth [54, 55]. The findings indicated that adding turmeric to the diet had a substantial impact on increasing the production of digestive enzymes in the fish, with the highest levels observed in the group that received 4% turmeric supplementation. These findings align with the findings of [56], who fed *Litopenaeus vannamei* with a diet enriched with turmeric. Similar outcomes have also been documented in the case of crucian carp that were fed a turmeric-supplemented diet, leading to improved digestive enzyme activity [28]. The significant impact of turmeric on the activity of digestive enzymes is also documented in the research conducted by [10]. Phyto-additives likely have the potential to promote gut health by fostering the growth of beneficial microorganisms, which, in turn, may regulate the functioning of digestive enzymes in fish [57]. This could be attributed to the possibility that the bioactive compounds in dietary phytogenic additives may stimulate the liver to release bile, and the pancreas and intestine to secrete proteases, amylase, and lipase. This stimulation enhances the digestion and absorption of dietary nutrients, ultimately resulting in improved nutrient utilization and fish growth [58]. In this context, [59] noted that turmeric acts as a digestive stimulant and has a positive influence on boosting the functions of digestive enzymes. Curcumin, a primary constituent of turmeric, plays a crucial role in augmenting the functioning of digestive enzymes in the intestines [28]. This is further corroborated by the research conducted by [60, 61] which elucidates that curcumin possesses antibacterial properties against detrimental intestinal microorganisms. As a result, it promotes the growth of beneficial microorganisms, which play a crucial role in digestion and bolster local intestinal immunity.

The addition of turmeric to the fish diets has induced notable alterations in the composition of fish bodies. Turmeric supplementation led to a substantial enhancement in crude protein and ash content, although the response in crude lipid content was not statistically significant. Similar outcomes were observed in Nile Tilapia, where turmeric supplementation significantly elevated crude protein levels while simultaneously decreasing crude lipid contents as the amount of turmeric in the diets increased [33]. The research conducted by [62] reinforces the idea that including turmeric in the diet led to an increase in crude protein and ash content while reducing the levels of crude lipids in the body of black rockfish, *Sebastes schlegeli*. The outcomes reported by [10] differ from our research findings. We observed no statistically significant alterations in the body composition of Common Carp (*Cyprinus carpio*) when they were fed diets supplemented with turmeric. The changes in the fish's body composition resulting from the consumption of a diet enriched with turmeric could be attributed to processes such as synthesis, deposition rate in muscle, and growth rate [63, 64].

Numerous researchers have recorded the impact of dietary phyto-additives in regulating the antioxidant capacity of various aquaculture species [28, 65]. Adding turmeric to the fish feed resulted in elevated levels of SOD, CAT, and peroxidase enzyme activities in the fish. The most substantial values were recorded in the group that received a 4% dietary turmeric supplement. These results are in line with the observations in carp liver as reported by [66] in rats by [67], and in common carp as documented by [47]. It has been documented that turmeric contains significant levels of antioxidants, including curcumin, 1,8-cineole, and ascorbic acid [68, 69]. In the animal kingdom, the usual mechanism for diminishing the levels of reactive oxygen species (ROS) involves a combination of enzymatic and non-enzymatic antioxidant defense systems in the body. The bioactive compounds found in phyto-additives, particularly phenolic compounds, likely have the ability to decrease free radicals by providing hydrogen to shield cells from oxidative harm and by preventing the formation of free radicals [70]. As a result, including turmeric in the diet of Pangus led to an augmentation in the activity of antioxidant enzymes.

V. CONCLUSION

This study delved into how the performance of *Pangasius hypophthalmus* is influenced by the inclusion of turmeric in their diet. The findings indicated significant enhancements in the fish's growth performance. The research revealed that adding turmeric powder to the diet of *P. hypophthalmus* resulted in enhanced hematological parameters, including increased white blood cell count, and improved the fish's immune response, as evidenced by higher serum protein levels. The enhanced liver functions were corroborated by the increase in body weight gain, liver weight, and the reduction in serum SGPT and SGOT concentrations in the blood of the experimental pangus fish. Additionally, turmeric boosted the functions of digestive and antioxidant enzymes in pangus. Concluding from the results of this investigation, it can be deduced that introducing turmeric at a 4% inclusion rate is advantageous for improving the growth, hematological measures, digestive and antioxidant enzyme functions, and the general well-being of *Pangasius hypophthalmus* fingerlings.

VI. REFERENCES

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