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Effectiveness of Putak Starch Flour as an Energy Source for the Growth of Siamese Catfish (*Pangasius hypophthalmus*)

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ABSTRACT

The high cost of feed in Siamese catfish (*Pangasius hypophthalmus*) aquaculture encourages the exploration of alternative energy sources based on local raw materials. Putak starch flour, extracted from the pith of the gebang palm (*Corypha gebanga*), is a potential carbohydrate source with abundant availability in Indonesia, yet its utilization remains suboptimal. This study aimed to evaluate the effectiveness and determine the optimal inclusion level of putak starch flour as an energy source in feed on the growth performance of Siamese catfish. The study used an experimental method with a completely randomized design (CRD) consisting of five feed treatments with five replicates. The treatments were a commercial feed as a control (P0) and four levels of carbohydrate substitution with putak starch flour: 25% (P1), 30% (P2), 35% (P3), and 40% (P4). Test fish specimens, with an initial average weight of 6.88±0.99g, were cultured for 60 days. The results showed that the substitution of putak starch flour had a highly significant effect ($P< 0.05$) on absolute growth, specific growth rate (SGR), and feed conversion ratio (FCR), but no significant effect ($P> 0.05$) was detected on the survival rate. The highest growth performance was achieved by the P0 control treatment (absolute growth 107.29±17.26g; SGR 2.45±0.24 g%/day; FCR 0.90±0.10). Increasing the level of putak starch flour above 30% significantly decreased growth performance and feed efficiency, with the FCR increasing to 1.95±0.35 in the P4 treatment. The survival rate was high across all treatments, ranging from 80-96%. It was concluded that putak starch flour has the potential to be used as an alternative energy source in Siamese catfish feed, with a recommended maximum inclusion level of 30% to maintain optimal growth performance and feed efficiency.

INTRODUCTION

The aquaculture of Siamese catfish (*Pangasius hypophthalmus*) is a fisheries subsector with significant industrial prospects in Indonesia. However, the sustainability and profitability of this enterprise face a major challenge related to operational costs, with feed accounting for up to 60–70% of total production costs **(Tacon & Metian 2008)**. In fish feed formulation, carbohydrates play a crucial role as the most cost-effective non-protein energy source, supporting basal metabolism and sparing protein for growth **(NRC, 2011)**. The efficiency of carbohydrate utilization is highly dependent on the fish species and the starch source. For Siamese catfish, the balance of the carbohydrate-to-lipid ratio in the diet has been shown to directly influence growth performance and nutrient utilization **(Akter *et al.,* 2018)**.

The use of conventional carbohydrate sources such as cornmeal or tapioca **(Yuangsoi *et al.,* 2019)** is often constrained by price fluctuations and competition with the human food sector, thus necessitating the exploration of alternative energy sources. In line with the strategy to improve aquaculture efficiency, the utilization of underutilized local raw materials has become a research priority **(Polak *et al.,* 2020; Hardi *et al.,* 2021; Nalle, 2025)**. One such potential local resource is putak starch flour, extracted from the pith of the gebang palm (*Corypha gebanga*). This tree is widely available in several regions of Indonesia, and its pith is not used as a primary food source for humans, thereby reducing the potential for resource allocation conflict **(Yuliana *et al.,* 2019)**. A single gebang palm tree (*Corypha gebanga*) with an approximate height of 13 meters can yield up to 396kg of dried putak, containing an energy value of 4,210 kcal, crude fiber of 12.04%, and crude protein of 2.53% **(Nullik *et al.,* 1988)**. Furthermore, according to **Lazarus and Lawa (2025)**, putak starch possesses an extremely high carbohydrate content, as reflected in its nitrogen-free extract (NFE) value of 89.90%. This high carbohydrate content makes putak a promising alternative energy source that is both low-cost and sustainable **(Manao *et al.,* 2022)**.

The potential of starches from the Palmae family as an energy source in aquatic feeds has shown promising results. Studies on the sago starch (*Metroxylon sagu*), which is taxonomically closely related, indicate that this starch can effectively replace other carbohydrate sources and support growth in several fish species **(Hoseinifar *et al.,* 2021; Manoppo *et al.,* 2022)**. This provides a strong scientific basis for investigating the potential of putak starch as a functional substitute. Nevertheless, scientific data evaluating the effectiveness of putak starch flour specifically for the Siamese catfish is still very limited. Information regarding the optimal inclusion level, digestibility, and its impact on key parameters such as specific growth rate (SGR), feed conversion ratio (FCR), and protein retention efficiency has not been well quantified. Understanding this is a fundamental prerequisite before recommending its use on an industrial scale.

Therefore, this research was systematically designed to evaluate the effectiveness of putak starch flour as an alternative energy source in formulated feed on the growth performance, feed efficiency, and nutrient utilization in Siamese catfish (*Pangasius hypophthalmus*).

MATERIALS AND METHODS

This research was conducted from February to March 2025 at the Fisheries and Marine Laboratory of the Kupang State Agricultural Polytechnic. The equipment used in this study included 40 × 30 × 30 cm aquaria, a thermometer, a DO meter, a pH meter, buckets, aerators, aeration hoses, airstones, a digital scale, a feed pellet machine, a flour mill, an oven, a mixer, a sieve, basins, and plastic containers.

The materials used consisted of putak flour, fish meal, amino acids (methionine and lysine), carboxymethyl cellulose, a vitamin premix, Hi-Provit 781-1 pellets, Hi-Provit 781-2 pellets, PF999, and Pangasius catfish (*Pangasianodon hypophthalmus*) fingerlings, which were obtained from the Balai Besar Perikanan Budidaya Air Tawar (Main Center for Freshwater Aquaculture Development), Sukabumi, Indonesia.

Research procedure

The feed formulations used in this study were designed based on varying inclusion levels of putak starch flour as the carbohydrate source, combined with fish meal as the primary source of animal protein. Table (1) presents the composition of feed ingredients for each treatment (P1 to P4), with the proportion of putak starch flour gradually increasing from 25 to 40%.

Additionally, the feed formulations were supplemented with other nutritional components such as fish oil, crude palm oil, essential amino acids (lysine and methionine), vitamin and mineral premixes, and feed attractants (shrimp/crab meal and betaine).

Table 1. Feed formulation used in the study

Ingredient	Treatment (%)			
	P1	P2	P3	P4
Fish meal	45.691	40.088	34.485	28.882
Putak starch flour	31.309	36.912	42.515	48.118
Fish oil	5.5	5.5	5.5	5.5
Crude palm oil	2.5	2.5	2.5	2.5
Lysin	2	2	2	2
Metionin	2	2	2	2
Vit premix	2.5	2.5	2.5	2.5
Mineral premix	2.5	2.5	2.5	2.5
Carboxy methyl cellulose / CMC	2	2	2	2
Shrimp/crab meal: Attractant	3	3	3	3
Betaine (Trimethylglycine)-Attractant	1	1	1	1
Proximate analysis (%)				
Crude protein	35.15	35.05	35.05	35.05
Crude fat	8.50	8.45	8.45	8.45
Crude fiber	3.50	4.20	4.20	4.20
Ash	8.00	7.80	7.80	7.80
NFE (carbohydrate)	25.00	30.00	35.00	40.00
Energy *(kcal/kg,GE[1])*	3792.4	3988.1	4193.1	4398.1
E/P ratio *(GE)*	107.9	113.8	119.6	125.5

Note: P0: Commercial feed Hi-Provit 781-1

[1]Gross Energy, Protein: 5.6 kcal/g; Lipid: 9.4 kcal/g; Carbohydrate: 4.1 kcal/g (National Research Council, 1977).

Preparation of experimental units

The experimental units consisted of aquaria measuring 50 × 30 × 30 cm, each filled with 36 liters of water and equipped with an aerator, aeration hose, and airstone. A total of 25 aquaria were used. Prior to use, the aquaria were cleaned and sterilized with chlorine at a concentration of 0.1g L^{-1} and left to stand for three days.

The test fish used were Siamese catfish (*Pangasianodon hypophthalmus*) with an initial average standard length of 9cm and an initial average weight of 6.88 ± 0.99g. Fish were stocked at a density of five individuals per aquarium. Before the treatments were applied, the fish were acclimated for one week. During acclimatization, they were fed commercial feed twice daily. The water source was well water, with minimal water exchange—only replacing losses due to evaporation.

Test animal maintenance

To biologically assess the quality of the formulated diets, the experimental fish were reared for 60 days. Feeding was conducted twice daily, in the morning and evening. Water quality parameters, including temperature, pH, and dissolved oxygen (DO), were measured daily using a multiparameter meter (HI98194; Hanna Instruments, Woonsocket, RI, USA). Ammonia concentration was measured weekly using a photometer (HI96733; Hanna Instruments). Fish waste and uneaten feed were siphoned from each aquarium every morning, and water was replenished to maintain the original volume.

Fish growth was monitored biweekly by measuring body weight, while survival rate was assessed at the end of the experiment. The feed conversion ratio (FCR) was calculated based on total feed intake and total weight gain.

Experimental design

This study employed a completely randomized design (CRD) with five treatments and five replicates, totaling 25 experimental units. The treatments involved different substitution levels of putak starch flour as a carbohydrate source in the fish diet:

- **Treatment P0:** Commercial feed (control)
- **Treatment P1:** Feed with 25% carbohydrate content
- **Treatment P2:** Feed with 30% carbohydrate content
- **Treatment P3:** Feed with 35% carbohydrate content
- **Treatment P4:** Feed with 40% carbohydrate content

Observed parameters

- **Absolute Growth (Weight Gain):** Calculated using the formula from **Everhart *et al.* (1981)**:
  $H = Wt - Wo$, where H is absolute growth, Wt is the total fish weight at the end, and Wo is the total weight at the beginning of the experiment.
- **Specific Growth Rate (SGR):** Calculated according to **Jauncey and Ross (1982)**: $SGR = [(Ln\ Wt - Ln\ Wo) / T] \times 100\%$, where SGR is the specific growth rate, Wt is fish weight at a specific time, Wo is weight at the start, and T is the number of days.
- **Survival Rate (SR):** Calculated using the formula from **Effendie (2002)**:
  $SR = (Nt / No) \times 100\%$, where Nt is the number of surviving fish and No is the initial number of fish.
- **Feed Conversion Ratio (FCR):** Calculated according to **NRC (1993)**: $FCR = F / ((Wt + D) - Wo)$, where F is the total feed given, Wt is the final fish weight, Wo is the initial weight, and D is the weight of dead fish.

Data analysis

Data were analyzed using one-way analysis of variance (ANOVA) at a 5% significance level to determine the effect of treatments on the observed parameters. When a significant difference was found, Tukey's Honestly Significant Difference (HSD) test was applied as a post-hoc analysis.

RESULTS

The parameters observed for the growth performance of Siamese catfish (*Pangasius hypophthalmus*) included absolute growth, specific daily growth rate (SGR), feed conversion ratio (FCR), survival rate, and water quality.

Absolute growth

The results of the analysis of the absolute growth of Siamese catfish (*P. hypophthalmus*) during rearing are presented in Fig. (1).

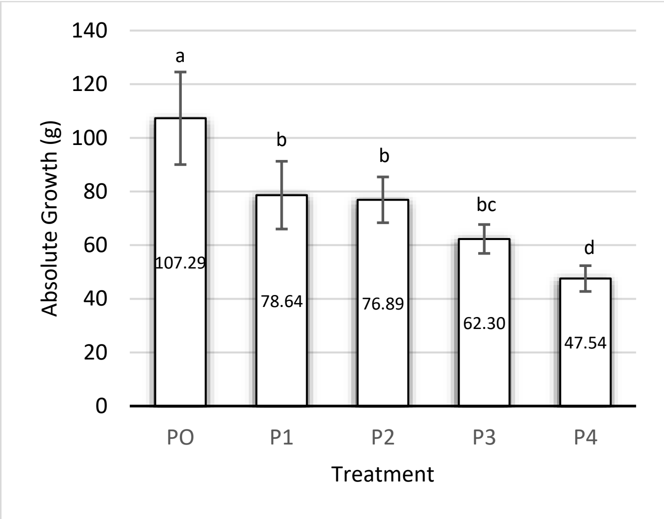

Fig. 1. Absolute growth of Siamese catfish (*P. hypophthalmus*) during rearing

The results for the absolute growth of Siamese catfish (*P. hypophthalmus*) during the culture period are presented in Fig. (1). Fig. (1) shows that the highest absolute growth occurred in treatment P0 (107.29±17.26g), followed by P1 (78.64±12.62g), P2 (76.89±8.53g), P3 (62.3±5.39g), and P4 (47.54±4.81g). The ANOVA test showed a highly significant difference among treatments ($P< 0.05$). Based on the HSD test, P0 showed the highest absolute growth (a), which was significantly different from P1 and P2 (b), P3 (bc), and P4 (d). This finding indicates that substituting putak starch flour above 30% begins to negatively impact growth.

Specific growth rate (SGR)

The results of the analysis of the daily specific growth of Siamese catfish (*P. hypophthalmus*) during rearing are presented in Fig. (2).

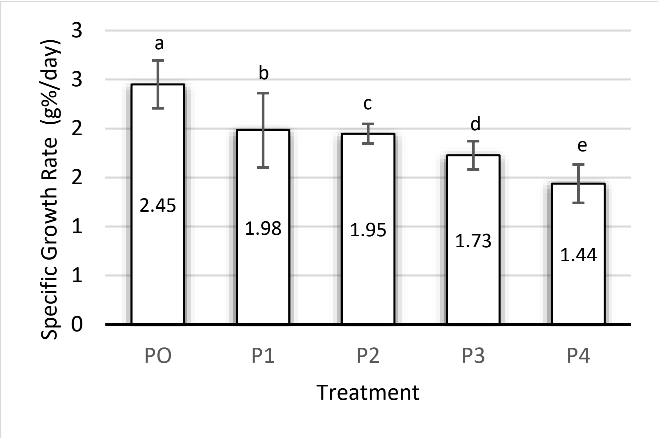

Fig. 2. Daily specific growth of Siamese catfish (*P. hypophthalmus*) during rearing

The results for the specific daily growth rate of Siamese catfish (*P. hypophthalmus*) are presented in Fig. (2). Fig. (2) shows that the highest specific daily growth rate was in treatment P0 (2.45±0.24 g%/day), followed by P1 (1.98±0.38 g%/day), P2 (1.95±0.10 g%/day), P3 (1.73±0.14 g%/day), and P4 (1.44±0.20 g%/day). The ANOVA test indicated that the substitution of putak starch flour had a highly significant effect ($P< 0.05$). Based on the HSD post-hoc test, there was a significant difference among all treatments (notations a ≠ b ≠ c ≠ d ≠ e). The highest value was obtained in the control (P0), while the lowest was in P4, showing that the higher the substitution of putak starch, the more significantly the growth rate decreased.

Feed conversion ratio (FCR)

The results of the analysis of the Food Convertion Ratio (FCR) of Siamese catfish *(P. hypophthalmus*) during rearing are presented in Fig. (3).

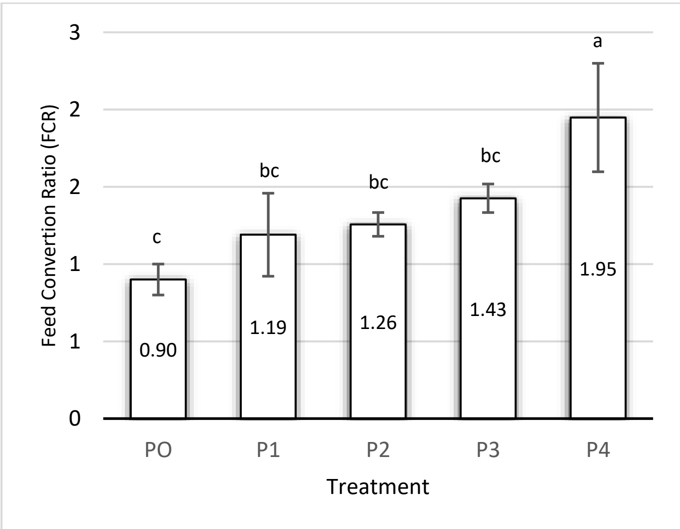

Fig. 3. Feed Conversion Ratio (FCR) growth of Siamese catfish (*P. hypophthalmus*) during rearing

The results for the Feed Conversion Ratio (FCR) of Siamese catfish (*P. hypophthalmus*) are presented in Fig. (3). Fig. (3) shows that the lowest FCR was demonstrated by treatment P0 (0.90±0.10), followed by P1 (1.19±0.27), P2 (1.26±0.08), P3 (1.43±0.09), and P4 (1.95±0.35). The ANOVA showed that FCR differed significantly among treatments ($P< 0.05$). The best (lowest) FCR value was found in the control (P0), indicating the highest feed utilization efficiency. The FCR increased sharply in P4 (1.95±0.35), indicating poor feed conversion at high substitution levels.

Survival rate

Data on the survival of Siamese catfish (*P. hypophthalmus*) during rearing is presented in Fig. (4).

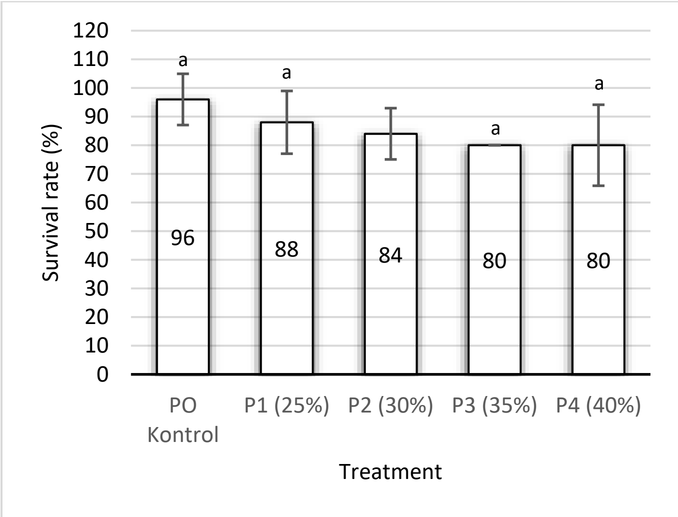

Fig. 4. Survival of Siamese catfish (*P. hypophthalmus*) during rearing

The survival rate data for Siamese catfish (*P. hypophthalmus*) are presented in Fig. (4). Survival across all treatments remained high, ranging from 80 to 96%, with the highest value observed in the control group (P0) at 96 ± 8.94%. A gradual decline was noted in the treatment groups: P1 (88 ± 10.95%), P2 (84 ± 8.94%), P3 (80 ± 0.00%), and P4 (80 ± 14.14%).

A one-way ANOVA indicated that the substitution of putak starch flour in the feed formulation had no statistically significant effect on the survival rate of Siamese catfish ($P > 0.05$). This finding was supported by Tukey's Honestly Significant Difference (HSD) test, which showed that all treatments belonged to the same statistical group.

Although a decreasing trend in survival was observed at the 35 and 40% substitution levels, the differences were not statistically significant. Thus, putak starch flour can be incorporated into feed formulations at levels up to 40%, without significantly compromising fish survival.

Water quality

The results of water quality measurements throughout the culture period are presented in Table (2).

Table 2. Water quality measurement results during the culture period

Parameter	Average Measurement Result	Optimum Range **(SNI 01-6483.5-2002)**
pH	7	6,5 – 8,5
Temperature (^{0}C)	28,24	25 – 30
Dissolved oxygen (mg/L)	6,54	> 4
Amonia (mg/L)	0	< 0,01

The water quality values for pH, temperature, DO, and ammonia were 7, 28.24°C, 6.54mg/ L, and 0mg/ L, respectively. The data show that the water quality during the culture period was in optimal condition according to SNI 01-6483.5-2002, which effectively supports the growth and survival of the Siamese catfish.

DISCUSSION

The survival rate of fish is a critical parameter reflecting their adaptation and tolerance to environmental conditions and feed quality. In this study, all treatments showed high survival rates, ranging from 80% to 96%. This indicates that the Siamese catfish possess a strong ability to adapt to variations in feed ingredients, including the inclusion of putak starch flour as an energy source. Although survival rates decreased slightly in treatments P3 and P4, the values remained above the safe threshold of 80%, as per the standard for cultured fish survival **(NRC, 2011)**.

This decline may be associated with elevated crude fiber content and the presence of antinutritional compounds in higher doses of putak starch flour, which can negatively impact the physiological and digestive functions of the fish. Raw putak starch contains digestive inhibitors such as tannins and hemicellulose, which may irritate the digestive tract. The standard deviation of 0.00% in P3 suggests uniform survival among all replicates, while the higher variation in P4 indicates inconsistent tolerance among experimental units—likely influenced by individual fish condition or microhabitat variation.

These results align with the findings of **Hasan and Chakrabarti (2009)**, who reported that unrefined local ingredients can be incorporated into fish feeds, but only within controlled inclusion levels to prevent negative physiological effects. Therefore, although generally safe, further investigations—including hematological and histological assessments—are necessary to evaluate the sublethal effects of putak starch flour. From a practical standpoint, the high survival rate observed supports the potential use of putak starch flour at substitution levels of up to 40%, particularly in consideration of its local availability and cost-effectiveness.

Specific growth rate (SGR)

The specific growth rate (SGR) reflects the relative daily increase in biomass. The highest SGR was observed in P0 (2.45 g%/day), with significant reductions as the substitution level of putak starch increased. This suggests that the energy provided by feeds containing putak starch flour was not optimally utilized. The decline in SGR from P1 to P4 is likely attributed to the nutritional profile of putak flour. Although rich in carbohydrates, putak flour's metabolic energy value may be limited if the carbohydrates are structurally complex or poorly digested.

Hardy (2010) emphasized that growth efficiency is closely tied to the form and bioavailability of carbohydrates. Putak starch, with its high amylose-to-amylopectin ratio, contains more amylose—less digestible by fish compared to amylopectin. In addition, elevated crude fiber and antinutrients can reduce the activity of digestive enzymes such as amylase, thereby limiting carbohydrate utilization and forcing the fish to use protein as an energy source instead of being used for tissue growth **(NRC, 2011)**. This observation is consistent with the findings of **Yuliana *et al.* (2019)**, who suggested that pre-processing treatments like gelatinization or fermentation are necessary to improve the digestibility of putak starch flour.

While SGR in P1 and P2 remained within acceptable ranges, optimal growth performance was only achieved in the control group. Statistically, distinct notations across treatments (a–e) confirm that changes in SGR were both significant and consistent, underscoring the need to assess digestibility before incorporating local ingredients into commercial feed formulations.

Absolute growth

Absolute growth provides a direct measure of weight gain during the culture period. In this study, a clear decreasing trend was observed, with P0 showing the highest value (107.29g) and P4 the lowest (47.54g; corrected from 47.44g as stated in the results section). This trend reflects reduced feed efficiency in treatments with high levels of putak starch substitution.

The decline in absolute growth is likely due to the interaction between feed quality and the physiological capacity of fish to utilize available nutrients. Substituting conventional energy sources like cornmeal with coarse, less bioavailable carbohydrates results in lower usable energy. Under such conditions, fish may catabolize body protein to meet energy demands, thereby inhibiting tissue growth **(Hardy, 2010)**.

Statistical groupings indicate that P1 and P2 (notation "b") were not significantly different from one another, suggesting that the fish's tolerance threshold for putak flour lies between 25 and 30% substitution. In contrast, the sharp drop observed in P4 (notation "d") suggests that this limit was exceeded. Biologically, this may also reflect long-term metabolic inefficiency or depletion of internal energy reserves. Additional biochemical or body composition analyses could provide deeper insight into these physiological responses.

From the perspective of absolute growth, it is recommended that putak starch flour substitution be limited to levels that do not significantly impair energy efficiency—specifically, no more than 30%.

Feed conversion ratio (FCR)

FCR is a critical indicator of feed efficiency in aquaculture, with lower values indicating more efficient feed utilization. The best FCR was recorded in P0 (0.90), while P4 exhibited the highest (least efficient) value at 1.95. This increasing trend correlates directly with reductions in SGR and absolute growth, suggesting that higher substitution levels of putak starch result in reduced nutrient utilization.

The elevated FCR values in higher substitution treatments are likely due to the high fiber and complex carbohydrate content in putak flour, which reduces digestibility. Statistically, significant differences between treatments were indicated by distinct notations (c–a), confirming the real impact of feed treatment on FCR. Nevertheless, the FCR values for P1 to P3 (1.19–1.43) suggest that putak flour can still be used at moderate levels without major efficiency losses.

An FCR exceeding 1.5 is generally considered inefficient in intensive aquaculture **(Tacon & Metian 2008)**. Therefore, feed containing 40% putak starch flour (P4) is not practically feasible unless additional processing improves energy availability. This highlights the need to consider both biological and technical aspects when formulating feeds using local raw materials. Improvements in feed efficiency could be achieved through pre-treatment methods such as fermentation or enzymatic hydrolysis.

Water quality

The measured pH value of 7 indicates neutral water conditions conducive to the physiological stability of fish. According to **Effendi (2003)**, an ideal pH range for freshwater fish lies between 6.5 and 8.5 to support optimal metabolism and enzymatic activity. The recorded water temperature of 28.24°C falls within the optimal range for tropical fish, as noted by **Boyd (2019)**, who identified 25– 30°C as ideal for the catfish growth.

The dissolved oxygen (DO) level of 6.54mg/ L exceeded the minimum requirement of 4mg/ L, promoting efficient metabolism, tissue growth, and immune response **(Hasan *et al.,* 2020)**. Moreover, the absence of detectable free ammonia (0mg/ L) indicates effective waste management and water circulation. Ammonia is a toxic compound that can impair gill function, suppress growth, and cause mortality if concentrations exceed safe thresholds **(Boyd & Tucker 2012)**.

Overall, the physicochemical parameters of the rearing environment remained within acceptable limits for the biological performance of the Siamese catfish, confirming that the observed differences in growth and feed efficiency were attributable to dietary treatments rather than environmental stressors.

CONCLUSION

Based on the results of this study on the effectiveness of putak starch flour as an energy source in feed for the growth of the Siamese catfish (*Pangasius hypophthalmus*), the following conclusions can be drawn:

1. Putak starch flour can be effectively used at substitution levels up to 30% (P1 and P2), as it supports satisfactory growth performance—demonstrated by survival rates above 80%, competitive specific and absolute growth rates, and efficient feed conversion ratios (FCR).
2. Substitution levels above 30% (P3 and P4) lead to a significant decline in growth performance and feed efficiency, characterized by reduced specific and absolute growth rates and an increased FCR, reaching >1.9 ± 0.35 in P4.
3. The consistently high survival rate across all treatments indicates that putak starch flour is non-toxic. However, growth efficiency appears to be closely linked to the digestibility and nutritional bioavailability of the starch.
4. Putak starch flour holds promise as a locally sourced alternative raw material for fish feed formulation. Nevertheless, its inclusion should be limited to a maximum of 30% to maintain optimal growth performance and feed utilization efficiency.

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