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Effect of fermented restaurant waste meal addition on growth performance of pangasius catfish (*Pangasius pangasius*) for promoting sustainable aquaculture

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Abstract. This study evaluates the use of fermented restaurant waste flour (FRWF) in artificial feed for improving the growth performance of catfish fry (*Pangasius pangasius*). Restaurant waste, containing 10.89% protein, 9.70% fat, 0.39% phosphorus, and 0.08% calcium and 9.13% crude fiber, was fermented to enhance its nutritional value and determine its potential as a cost-effective feed ingredient. The research identified the optimal fermentation duration and FRWF inclusion rate through a completely randomized design with five treatments (0%, 10%, 20%, 30%, and 40% FRWF) and three replicates each. Parameters assessed included fermentation outcomes, daily growth, survival rate, and water quality. A seven-day fermentation period was optimal, yielding 25.38% protein, 15.97% moisture, and 4302 Kcal/kg energy. The 40% FRWF inclusion achieved the highest growth rate (1.93%/day) and acceptable survival rates (80–95%). Water quality parameters, including temperature (25.8°C), dissolved oxygen (4.80 mg/L), pH (7.15), and ammonia (0.03 mg/L), remained within suitable ranges. These findings suggest that incorporating fermented restaurant waste into fish feed can enhance growth performance while maintaining water quality, presenting a sustainable alternative for reducing feed costs in aquaculture.

1 Introduction

Patin fish (*Pangasius pangasius*) or Pangasius catfish is one of the freshwater fish species that is widely cultivated in Indonesia. According to data from the Director General of Aquaculture (2018), the production of patin fish in Indonesia is significant, reaching 488,435 tons. This indicates that the market demand for patin fish is very high [1] The high production of patin fish in Indonesia necessitates an increased supply of quality feed at relatively affordable prices. Fish feed plays a crucial role in aquaculture activities, as it serves as a source of nutrients and energy essential for fish growth [2]. Artificial feeding in intensive patin fish farming is indispensable as it supports optimal growth. However, using artificial

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feed or pellets tends to incur relatively high costs, with feed requirements during cultivation accounting for approximately 60-70% of the total production costs [3]. Thus, it is crucial to explore alternative raw materials to reduce feed costs.

One potential alternative feed ingredient is restaurant waste, which is abundant and has not been fully utilized. Based on research conducted by [4], restaurant waste production in the Jatinangor area alone reaches 10-15 kg per day. Additionally, according to [5], restaurant waste still contains a considerable amount of nutrients, including 10.89% protein, 0.08% calcium, 0.39% phosphorus, 9.13% crude fiber, and 9.70% fat. Despite this potential, the low levels of protein and high crude fiber content remain challenges for its use as fish feed. To address these challenges, fermentation is a viable approach, as it can enhance the nutritional content of fibrous materials [2].

Fermentation is a process that involves the biochemical transformation of complex substances into simpler compounds through the activity of enzymes produced by microorganisms, such as bacteria, molds, and yeasts [6]. The fermentation process commonly employs cellulolytic microbes, which can either be isolated from natural sources or obtained from commercial microbial products, such as probiotics. Several factors influence the fermentation process, including the fermentation medium (substrate), the microorganisms used, environmental conditions, inoculum dosage, and incubated time [7]. Incubated time for food waste variated about 1 day [38], 2 days [39], 6 days [40], and 7 days [41]. The duration of fermentation is closely linked to the growth and multiplication of microorganisms. Prolonged fermentation allows microbes to utilize more substrate for their metabolic activities, increasing acidity and a subsequent decrease in pH value [8]. This study aims to evaluate the potential of fermented restaurant waste as an alternative ingredient in feed formulations for catfish fry (*Pangasius pangasius*), focusing on its effects on growth performance, survival rate, and water quality. This research is essential to address gaps in the utilization of fermented restaurant waste as an alternative feed source and to provide innovative solutions for reducing aquaculture feed costs. To the best of our knowledge, no prior studies have reported on the specific impact of fermentation duration and inclusion rates of fermented restaurant waste flour in feed formulations for Pangasius catfish.

2 Methods

2.1 Research design

This research was conducted between March and May 2021 at Biomethagreen Rumah Edukasi, Tanjung Sari, Sumedang for the fermentation process, and at the Ciparanje Aquaculture Area, Faculty of Fisheries and Marine Science, Padjadjaran University for biological testing. The methodology of this research was divided into two phases:

2.1.1 Phase 1

This study employed an experimental method using a completely randomized design (CRD) consisting of 4 treatments with 4 replications. The treatment applied was the variation in fermentation duration: 0 days or without fermentation (P1), 3 days of fermentation (P2), 5 days of fermentation (P3), and 7 days of fermentation (P4).

2.1.2 Phase 2

This study also employed an experimental method using a completely randomized design (CRD) but with 5 treatments and 3 replications. The treatments involved the addition of Fermented Restaurant Waste Flour (FRWF) at various percentages: 0% (treatment A), 10% (treatment B), 20% (treatment C), 30% (treatment D), and 40% (treatment E).

2.2 Research procedure

2.2.1 Waste fermentation and test feed preparation

The waste used in this study was sourced from four different restaurants in Jatinangor, consisting of leftover rice, bones, and vegetables. The waste underwent a series of processes including sorting, chopping, and fermentation. The fermentation process was carried out using probiotics at a dosage of 8% of the total weight of the restaurant waste, by the method described by [9]. The fermentation periods were 3, 5, and 7 days. After fermentation, the waste was dried and subjected to proximate analysis to determine protein content, crude fiber, moisture content, and energy. The criteria for selecting the best fermentation outcome were the highest increase in protein content and the greatest reduction in crude fiber. The optimal fermentation duration was then used in the subsequent scale-up for feed formulation with FRWF additions of 0%, 10%, 20%, 30%, and 40%. Feed formulation was carried out using the Pearson Square method with a target protein content of approximately 30%. The nutritional composition of the test feeds was determined through proximate analysis, as shown in Table 1.

Table 1. Results of proximate analysis of test feed.

Treatment	Water %	Protein %	Fiber %	Energy Kcal/kg
A (Control)	8.18	18.20	7.91	3454
B (10% FRWF addition)	8.42	21.23	9.85	3162
C (20% FRWF addition)	8.51	24.93	8.32	3433
D (30% FRWF addition)	8.89	26.77	7.57	3767
E (40% FRWF addition)	9.01	28.43	5.69	3952

2.2.2 Feeding test

In this phase, 15 Pangasius catfish fry per aquarium, weighing 4-5 grams, were used for a 42-day feeding experiment. The fish test were reared based on the guidelines of the Institutional Animal Care and Use Committee (IACUC, 2018) and have ethical approval number 302/UN6.KEP/EC/2024 from The Research Ethics Committee Universitas Padjadjaran Bandung. The feed was administered three times daily at a dosage equivalent to 5% of the total fish biomass. Water quality parameters such as temperature, dissolved oxygen (DO), pH, and ammonia concentration were monitored periodically every 7 days. Observed parameters in the test fish included the specific growth rate (SGR) and survival rate (SR), which were calculated using the methods of [10] and [11]:

$$SGR\ \%/day = \frac{lnW_t - lnW_0}{t} \times 100\%$$

$$SR = \frac{N_t}{N_0} \times 100\%$$

Where:
t represents the duration of the experiment (in days),
lnW_0 is the natural logarithm of the initial weight of the catfish fry,
lnW_t is the natural logarithm of the final weight of the catfish fry, and
N_0 and N_t represent the number of fish at the start and end of the experiment, respectively.

2.3 Data analysis

Data analysis was performed using descriptive comparative analysis for proximate test results and water quality data. For biological test data, such as the daily growth rate and survival rate, statistical analysis was conducted using ANOVA (F-test) at a 95% confidence level, followed by Duncan's multiple range test at the same confidence level.

3 Results and discussion

3.1 Changes in nutrient content of restaurant waste

The changes in the nutritional value of restaurant waste, as shown in Fig. 1, indicate that all treatments resulted in nutritional modifications, particularly in protein and crude fiber content. The best results were observed in the restaurant waste fermented for 7 days, where the protein content increased by approximately 10%, from 16.3% to 25.38%. This observation aligns with the findings of [12], which state that the fermentation process with probiotics can enhance the microbial cell mass. This increase is attributed to the production of single-cell proteins, and microbial metabolic by-products such as amino acids, nucleotides, and proteins during fermentation. Furthermore, the prolonged fermentation time is associated with increased protein synthesis activity, driven by microbial enzymes and the rearrangement of compounds, as well as the degradation of other compounds [13].

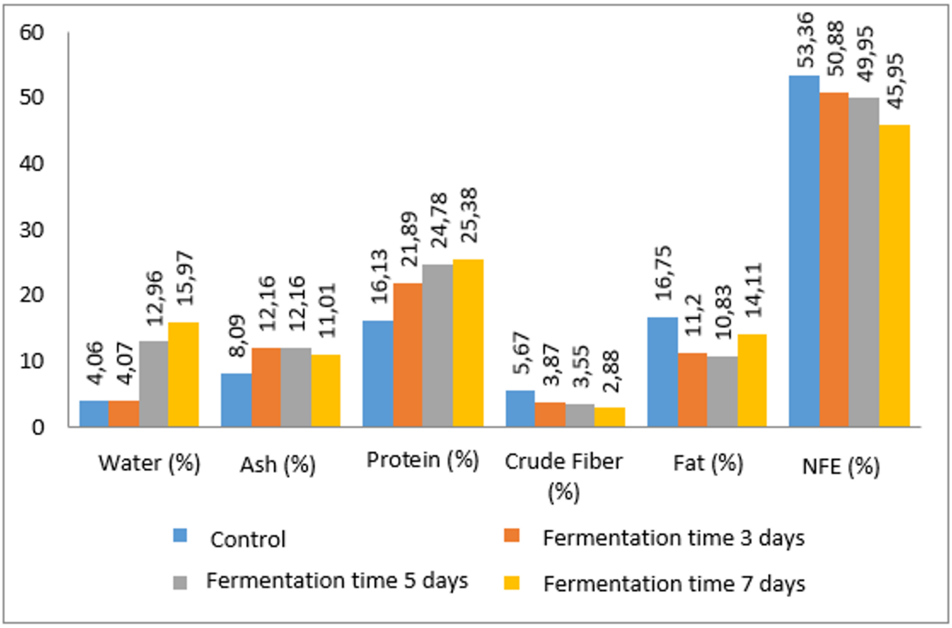

Fig. 1. Nutrient content of fermented restaurant waste.

In addition to the changes in protein content, the fermentation process also impacted crude fiber content. As depicted in Fig. 1, the crude fiber content of the fermented restaurant waste flour decreased by 2%, from 5.67% to 3.55%. This reduction is attributed to the utilization of crude fiber by lactic acid bacteria, which convert cellulose into simpler compounds [14]. Furthermore, the fat content of the restaurant waste after fermentation decreased to 14.11%, reflecting a 2% reduction. This decline in fat content can be explained by the activity of lactic acid bacteria, which hydrolyze fat into fatty acids and glycerol through the production of the enzyme lipase. This is consistent with the findings of [15], who reported that *Lactobacillus* sp. bacteria possess the capability to hydrolyze both protein and fat.

The highest water content is found in fermented restaurant waste with a duration of 7 days, which is 15.97%, which means that there is an increase of 10% from the water content before fermentation. The change in water content is due to activity during the fermentation process which can increase the water content of the material, the high increase in water content indicates that the fermentation process is more effective [16]. In addition, the ash content in waste after fermentation increased by 3%. The increase in ash content occurs along with a decrease in non-nitrogen extractives (NFE) value in waste, which is caused by the degradation process of materials (substrates) by microbes, the higher the ash content in a material indicates that less organic material is formed from the fermentation results. The ash content in the feed shows an indicator of the large content of minerals in the feed [17].

The effects of fermentation on restaurant waste flour demonstrate that fermentation technology can enhance the nutritional value of feed. The fermentation process results in the production of simpler compounds such as amino acids convert long-chain proteins into short-chain peptide bonds, improving protein quality, preserving nutritional value during storage, and eliminating anti-nutritional factors [18-20].

3.2 Specific growth rate

The addition of Fermented Restaurant Waste Flour (FRWF) to the feed generally had a positive impact on the growth of Pangasius catfish fry across all treatments. Table 2 shows that the ANOVA result confirming the treatments significant effect on growth. Further test indicates that A (Control) and B (10% FRWF addition) treatments are not significantly different; C (20% FRWF addition) is significantly different from A and B but not significantly different from D; D (30% FRWF addition) is significantly different from A, B, and C but not significantly different from E while E (40% FRWF addition) is significantly different from all other treatments.

As shown in Fig. 2, the specific growth rate (SGR) of *Pangasius* catfish fry increased in all treatments, with the highest growth observed in Treatment E (40% FRWF), which recorded a SGR of 1.93. The lowest growth rate was observed in Treatment A (0% FRWF), with a SGR of 1.21. The increase in the SGR of *Pangasius* catfish fry corresponded to the increasing addition of FRWF in the fish feed, as illustrated in Figure 2. This improvement can be attributed to the fermentation process undergone by the FRWF, which resulted in simpler compounds, such as amino acids. These compounds make the nutrients in the feed more easily digestible, thus supporting the growth and development of the fish [18].

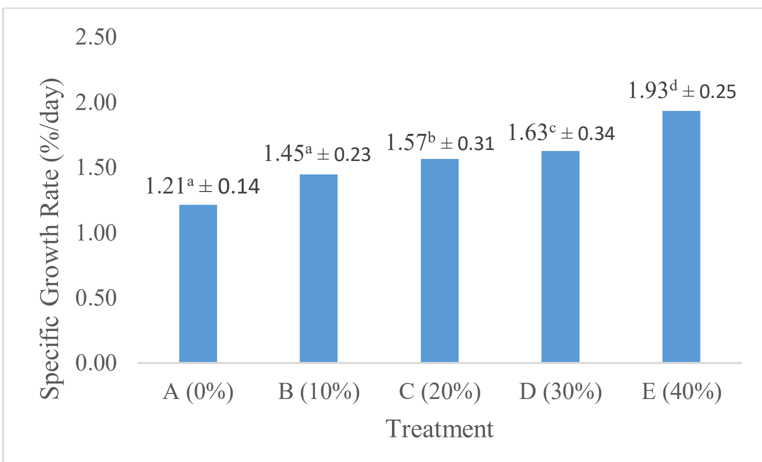

Fig. 2. Specific growth rate of Pangasius catfish fry.

The daily growth rate value has a significant difference between the control and the treatment that has been added with FRWF, meaning that the addition of FRWF in the feed affects the growth rate of catfish, because the higher the dose of FRWF given, the higher the rate of increase in the weight of catfish. This is supported by research [21], that the use of fermented lemna flour in feed produces the highest daily growth rate in carp, which is 2.11%.

The treatment with the highest FRWF inclusion (40%) produced the highest specific growth rate. This result can be linked to the adequacy of the nutritional content in the feed for supporting fish growth. The proximate analysis of the experimental feed revealed a protein content of 25.38%, which aligns with the protein requirement for optimal growth of *Pangasius* catfish, generally estimated to be around 25% [22].

The protein content in the feed affects the growth rate of catfish because the protein is used as the main energy source for fish [23]. The higher the digestibility value of the feed, the more nutrients are available and absorbed by the fish, so that only a few nutrients are wasted through feces, with that the fish are able to survive, repair and renew body tissues and their growth will be better [24]. In addition to the fairly high protein content, faster fish growth can also be caused by the presence of fat content which can be used as a source of energy for fish activities. The study of [25], stated that the presence of non-protein energy sources derived from fat in the feed will break down the use of protein as the main source (protein sparing effect), so that more protein will be stored for the needs of the growth process, and this will have an impact on the growth rate of fish.

3.3 Survival rate

The survival rate (SR) of *Pangasius* catfish fry during the study is presented in Table 2. There are no statistically significant differences in survival rates among these treatments according to the ANOVA test (p>0.05).

Table 2. Survival rate of *pangasius* catfish fry.

Treatment	Survival Rate (%)
A (Control)	$87.5^{a} \pm 2.10$
B (10% FRWF addition)	$88.8^{a} \pm 3.84$
C (20% FRWF addition)	$91.1^{a} \pm 3.84$
D (30% FRWF addition)	$93.0^{a} \pm 1.89$
E (40% FRWF addition)	$95.5^{a} \pm 3.85$

Description:
*FRWF (Fermented Restaurant Waste Flour)
**Values followed by the same lowercase letter are not significantly different based on Duncan's multiple range test at the 95% confidence level.

The highest survival rate (SR) of *Pangasius* catfish fry (*Pangasius pangasius*) was observed in Treatment E (40% FRWF), with an average value of 95.5%. Conversely, the lowest survival rate was found in Treatment A (0% FRWF), with an average of 87.5%. According to [26], an SR ≥ 50% is considered good for aquaculture. The high survival rate of catfish is due to the feed provided and the rearing environment conditions are in accordance with the needs of the fish. This is supported by [27] statement that the survival rate of fish is due to the quality and nutritional content of the feed and appropriate environmental factors such as pH, DO and temperature. In addition, the high survival value of catfish is also due to the good absorption of energy through fermented waste-based feed. The fermentation process has the potential to enhance the efficacy of energy absorption from feed in fermented waste-based food. This is due to the fact that the fermentation process can reduce the content of antinutrients and increase protein bioavailability. As a result, feed is more easily digested and converted into energy [37]. Furthermore, fermentation in restaurant waste can improve the quality of materials by increasing the nutrient content and breaking down complex compound in crude fiber, making it easier for fish to digest the feed given [2].

Overall, feeds with the addition of FRWF showed a higher survival rate compared to those without FRWF. This improvement may be attributed to the fermentation process, which simplifies the composition of the compounds in the FRWF, making them more easily digestible for the fish. As a result, less energy is required for digestion, allowing more energy to be allocated to essential biological processes such as growth and survival. The survival rate in this study aligns with the research of [28], which showed that adding fermented rice bran and tofu dregs to the feed resulted in a catfish survival rate of 95%. Similarly, in research

[29], substituting fermented tuna entrails in the feed resulted in a catfish survival rate of 98.33-100%.

3.4 Water quality

A crucial factor in aquaculture activities is the availability of good-quality water [27]. Water quality parameters during the study remained within acceptable ranges for *Pangasius* catfish fry, as shown in Table 3.

Table 3. Water quality parameters during the study.

Treatment	pH	DO (mg/L)	Temp. (°C)	Ammonia (mg/L)
A (0%)	7.24	5.07	28.96	0.03
B (10%)	7.21	4.59	29.49	0.04
C (20%)	7.28	5.10	25.58	0.04
D (30%)	7.15	5.20	29.20	0.04
E (40%)	7.28	4.80	28.88	0.04
Standard*	6.5 – 8.5	3- 8	27-31°C	≤ 1

Description: [30]

The water temperature during the research ranged from 25°C to 29°C, which is still within the optimum range for *Pangasius* catfish fry, as supported by [31], who stated that a temperature between 25°C and 33°C is ideal for growth. Water temperature can affect the metabolic rate and appetite of fish, so it will indirectly affect fish growth [32]. The pH values recorded during the study were between 7.15 and 7.28, indicating that the water remained within natural limits suitable for aquaculture. [33] reported that *Pangasius* catfish have a broad tolerance to pH, ranging from 5.0 to 9.0. The pH value is one of the indicators for survival rate, a pH value that is not optimal will make fish stressed, susceptible to diseases and will interfere with the growth process [32].

The dissolved oxygen (DO) levels ranged from 4.59 to 5.2 mg/L, which is also within the optimal range of 2 to 7 mg/L for *Pangasius* catfish, ensuring sufficient oxygen availability for growth and metabolic processes. The ammonia concentration during the research was maintained between 0.03 and 0.04 mg/L, which is well below the critical tolerance limit of 16 mg/L for catfish fry, as noted by [34]. Ammonia levels in the maintenance media can be caused by feed that is not eaten by the fish so that it will settle at the bottom of the pond [35]. Ammonia is a toxic substance that can cause fish death in a short period of time, in addition, long-term exposure to ammonia will cause gill damage and reduce fish growth performance [36].

4 Conclusion

The study concluded that fermentation of restaurant waste for 7 days resulted in the best quality, characterized by a 9% increase in protein content, a 2% reduction in crude fiber, and a 2% reduction in fat content. The optimum concentration of Fermented Restaurant Waste Flour (FRWF) in feed was 40% (Treatment E), which yielded the highest daily growth rate of *Pangasius* catfish fry at 1.93%, with a survival rate of 95.5%. Additionally, water quality parameters remained within acceptable limits for aquaculture, with an average temperature of 25.8°C, dissolved oxygen (DO) of 4.80 mg/L, pH of 7.15, and ammonia concentration of 0.03 mg/L.

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