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The Effect of Probiotic-Induced Fermentation of Restaurant Waste on the Growth of Common Carp (*Cyprinus carpio*) Fry

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Abstract*—The study explores using the fermentation process to convert organic restaurant waste into fish feed, a promising solution for aquaculture. The aim is to determine the best type and dosage of probiotics for fermenting restaurant waste (FRWM) and evaluate their impact on common carp (*Cyprinus carpio*) fry growth. Three commercial probiotics (P1, P2, and P3) were used at an 8% concentration for fermenting the waste. The best result from the fermentation trial was tested as feed containing different FRWM proportions: 0% (T_A), 10% (T_B), 20% (T_C), 30% (T_D), and 40% (T_E) with 30% protein content. The trial lasted 42 days, assessing waste chemical composition before and after fermentation, growth rate, amylase and protease activity, feed conversion, survival rate, and water quality. Results showed P1 was most effective, increasing FRWM protein content by 84.25% and reducing crude fiber and fat by 15.17% and 3.94%, respectively. T_E (40% FRWM) yielded the best outcomes, with fry common carp achieving a 1.05% daily growth rate and a feed conversion ratio of 0.80, indicating efficient feed utilization. T_C (20% FRWM) exhibited the highest survival rate at 88.33%. The inclusion of FRWM influenced amylase activity, increasing enzyme levels and improving feed efficiency and growth rate. In conclusion, using FRWM, fermented with P1 probiotics, showed significant improvements in its composition, leading to enhanced fish growth and feed utilization. The 40% FRWM diet demonstrated the best fish growth rate and feed conversion performance. These findings support using fermented restaurant waste as sustainable and nutritious fish feed in aquaculture.

***Keywords*— Common carp; enzyme activity; fermented restaurant waste meal; growth; probiotics.**

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I. INTRODUCTION

Common carp (*Cyprinus carpio*) is a freshwater aquaculture commodity with promising development potential owing to its relatively fast growth, high demand, and economic value [1],[2]. According to the Ministry of Maritime and Fisheries Affairs of the Republic of Indonesia, carp cultivation in Indonesia increased by 34.51% to 620,831 metric tons between 2015 and 2019 [3]. The rise in aquaculture production indicates a continuing high demand for carp in the community. With the projected increase in the world's population, which could reach 9.8 billion people in 2050 [4], the need for fish is expected to rise. Sustainable aquaculture activities that consider the environment's carrying capacity are essential to meet the world's future fish demand and environmental protection [5],[6]. As a high-demand commodity, the increase in aquaculture production of common carp is crucial in contributing to world food security.

Ensuring the success of aquaculture involves modifying feed ingredients to improve the feed's nutritional content, increasing fish growth rate, effectiveness, and productivity. Feed is a crucial factor in the success of aquaculture, as it accounts for up to 70% of total production costs [7]. Using feed ingredients sourced from restaurant waste presents one of the best solutions to meet feed needs while simultaneously addressing the issue of organic waste [8]. The amount of food waste generated differs significantly among countries and is influenced by factors such as affluence, industrialization, and development levels [9],[10]. The future progress of feed aquaculture relies on the identification of sustainable and cost-effective ingredients that fulfill the nutritional requirements of fish [11]. Utilizing food waste as animal feed presents a solution that addresses waste management and food security challenges while reducing the need for conventional feed production, which imposes both resource and environmental burdens [12]. Incorporating food waste meal from leftover vegetables, fruits, cereals, bones, and meat into fish feed not only had no negative impact but also demonstrated positive effects, including increased growth, enhanced fish immunity, and improved feed conversion values [13],[14],[15]. Organic waste is highly suitable as an alternative fish feed, offering a way to reduce reliance on commercial feed. Embracing this approach can yield significant cost savings for fish farmers, providing them a tangible benefit [16]. The fermentation process is the first step in utilizing organic restaurant waste, aiming to ensure sanitation and improve nutritional content. Fermentation can be carried out by adding fermenter microbes obtained through pure breeding or commercial probiotics. Probiotics are live microorganisms that can help maintain health by improving the microbial balance in the digestive tract [17].

Numerous studies have explored the utilization of food waste as fish feed; however, the process of fermenting food waste with probiotics remains unexplored. Therefore, it is hoped that incorporating probiotics into food waste can enhance its potential as a fish feed ingredient. The primary objective of this study is to assess the impact of probiotics added to local restaurant waste and the effect of including fermented restaurant waste in fish feed on the growth of common carp (*Cyprinus carpio*).

II. Materials and Methods

Phase one of the research aimed to determine the most effective probiotic for enhancing the nutrient content of the waste from fermented restaurant waste meals. The restaurant waste collected originates from Javanese and Sundanese restaurants in the Jatinangor area, Indonesia. This waste is then categorized into three types: rice, vegetables, bones, and meat. Subsequently, the food waste is chopped and mixed with 8% of three probiotics (P1, P2, and P3) and incubated for seven days. After the fermentation process, the restaurant waste undergoes drying in an oven at 80°C and is ground into powder. The proximate test was used to measure the changes in chemical composition (protein, fiber, and lipid) after fermentation. The treatment that produced the best results was chosen for the second phase of the research, which involved biological testing on carp.

The second phase of the research was conducted to investigate the impact of adding Fermented Restaurant Waste Meal (FRWM) to feed on the growth of common carp fry (2.27 g ± 0.02) over 42 days. FRWM is utilized as a replacement for fish meal and soybean flour, with varying additional percentages of 0% (T_A) as a control treatment, 10% (T_B), 20% (T_C), 30% (T_D), and 40% (T_E). Based on the Pearson Square method, the feed formulation calculations maintain a feed protein content of 30%. Subsequently, all feed ingredients are thoroughly mixed and pelletized using a meat grinder, followed by drying under sunlight for 1 day. During the experimental period, the test fish are fed three times a day at 07.00, 12.00, and 17.00, with a feeding amount equivalent to 5% of the tested fish biomass. Parameters observed in the second phase include growth, digestive enzyme activity, feed conversion ratio, survival rate, and water quality indicators such as temperature, dissolved oxygen, pH, and ammonia levels.

Specific growth rate (SGR), feed conversion ratio (FCR), and survival rate (SR) were calculated according to [18]:

$$SGR\ (\%\ day^{-1}) = (\ln W_t - ln\ W_0)\ x\ 100\ /\ t;$$
$$FCR = feed\ intake\ /(W_t + D) - W_0\ ;$$
$$SR\ (\%) = (final\ fish\ count/initial\ fish\ count)\ x\ 100$$

The collected data from the observations underwent statistical analysis using analysis of variance (ANOVA) with a significant level of 5%. In cases where significant differences were detected, Duncan's test was employed for further analysis.

III. Results and Discussion

A. Chemical Composition of FRWM

Adding probiotics during the fermentation process enhances the chemical composition of FRWM. Probiotics serve as an additive to feed ingredients, supplying beneficial microbial cells or components of microbial cells, contributing to the host organism's benefits. The activity of *Bacillus* sp. bacteria during fermentation causes an increase in protein levels (Fig. 1) by breaking down the protein-protein-mineral covalent bonds through the production of chitinolytic protease enzymes, leading to an increase in the protein content of the ingredients [19]. As stated by [20], *Bacillus* sp. bacteria possess proteolytic properties, enabling them to convert proteins into amino acids. The bacteria utilize These amino acids for their own proliferation, consequently enhancing the protein content.

Furthermore, [8] stated that *Bacillus* sp. bacteria are saccharolytic and capable of decomposing disaccharides or polysaccharides into simpler molecular groups. The bacterial activity of *Bacillus* sp. increases the protein content in feed ingredients through their multiplication. In bacterial mortality, there will be a rise in nitrogen levels, increasing protein content since a significant portion of the body's cells consists of protein. The solid-state fermentation of whole grain barley by *Rhizopus oligosporus* under optimized conditions contributed to a significant increase in protein content, reaching up to 64.3%, showcasing the impact of microbial activity on protein enhancement [21].

TABLE I
CHEMICAL COMPOSITION OF FRWM

	P0	P1	P2	P3
Protein	16.13^{a}±0.33	29.72^{d}±0.51	24.32^{b}±0.65	27.44^{c}±0.72
NFEM	53.36^{d}±0.71	36.44^{a}±0.93	43.47^{c}±0.30	49.81^{b}±0.53
Lipid	16.75^{c}±0.34	16.07^{bc}±0.56	12.87^{a}±0.48	15.63^{b}±0.44
Crude Fiber	5.67^{b}±0.70	4.81^{b}±0.32	2.78^{a}±0.41	3.04^{a}±0.34

*Means in the same column followed by the same letter are not significantly different at p<0.05

Crude fiber comprises undigestible carbohydrates, including cellulose, lignin, polysaccharides, and hemicellulose [19]. The high crude fiber in feed can result in decreased digestibility, absorption, and water quality and increased metabolic waste [22]. In the P2 treatment, there was a reduction in the crude fiber of 50.97%. The decrease in crude fiber content is due to the activity of fermenter microbes that produce enzymes from secondary metabolite activity. The fibrinolytic enzyme cellulase, for instance, can hydrolyze fiber into glucose, and the reduced crude fiber content is assisted by the mycelium produced by *Saccharomyces cerevisiae* [19].

In addition, *Saccharomyces cerevisiae* produces α-galactosidase enzymes that break down polysaccharides into disaccharides and monosaccharides, and cellulase enzymes that convert crude fiber into glucose [23]. *Bacillus subtilis*, a type of bacteria that can produce proteases, also has the potential to degrade cellulose, although it produces cellulase enzymes in small quantities [24]. Moreover, microbes use crude fiber as an energy source, which aids in the fermentation process and decreases crude fiber content.

The reduction in fat content in FRWM ingredients is attributed to the activity of lactic acid bacteria, which produce lipase enzymes that hydrolyze fats into fatty acids and glycerol. This finding is consistent with the research conducted by [25], which identified *Lactobacillus* sp. as having the ability to hydrolyze proteins and fats. In addition, the energy used by mold to reform complex carbohydrates is obtained from fat, which decreases fat levels.

Regarding the decrease in the content of nitrogen-free extract material (NFEM) in FRWM, the percentages were 31.71% (P1), 6.65% (P2), and 18.53% (P3). The reduction of NFEM levels in all treatments indicates the successful fermentation process. NFEM is a nutrient fraction easily fermented and hydrolyzed quickly during fermentation [26]. As a result, NFEM in the fermentation medium is always reduced.

The differences in chemical composition observed in FRWM after fermentation using various probiotics can be attributed to the different microorganism content and microbial colony density present in each type of probiotic. In the P1 treatment, *Saccharomyces* sp., *Bacillus* sp., and *Lactobacillus* sp. were the primary microorganisms, while in the P2 treatment, *Bacillus* sp., *Lactobacillus* sp., and *Saccharomyces* sp. were the primary microorganisms. The P3 treatment had a different microorganism composition, including *Rhodopseudomonas* sp., *Lactobacillus* sp., *Actinomycetes* sp., *Streptomyces* sp., and yeast. The P1 treatment exhibited the highest increase in protein value, as the microorganisms present in this treatment played a more prominent role in increasing the protein value than the other probiotics. According to [27], the P1 probiotics contained a colony count of 108-109 CFU/ml, which is included in the total criteria for probiotic bacteria for fermentation. [28] states that the minimum requirement for total Lactic Acid Bacteria (LAB) is 106 CFU/ml. The number of probiotic microbial colonies during fermentation can indirectly increase the protein content because microbes are a single-cell protein source. The more microorganisms present in the fermentation process that play a role in the overhaul, the more substrate will decompose, which can lead to a high protein contribution.

Microbial composition during fermentation can significantly impact the final quality of the fermented product. According to [29], the fermentation process is a result of the activities of several types of microorganisms, including bacteria, yeast, and mold. [30] further noted that several factors can affect the fermentation process, such as substrate, temperature, pH, oxygen, dose of microorganisms, and incubation time. By carefully controlling these factors, optimizing the fermentation process to produce a high-quality product with desirable nutritional characteristics is possible.

B. *Specific Growth Rate*

The addition of FRWM to the feed for carp fry had a notable impact on the daily growth rates, showing significant differences, as shown in Fig. 1.

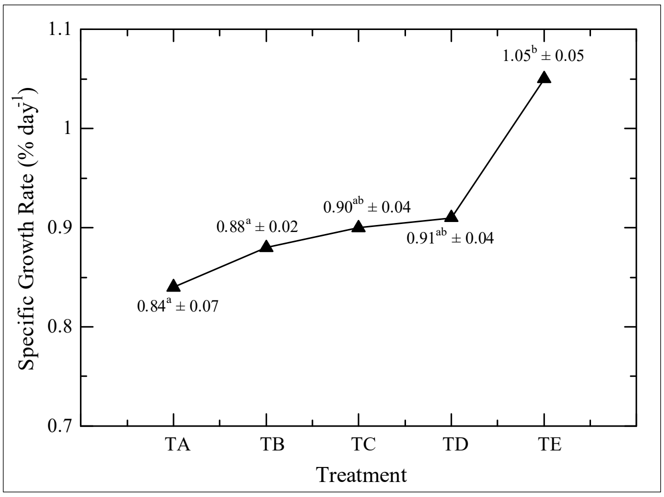

Fig. 1 Specific Growth Rate of Common Carp Fry

According to the results presented in Fig. 1, T_E (FRWM 40%) showed a significant increase in the daily growth rate of common carp fry compared to T_A (FRWM 0%). Although T_E did not show a statistically significant difference when compared to T_C and T_D, the daily growth rate of T_E was the highest among all treatments, reaching 1.05%, This can be attributed to the higher attractiveness of the FRWM substitute feed to the fish, as evidenced by their response to T_E being higher than that of T_A, T_B, T_C and T_D. The nutrients contained in feed, especially proteins, can be more easily absorbed by the bodies of fish, which can be converted into energy for growth when they consume a more attractive feed [31].

Additionally, the provision of fermented feed ingredients can increase the digestibility of the feed, resulting in better fish growth. The fish exhibited improved digestion of the 40% FRWM treatment due to the fermentation process, which transformed long-chain proteins into shorter-chain peptide bonds. The fish readily absorbed these shorter chains to support their growth [32]. This process results in simpler compounds, such as amino acids, which can be easily digested and distributed throughout the body via the blood circulation system [33].

C. *Enzyme Activity*

Fish growth depends on the quality of the feed, as it affects the digestion of protein to produce energy. According to [27], protein is the most important nutrient needed by fish, and if its availability and quality are balanced, then the fish will grow well. Protein is required for energy, growth, and maintenance of body tissues. Digestive enzyme activity is a reliable indicator of the fish's ability to digest feed, where high enzyme activity signifies that the fish's body can digest the nutrition of the feed given [34]. The amount of substrate for enzymes increases with the higher feed consumed, increasing enzyme activity. In the case of adding FRWM as a substitute for fish feed, it positively affects the activity of protease enzymes in the fish's digestive tract (Fig. 2). Carbohydrates are also essential for fish growth, and the production of amylase enzymes in the fish's body determines the amount of carbohydrates needed by the fish [35]. The addition of different FRWM to fish feed also affects the amylase enzyme's activity in the test fish's digestive tract (Fig. 2).

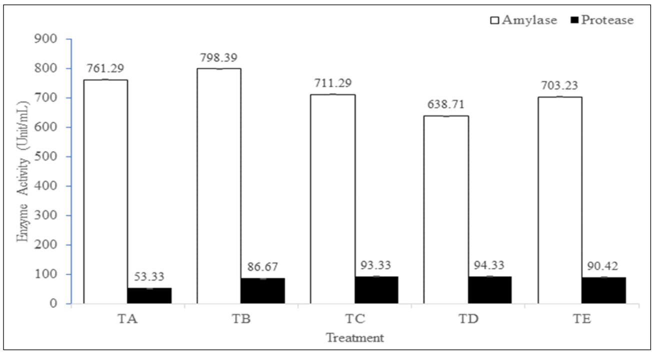

Fig. 2 Enzyme activity in the digestive tract of the studied fish

The process of fermenting FRWM leads to the breakdown of carbohydrates into simpler monosaccharides. Interestingly, the addition of 40% FRWM increased the activity of the amylase enzyme, which had previously decreased at 20% and 30% additions. This is likely due to the higher content of peptides and free amino acids in T_E compared to T_C and T_D. Numerous studies have demonstrated that fermentation can lead to an increase in the concentration of free amino acids and bioactive peptides in various fermented ingredients [36],[37],[38]. The faster absorption of these peptides and amino acids triggers the release of signals modulated by intracellular calcium, which then leads to the release of digestive enzymes, including amylase, lipase, and protease, at higher levels [39]. The resulting increase in digestive enzymes in the fish's digestive tract contributes to higher feed efficiency and growth rates in the studied fish. According to [40], research indicates that the composition of starch and protein in feed influences the growth and activity of protease, amylase, and lipase enzymes in European sea bass (*Dicentrarchus labrax*).

D. Feed Conversion Ratio (FCR)

The development of sustainable feed using alternative ingredients should be informed by the efficiency of feed with a lower FCR [41]. It was observed that the inclusion of FRWM has a positive influence on fish FCR ($P < 0.05$) (Table 2). The research findings indicate a range of feed conversion ratios from 0.80 to 1.06, FCR reduced significantly by increasing the level of FRWM.

TABLE II
FEED CONVERSION RATIO OF COMMON CARP FRY

Treatments	Feed Conversion Ratio
T_A	$1.06^b \pm 0.11$
T_B	$0.98^b \pm 0.04$
T_C	$0.95^b \pm 0.03$
T_D	$0.95^b \pm 0.02$
T_E	$0.80^a \pm 0.06$

*Means in the same column followed by the same letter are not significantly different at p<0.05

Table 2 reveals that T_A (FRWM 0%) had a significantly different feed conversion value compared to T_E (FRWM 40%), while the other treatments did not show significant differences. This discrepancy can be attributed to the varying balance of protein, fat, and carbohydrate levels in the feed with the addition of FRWM, which exerts a distinct effect on the feed conversion ratio. T_A (FRWM 0%) yielded a feed conversion ratio of 1.06, indicating that 1.06 kg of feed was required to produce 1 kg of fish meat. The higher feed conversion value is due to the absence of FRWM, which otherwise enhances digestibility through the breakdown of nutritional content by enzymes produced by microorganisms.

The feed treatment supplemented with FRWM exhibited a feed conversion ratio below 1, indicating improved conversion efficiency. This favorable feed conversion value is attributed to the fermentation process, which simplifies the compounds in FRWM, facilitating proper digestion and absorption of feed derived from FRWM and resulting in a low feed conversion ratio. [42] supports this notion, stating that fermentation breaks down complex molecules in proteins, carbohydrates, and fats into simpler forms that are easier to digest. The low feed conversion value signifies that FRWM provides a well-balanced nutritional composition suitable for fish growth, ensuring sufficient energy production. Additionally, fermentation can enhance nutritional content through biosynthesis, including the production of vitamins, essential amino acids, and proteins, while also improving protein quality and digestibility of crude fiber by reducing its content [43]. High-quality amino acids resulting from protein breakdown increase feed consumption as the feed becomes easily digestible and converted into meat, leading to a low feed conversion value.

The increase in the feed conversion ratio is not solely attributed to the fermentation process but also to the composition of the FRWM material used in the study. The waste composition included animal protein sources (bone, beef, chicken, and fish remains), vegetable protein sources (vegetable remains), and carbohydrates (rice and potato residue). The FRWM underwent a cooking process before fermentation, simplifying its content. This aligns with [44] opinion that the ripening process enhances starch digestibility for both animals and humans.

Among the feed treatments, the addition of 40% FRWM resulted in the lowest feed conversion value of 0.80. The reduced feed conversion ratio is attributed to the higher FRWM content, which facilitates enhanced nutrient absorption due to an increased population of Bacillus sp. and Lactobacillus sp. bacteria in the digestive tract. This, in turn, increases the availability of readily absorbable nutrients through protein hydrolysis into simpler compounds like amino acids. The presence of protease enzymes aids in protein absorption, facilitating fish metabolism. [45] support this observation, stating that the secretion of enzymes increases with the number of probiotics in the digestive tract, leading to improved feed digestion. Increased digestibility indicates a higher availability of nutrients for absorption by the fish's body. FCR values for all treatments comply with the standards set by [46] for common carp fry, ranging from 1.24 to 2.38.

Compared with previous studies' findings, the feed conversion ratio achieved in the present research demonstrates superior outcomes. For instance, a study conducted by [47] reported a common carp feed conversion ratio of 0.87 with the incorporation of fermented cassava leaf. Moreover, the results of this investigation surpass those observed in the utilization of fermented bambara nut meal

(BNM) in African catfish *Clarias gariepinus*, where the feed conversion ratio was noted to be 1.20 [48].

E. Survival Rate

The survival rate, defined as the percentage of fish that remained alive during the rearing period compared to the initial stocking number [49], is a key indicator of fish tolerance and viability [50]. Table 3 presents the survival rate of carp fry reared for 42 days.

TABLE III
SURVIVAL RATE OF COMMON CARP FRY

Treatments	Survival Rate (%)
T_A	$70.00^{a} \pm 0.50$
T_B	$80.00^{ab} \pm 0.50$
T_C	$88.33^{b} \pm 0.76$
T_D	$83.33^{b} \pm 0.58$
T_E	$85.00^{b} \pm 0.50$

*Means in the same column followed by the same letter are not significantly different at p<0.05

Based on the data in Table 3, feeds supplemented with FRWM exhibited a survival rate exceeding 80%. This can be attributed to the digestibility of feed ingredients processed through fermentation, which reduces the energy expenditure required for digestion and allows for enhanced vitality. [51] support this finding, suggesting that fermented feed ingredients offer improved nutrition and digestibility, resulting in increased energy absorption. A high survival rate is often associated with two other parameters: the feed conversion ratio and the daily growth. Proper fish health management, as indicated by favorable daily growth rates and feed conversion, contributes to an increased survival rate.

The survival rate of fish is influenced by both abiotic and biotic factors, including competition, population density, age, and adaptability to the environment [52]. In this research, age plays a crucial role, as the carp seeds used were relatively uniform, enabling equitable competition for available feed. The survival rates observed in all treatments fell within the normal range. According to [53] guidelines for common carp fry production, a minimum survival rate of 70–80% is considered acceptable, indicating that the overall survival rate in this study meets the specified standards.

Effective cultivation management, including attention to stocking density, feed quality, and water quality, significantly influences the survival rate [54]. Feed quality, particularly through fermentation, plays a vital role in supporting fish survival. FRWM, like other fermented feeds, generally provides higher quality compared to non-fermented feeds, including a softer texture and improved aroma, resulting in increased fish appetite and positively impacting fish growth and survival [55]. However, it is important to note that feeding alone does not singularly affect fish survival; other factors, such as stress during the rearing period, may contribute to fish mortality. [56] concur that carp (*Cyprinus carpio*) survival is not solely dependent on feed quality.

The survival rate of carp fry in this study demonstrated favorable outcomes comparable to previous research. [57] reported a survival rate ranging from 50.0% to 88.9% for common carp fed fermented substrate consisting of rice bran and coconut dregs using *Rhizopus oryzae*. [58] achieved an optimal survival rate of carp ranging from 86.67% to 93.33% with the addition of fermented cassava leaf meal. [59] A survival rate of 96.00% was observed for carp treated with additional fermented cocoa pod meal. Additionally, [60] reported a survival rate ranging from 83% to 100% for carp fed with fermented cassava leaf meal as a substitute, utilizing *Rhizopus* sp.

F. Water Quality

The quality of water is a crucial factor in ensuring the success of fish farming. It plays a significant role in the growth and development of fish. Therefore, it is essential to regularly monitor water quality parameters such as temperature, dissolved oxygen (DO), pH, and ammonia concentration. Once a week, temperature, dissolved oxygen (DO) measurements, and pH levels were taken, whereas ammonia concentration was measured at the beginning, middle, and end of the observation period. The results of the water quality measurements obtained during the study are presented in Table 4.

TABLE IV
AVERAGE VALUE OF WATER QUALITY

Treat.	Observed Parameters			
	Temp. (°C)	pH	DO (mg/L)	Ammonia (mg/L)
T_A	28.28±0.95	7.98±0.27	6.70±0.82	0.11±0.04
T_B	27.87±1.00	8.00±0.21	6.68±0.89	0.07±0.02
T_C	27.64±0.37	7.87±0.23	6.84±0.87	0.06±0.01
T_D	28.23±1.23	7.90±0.22	6.76±1.04	0.06±0.01
T_E	29.09±1.60	7.90±0.23	6.47±0.95	0.06±0.01
Standard	24-30°C[a]	6.5 – 8.5[a]	≥3[a]	<1[b]

[a][53], [b][62]

Optimal water quality is crucial for the growth and success of fish farming activities. The results of water quality measurements for all feed treatments during the study indicated that water quality was within the standard range for fish growth [53,62]. The incorporation of fermented FRWM meal in carp feed did not produce any notable impact on water quality throughout the fish-rearing procedure. The pH levels measured during the study ranged from 7.87–8.00, which falls within the pH tolerance limit for carp growth according to [60]. [61] explained that the tolerance limits of organisms to pH can be affected by various factors, including temperature, dissolved oxygen, alkalinity, and the presence of anions and cations. Low pH levels can reduce dissolved oxygen content, which may lead to decreased oxygen consumption, increased respiratory activity, and decreased appetite.

Ammonia (NH_3) is a toxic end product of nitrogen metabolism that originates from organic materials and fish metabolism excretions and is eliminated through the kidneys and gill tissue [60]. During the observation period, the recorded water parameter readings for ammonia ranged from 0.06 to 0.11 mg/L, which falls within the acceptable water quality range that promotes the growth of carp. This is consistent with [62] suggestion that the optimal ammonia level for common carp farming is less than 1 mg/L. Maintaining the ammonia level within the acceptable range is essential to prevent the accumulation of toxic substances in the fish farming environment, which can negatively impact fish health and growth.

IV. CONCLUSION

The research findings demonstrate that the probiotic, when used at a dose of 8% (P1), is effective as a starter in the fermentation process and enhances the chemical composition of FRWM. The protein content increased by 84.25%, while the crude fiber and fat decreased by 15.17% and 3.94%, respectively, surpassing other treatments. Furthermore, the treatment with the most favorable results regarding FRWM was T_E, where 40% FRWM was added. This is evident from the specific growth rate of common carp (*Cyprinus carpio*) fry, which reached 1.05%, a feed conversion ratio of 0.80, and the highest survival rate observed in T_C, with an addition of 20% FRWM, reaching 88.33%. These results highlight the potential of utilizing FRWM as a key ingredient in fish feed, as it can be developed into a viable feed source that improves carp cultivation productivity.

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REFERENCES

[1] Rahmawati, Y., Kismiyati, M. and Lamid. "Effect of bromelin enzyme from pineapple weevil on efficiency and anatomical pathology in carp (*cyprinus carpio*) infested with *Argulus japonicus,*" *Proceedings Series on Physical & Formal Science,* vol. 4, pp. 467-474, 2022.

[2] R. Suwandi, F.R. Karima, A.M. Jacoeb, and R. Nugraha. "Effect of cinnamon extract (*Cinnamomum* sp.) and freezing on common carp physiology (*Cyprinus carpio*)," *Jurnal Pengolahan Hasil Perikanan Indonesia,* vol. 24, no. 2, pp. 255-268, 2021.

[3] Statistik KKP. "Fisheries production" [Online]. Available: https://statistik.kkp.go.id/home.php?m=total&i=2#panel-footer. Accesed on Feb 3, 2023

[4] United Nations (UN), "World Population Prospects: The 2010 Revision, Volume 1: Comprehensive Tables*"* New York: Department of Economic and Social Affairs, Population Division, ST/ESA/SER.A/313, 2011

[5] G. Merino, M. Barange, J. I. Blanchard, J. Harle, R. Holmes, I. Allen, E. H. Allison, M. C. Badjeck, N. K. Dulny, J. Hilt, S. Jennings, C. Mullon, L.D. Rodwell, "Can Marine Fisheries and Aquaculture meet Fish Demand from a Growing Human Population in a Changing Climate". *Global Environmental Change,* vo. 22, pp. 795-806, 2012.

[6] Boyd, C.E., D'Abramo, L.R., Glencross, B.D., Huyben, D.C., Juarez, L.M., Lockwood, G.S., McNevin, A.A., Tacon, A.G.J., Teletchea, F., Tomasso Jr, J.R., Tucker, C.S., Valenti, W.C. 2020. Achieving Sustainable Aquaculture: Historical and Current Perspectives and Future Needs and Challenges. *Journal of the World Aquaculture Society,* 51, 578-633.

[7] M. A. Sandra, Y. Andriani, K. Haetami, W. Lili, M.F. Wiyatna. "Effect of adding fermented FRWM meal with different concentration to physical quality of fish pellet," *Asian Journal of Fisheries and Aquatic Research,* vol. 5, no.3, pp. 1-7, 2020.

[8] Y. Andriani, M. F. Wiyatna, W. Lili, I. Zidni, and M. A. Sandra, "Effect of addition of fermented FRWM meal in artificial feed on the growth of nile tilapia (*Oreochromis niloticus*)" *International and National Symposium on Aquatic Environment and Fisheries.* 2021.

[9] M. G. Abiad and L. I. Meho, "Food loss and food waste research in the Arab world: a systematic review" *Food Security* vol. 10, pp. 311-322, 2018.

[10] Barrera, E.L., Hertel, T. 2021. Global Food Waste across the Income Spectrum: Implication for Food Prices, Production and Resource Use. *Food Policy,* 98, 101874

[11] R. Zeineddine, S. Monzer, I. P. Saoud, and B. Ireland, "Preliminary assessment of restaurant food waste as a feed ingredient for small juvenile rainbow trout (*Oncorhynchus mykiss*)" *Aquaculture International* vol. 29, no. 2., pp. 669-679, 2021

[12] C. Rajeh, I. P. Saoud, S. A. Kharroubi, and S. Nalbandian, "Food loss and food waste recovery as animal feed: a systematic review" *Journal of Material Cycles and Waste Management*, vol. 23, no. 3., pp. 1-17, 2020

[13] Mo, W.Y., Choi, W.M., Man, K.Y., Wong, M.H. 2020. Food Waste-based Pellets for Feeding Grass Carp (*Ctenopharyngodon idellus*): Adding Baker's Yeast and Enzyme to enhance Growth and Immunity. *Science of the Total Envuronment,* 707, 134954.

[14] Nasser, N., Abiad, M.G., Babikian, J., Monzer, S., Saoud, I.P. 2018. Using Restaurant Food Waste as Feed for Nile Tilapia Production. *Aquaculture Research,* 2018, 1-9.

[15] Mo, W.Y., Cheng, Z., Choi, W.M., Man, Y.B., Liu, Y., Wong, M.H. 2014. Application of Food Waste based Diets in Polyculture of Low Trophic Level Fish: Effect on Fish Growth, Water Quality and Plankton Density. *Marine Pollution Bulletin,* 85 (2), 803-809.

[16] Y. Achadri, F. G. Tyasari, and P.A. Dughita, "Utilization of organic waste from restaurants as an alternative to aquaculture feed" *Jurnal Agronomika*, vol. 13, no. 1, pp. 210-213, 2018

[17] M. El-Saadony, M. Alagawany, A.K. Patra, I. Kar, R. Tiwari, M. A. O. Dawood, K. Dharma, and H. M. R. Abdel-Latif. "The functionality of probiotics in aquaculture: an overview" *Fish and Shellfish Immunology,* vol. 117, pp. 36-52, 2021.

[18] Effendie, M.I. 2006. *Biologi Perikanan.* Yayasan Pustaka Nusatama. Yogyakarta.

[19] Y. Andriani, W. Lili, I. Zidni, M. F. Wiyatna, and Risdiana, "The effect of fermentation process on physical properties of organic material from domestic food waste," *Jurnal Key Engineering Materials*, vol. 860, pp. 345-350, 2020

[20] A. M. Sholihati, M. Baharuddin, and Santi "Production and test of cellulase enzyme activity from bacteria *Bacillus subtilis*" *Jurnal Al-Kimia,* vol. 3, no. 2, pp. 78-90, 2015.

[21] Nolefer, R., Nadeem, M., Irfan, M., Syed, Q. 2018. Nutritional Enhancement of Barley in Solid State Fermentation by *Rhizopus oligosporus* ML-10. *Nutrition and Food Science,* 6 (5), 1-7.

[22] R. Iskandar, and S. Fitriadi, "Proximate analysis of processed feed for fish cultivators in Banjar Regency, South Kalimantan" *Jurnal Ziraa'ah*, vol. 42, no. 1., pp. 65-68, 2017.

[23] R. F. Christi, A. Rochana, and I. Hernaman, "Effect of fermented concentrate on gross energy content, crude fiber and crude protein" *Proc. Seminar Nasional Peternakan Berkelanjutan*, vol. 8, Sumedang, Indonesia, pp. 718-723, 2016

[24] H. P. Karlina, Y. Cahyoko, and Agustono "Coconut dregs fermentation using *Trichoderma viride*, *Bacillus subtilis* and EM4 on crude protein and crude fiber content as alternative fish feed ingredients" *Jurnal Ilmiah Perikanan dan Kelautan*, vol. 5, no. 1, pp. 77-84, 2013.

[25] P. Suciati, W. Tjahjaningsih, E. D. Masithah, and H. Pramono, "Enzymatic activity of lactic acid bacteria isolates from the digestive tract of mangrove crabs as probiotic candidates" *Jurnal Ilmiah Perikanan dan Kelautan,* vol. 8 no. 2, pp. 94-108, 2016.

[26] S. Syahrir, S. Rasjid, M. M. Zain, and Harfiah, "Mass change of protein, fat, fiber and BETN complete feed silage based on rice straw and mulberry biomass", pp. 135-146, 2014 [online]. Available: https://adoc.pub/perubahan-massa-proten-lemak-serat-dan-betn-silase-pakan-len.html

[27] Y. Andriani, Z. Anna, Iskandar., Z. Hasan and M. F. Wiyatna, "The effectiveness of commercial probiotics appropriation on feed on nile tilapia (*Oreochromis niloticus*)'s growth and feed conversion ratio," *Asian Journal of Microbiol. Biotech. Env. Sci*, vol. 21, no. 1, pp. 1-4, 2019

[28] K. Kailasapathy, and J. Chin. "Survival and therapeutic potential of probiotic organisms with reference to *Lactobacillus acidophilus* and *Bifidobacterium* spp.," *Immunology and Cell Biology,* vol. 78, no. 1, pp. 80-88. 2000.

[29] K. A. Buckle, R. A. Edwards, G. H. Fleet, and M. Wootton, "*Food Science*" Jakarta: Universitas Indonesia Press. 2013, 365 p.

[30] Andriani, Y., Hutapea, A.A., Zidni, I., Lili, W., Wiyatna, M.F. 2021. Literature Review on Fermentation Factors of Restaurant Organic Waste affecting Feed Quality. *Depik,* 10 (3), 277-283.

[31] L. G. Tanake, "Effect of fish meal substitution with earthworm silage (*Lumbricus rubellus*) in artificial feed on feed utilization and growth of tiger grouper juveniles (*Epinephelus fuscogutattus*)" *Journal of Aquaculture Management and Technology*, vol. 2, no. 3, pp. 26-27, 2013.

[32] F. Erfanto, J., Hutabarat, and E. Arini, "Effect of substitution of trash fish silage with different percentages of artificial feed on feed efficiency, growth and survival of carp fry (*Cyprinus carpio*)," *Jurnal of Aquaculture Management and Technology,* vol. 2, no. 2, pp. 26-36, 2013.

[33] M. U. Puspitasari, H. Johannes, and E. H. Vivi, "The effect of the use of *Lemna* sp. on feed on the efficiency of feed utilization, growth and survival of tilapia (*Oreochromis niloticus*)," *Jurnal Pena Akuatika*,

vol. 17, no. 1, pp. 53-75 2018.
[34] A. Gawlicka,B. Parent, M. H. Horn, N. Ross, N., I. Opstad, and O. J. Torrissen, “Activity of digestive enzymes in yolk-sac larvae of Atlantic Halibut (*Hippoglossus hippoglossus*): indication of readiness for first feeding,” *Aquaculture*, vol: 184, no. 3–4, pp. 303-314, 2000.
[35] M. Marzuqi, M., I W. Kasa, and N.A. Giri. “Growth response and amylase enzyme activity of milkfish (*Chanos chanos* Forsskal) fry fed with different carbohydrate content,” *Media Akuakultur,* vol. 14, no. 1, pp. 31-39, 2019.
[36] Li, S., Li, C., Chen, S., Wang, X., Liu, J., Deng, X., Cai, H., Liu, G. 2023. Effect of Solid-state Fermentation on the Standardized Ileal Digestibility of Amino Acids and Apparent Metabolizable Energy in Peanut Meal Fed to Broiler Chicken. *Fermentation,* 9 (346), 1-14.
[37] Yarlina, V.P., Djali, M., Andoyo, R. 2019. A Review of Protein Hydrolysis Fermented Foods and their Potential for Health Benefits. *International Conference on Food and Bio-Industry,* 443, 012085.
[38] Guo, Q., Chen, P., Chen, X. 2023. Bioactive Peptides Derived from Fermented Foods: Preparation and Biological Activities. *Journal of Functional Foods,* 101, 105422.
[39] D. Zhang, Y. Zhang, B. Liu, Y. Jiang, Q. Zhou, J. Wang, H. Wang, J. Xie, and Q. Kuang, “Effect of replacing fish meal with fermented mushroom bran hydrolysate on the growth, digestive enzyme activity, and antioxidant capacity of allogynogenetic crucian carp (*Carassius auratus gibelio*)” *Turkish Journal of Fisheries and Aquatic Sciences,* vol. 17, pp. 1039-1048, 2017.
[40] García-Meilán, I., Herrera-Muñoz, J.I., Ordóñez-Grande, B., Fontanillas, R., Gallardo, Á. 2023. Growth Performance, Digestive Enzyme Activities, and Oxidative Stress Makers in the Proximal Intestine of European Sea Bass (*Dicentrarchus labrax*) Fed High Starch or Lipid Diets. *Fishes,* 8, 223.
[41] Sarker, P.K. 2023. Microorganisms in Fish Feeds, Technological Innovations, and Key Strategies for Sustainable Aquaculture. *Microorganisms,* 11, 439.
[42] N. A. Fauzana, “Potential of Banana Peel (Fermentation Technology for Fish Feed)” Bandung: Unpad Press, 2012
[43] G. Oboh, “Nutrient enrichment of cassava peels using a mixed culture of *Saccharomyces cerevisiae* and *Lactobacillus* spp. solid media fermentation techniques,” *Biotechnology,* vol. 9, pp. 46-48, 2006
[44] Sukarman, “Various Alternative Local Raw Materials for Fish Feed” *Jurnal Media Akuakultur*, vol. 6, no. 1, pp. 36-42, 2011
[45] J. E. Setiawan, Y. T. A. Tarsim, and S. Hudaidah, “Effect of adding probiotics to feed with different doses on growth, survival, feed efficiency and protein retention in catfish (*Pangasius hypophthalamus*),” *Jurnal Rekayasa dan Teknologi Budidaya Perairan*, vol. 1, no. 2, pp. 151-162, 2013
[46] Kementerian Kelautan dan Perikanan, 2016. KEPMENKP No.24/KEPMEN-KP/2016. Pelepasan Ikan Mas (*Cyprinus carpio*) Rajadanu tahan Penyakit KHV.
[47] A. Nurulaisyah, D. N. Setyowati, B. H. Astriana, “Potential use of fermented cassava leaves (*Manihot utilissima*) as a feed ingredient to increase the growth of carp (*Cyprinus carpio*).” *Jurnal Perikanan*, vol. 10, no. 2, pp. 134-147, 2020.
[48] Enyidi, U.D., Etim, E.O. 2020. Use of Solid state Fermentation Bambara Nut meal as Substitute of Fishmeal in the Diets of African Catfish *Clarias gariepinus. Iranian Journal of Fisheries Science,* 19 (4) 1889-1910.
[49] Y. T. Saloko, Rachimi, I. R. Eka, and H. Yanti, “The effect of giving different fermented yellow corn in feed on the growth rate and survival rate of barnet fish (*Leptobarbus hoevenii*)” *Jurnal Ruaya*, vol. 5, no. 1, pp. 6-10, 2015
[50] Dedi, H. Irawan, and W. K. A. Putra, “The effect of giving thyroxine hormone to megami pellet feed on the growth of cantang grouper fries *Epinephelus fuscoguttatuslanceolatus*” *Jurnal Intek Akuakultur*, vol. 2, no. 2, pp. 33-48, 2018.
[51] Suwarsito and Cahyo, “Utilization of tofu waste as feed for nilem fish in Cikembulan Village, Pekucen District, Banyumas Regency” Univ. Muhammadiyah Purwokerto. Indonesia, 2005
[52] Y. I. Siregar, and Adelina. “Effect of vitamin c on increasing blood hemoglobin (Hb) and survival of common carp fries (*Cyprinus carpio).” Jurnal Natur Indonesia*, vol. 21, no. 1, pp. 75-81, 2009
[53] Indonesian National Standard “01- 6131 – 1999. Production of Common carp parent (*Cyprinus carpio* Linneaus) Majalaya strain main class parent (Parent Stock)*”* Jakarta: Badan Standarisasi Nasional, pp. 1-12, 1999
[54] M. A. Suprayudi, “Local raw materials: challenges and hopes for future aquaculture” *Proc. Simposium Nasional Bioteknologi Akuakultur III*. BDP FPIK. Institut Pertanian Bogor. Indonesia, 2010
[55] Heltonika, B., Afriani, S., Siagian, D.R., Lesmana, I., Karsih, O.R. 2022. Potential of Fermented Commercial Feed to Replace Silk Worms on Post Larvae of Asian Redtail Catfish (*Hemibagrus nemurus*). *IOP Conference Series: Earth and Environmental Series,* 1118, 012002.
[56] R. D. Umam, C. Sriherwanto, E. Yunita, I. and Suja’i, “Growth of common carp fed with rice bran-coconut bagasse mixed substrate fermented using *Rhizopus oryzae” Jurnal Bioteknologi dan Biosains Indonesia,* vol. 2, no. 2, pp. 81-87, 2015
[57] A. Nurulaisyah, D. N. Setyowati, and B. H. Astriana, “Potential use of fermented cassava leaves (*Manihot utilissima*) as a feed ingredient to increase the growth of carp (*Cyprinus carpio*)” *Jurnal Perikanan,* vol. 10, no. 2, pp. 134-147, 2020
[58] Seravina, Subandiyono and A. Sudaryono, “The effect of the use of fermented cocoa pod (*Theobroma cacao* L.) meal in feed on the efficiency of utilization and growth of carp (*Cyprinus carpio*)” *Jurnal Sains Akuakultur Tropis*, vol. 3 no. 2, pp. 31-40, 2019
[59] S. Rahmadani, D. N. Setyowati, and D. P. Lestari, “The effect of substitution of cassava leaf meal (*Manihot utilisima*) fermented using *Rhizopus* sp. on feed on the growth and survival of common carp fry (*Cyprinus carpio*)” *Jurnal Perikanan*, vol. 10, no. 1, pp. 70-76, 2020
[60] M. Arief, D. K. Pertiwi, and Y. Cahyoko, “The effect of artificial feed, natural feed and their combinations on growth, feed conversion ratio and survival rate of Anguila eel (*Anguilla bicolor*)” *Jurnal Ilmiah Perikanan dan Kelautan*, vol. 3, no. 1, pp. 61-65, 2011
[61] R. B. K. Haris, and I. A. Yusanti, “Water suitability analysis for floating net cages in Sirah Pulau Padang District, Ogan Komering Ilir Regency, South Sumatra Province” *Jurnal Lahan Suboptimal,* vol. 8, no. 1, 2019.
[62] M. G. H. Kordi, and A. B. Tancung, “Water Quality Management” Jakarta: PT. Rineka Cipta, 2007. 238 pp.