



Effects of Dietary Coffee Husk Fermentation on The Growth of Catfish (*Pangasianodon hypophthalmus*)

Azmi Afriansyah^{ID}, Mohamad Amin*, Ade Dwi Sasanti^{ID}, Sefti Heza Dwinanti^{ID}, Tanbiyaskur^{ID}

Study Program of Aquaculture, Department of Fisheries, Faculty of Agriculture, Universitas Sriwijaya, Palembang-Prabumulih Highway km 32, Indralaya-30662, Ogan Ilir, South Sumatra, Indonesia.

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E-mail addresses:

mohamadamin@fp.unsri.ac.id

*Corresponding author

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ABSTRACT

Coffee husk fermentation (CHF) might be utilized as an alternative plant protein source. This research evaluated dietary CHF supplementation's effects on growth for striped catfish. This study consisted of five grade levels of CHF as a treatment. The treatments were P0 (without the addition of CHF), P1 (addition of 6% CHF), P2 (addition of 12% CHF), P3 (addition of 18% CHF), and P4 (addition of 24% CHF). The results determined that dietary CHF inclusion had no significantly different effect on specific growth rate (SGR) and feed efficiency ($P > 0.05$). However, the P1 group (6% CHF) produced the best protein retention (PR), which was significantly different from the control (P0) and other CHF treatments ($P < 0.05$). No significant differences were observed in survival rates among the treatments. The inclusion of CHF up to 24% in the diet was found acceptable, as it did not negatively impact the striped catfish's overall health or growth performance. Although growth rate, feed efficiency, and survival did not significantly differ ($P > 0.05$).

Keyword: feed utilization, fermented coffee husk, growth performance, striped catfish (*P. hypophthalmus*)

INTRODUCTION

Striped catfish (*Pangasianodon hypophthalmus*) is a type of freshwater fish with high economic value and is the most widely cultivated in the world (Hoque *et al.*, 2021). Striped catfish production from 2019 - 2023 has increased by an average of 4.17% annually (Ministry of Fisheries and Marine Affairs, 2024). This increase is due to the high demand of the world community for animal protein sources to meet nutritional needs.

Thus, the application of intensive cultivation systems for this species continues to be carried out to meet needs. On the other hand, the problem in implementing an intensive cultivation system is the increasing need for feed as one of the main aspects in aquaculture (Zannat *et al.*, 2023). Nearly 60% of the total production cost is allocated for feed

(Daniel, 2018). Feed is a very important component in the growth rate and survival of fish. Currently, the source of protein in feed is still very dependent on fish meal and soybean meal, which are relatively more expensive (Ahmad *et al.*, 2020; Stockhausen *et al.*, 2023). Thus, one effort to reduce feed costs is by using alternative feed ingredients.

Generally, alternative proteins come from ingredients that are not used by humans but have nutritional content for the fish's body. One of these alternative feed ingredients is coffee skin, which is a waste product of coffee fruit processing, with a protein content ranging from 7-17% (Nuraisah *et al.*, 2013; Cangussu *et al.*, 2021; Afriansyah *et al.*, 2023). Coffee skin is a by-product (waste) of coffee beans and must be handled further so as not to cause pollution. Although it has not been utilized

optimally (Vivas *et al.*, 2025). At least each coffee bean processing produces 35% coffee skin (Iriondo-Dehond *et al.*, 2020). Therefore, this considerable potential needs to be utilized. Coffee skin contains micro- and macronutrients that are very much needed by the body (Bondesson, 2015; Esquivel & Jiménez, 2012).

In addition, there are also phytochemical compounds of the polyphenol group that act as antioxidants that help improve fish health (Blinová *et al.*, 2017; Rahimnejad *et al.*, 2015; Ameca *et al.*, 2018; Hoseini *et al.*, 2021; Van Doan *et al.*, 2021; Van Doan *et al.*, 2022). Furthermore, the use of coffee skin in fish feed has been explored previously, especially in species such as red tilapia (*Oreochromis sp.*). Supplementation of 4% coffee skin flour has a positive effect on growth performance and antioxidants (Afriansyah *et al.*, 2023). Meanwhile, fermented coffee skin in feed for *Boranomys Goniatus* produced the best intestinal villi growth (Dhani *et al.*, 2023).

However, the high amount of crude fiber, namely 17.2%, is one of the weaknesses of using coffee skins (Analianasari *et al.*, 2022). High levels of crude fiber make feed more difficult for fish to digest, while the tolerance limit for crude fiber that can be digested by fish is in the range of less than 8% (Nuraisah *et al.*, 2013). This weakness can be overcome through initial processing with fermentation (Nuraisah *et al.*, 2013; Fitria *et al.*, 2020; Siddik *et al.*, 2024; Yafetto *et al.*, 2023).

Through fermentation, complex molecules such as proteins, carbohydrates, and fats are converted into simpler and more digestible forms. CHF fermentation using several microbes can reduce crude fiber by 23.1% (Nuraisah *et al.*, 2013). The purpose of this study was to determine the effect of CHF as a

feed supplement on the performance of striped catfish.

MATERIALS AND METHODS

Preparation of coffee husk fermented

The coffee skin used in this study came from a local plantation in Buay Rawan Regency, South Sumatra, Indonesia. The coffee skin was dried for about 7 hours and ground using a disk mill. The fermentation process of coffee skin flour refers to Warasto & Fitriani (2013), namely by making a fermentation solution by mixing commercial probiotics (EM4™) into water with a ratio of 1:100. Then, 150 grams of sugar was added as a carbon source. Furthermore, the coffee skin flour was mixed evenly with the fermentation solution. The mixing ratio is 3 ml of fermentation solution for 10 grams of coffee skin flour. The mixing results are then put into a plastic bag and stored at room temperature for seven days.

Experimental design

Striped striped catfish were obtained from local ponds in Indralaya, Ogan Ilir Regency, South Sumatra Province. Striped catfish were kept in a $2 \times 2 \times 1$ m³ hapa for one week to adapt to the research environment. The hapa used in this study measured $50 \times 50 \times 50$ cm³ with a total concrete pool size of $4 \times 4 \times 1$ m³. A total of 300 striped catfish with an average initial weight of 5.54 ± 0.38 g were used in this study. This study used a completely randomized design (CRD) with five treatments and three replications. The percentage dose of coffee husk given was different for each treatment, namely P0 (0% CHF), P1 (6% CHF), P2 (12% CHF), P3 (18% CHF), and P4 (24% CHF). This dose refers to the research of Fitria *et al.* (2020) and Afriansyah *et al.* (2023), which is arranged in a feed formulation with a protein content of 30% (Table 1).

Proximate analysis using the Association of Official Analytical Chemists (AOAC, 2012). Maintenance of striped catfish was carried out during six weeks, and feeding at satiation was carried out 3 times a day, namely in the morning (08.00 am), afternoon, and evening (12.00 and 16.00 pm).

Growth Performance and Feed Utilization

During the research period, fish per cage were counted and weighed to calculate weight gain (WG), specific growth rate (SGR), feed efficiency (FE), survival rate (SR) and protein retention according to Nahida *et al.* (2025) and Tola *et al.* (2025):

$$SGR = \frac{(\ln \text{ Final weight} - \ln \text{ Initial Weight})}{\text{Days}} \times 100$$

$$WG = \text{final body weight} - \text{initial body weight}$$

$$FE = \frac{(\text{Final biomass} - \text{Initial biomass})}{\text{total feed}}$$

$$SR(\%) = \frac{(\text{Final number of fish})}{\text{initial number of fish}} \times 100$$

$$PR(\%) = \frac{(\text{Final biomass protein (g)} - \text{Initial biomass protein (g)})}{\text{total protein consumed}} \times 100$$

Water Quality Measurement

Water quality has a significant effect on fish survival and growth. The parameters observed

are water pH, dissolved oxygen, ammonia, and temperature.

Data analysis

All data obtained were analyzed using analysis of variance (ANOVA) to determine the effect of the treatment. Furthermore, Duncan's test with a 95% confidence interval (SPSS 22.0) was used to determine the differences between each treatment.

RESULTS AND DISCUSSIONS

Results

Growth Performance and Feed Utilization

The results showed that the addition of CHF did not have a significant effect on the specific growth rate, absolute weight gain, or survival rate of catfish ($P > 0.05$), including on feed consumption and efficiency. However, the addition of 6% CHF (P1) to the feed was able to significantly increase protein retention ($P < 0.05$) compared to other treatments. While treatments P2, P3, and P4 did not provide a significant difference with P0 ($P > 0.05$). All growth performance and feed utilization data are listed in Table 2.

Table 1. Diet formulation of five grade levels CHF

Ingredients (%)	Treatments of diet				
	P0	P1	P2	P3	P4
Coffee husk fermented	0	6	12	18	24
Fish meal	43	43	43	43	43
Soybean meal	18	17	16	15	14
Rice bran	23	18	13	8	3
Wheat flour	10	10	10	10	10
Vitamin mix	2	2	2	2	2
Fish oil	3	3	3	3	3
Diet proximate contents (%)					
Protein	29.82	30.16	30.89	30.90	30.05
Lipid	15.11	14.49	13.84	14.84	13.94
Moisture	8.50	9.48	8.71	8.97	8.26
Ash	12.96	12.50	7.88	7.26	11.57

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	Diet proximate contents (%)				
Crude fiber	6.80	7.21	7.28	10.90	9.94
NFE*	26.82	26.15	31.39	27.11	26.23
GE* (kcal/kg diet)	487.96	481.33	476.89	468.41	455.12

* NFE = nitrogen free extract; * GE = Gross energy (Watanabe, 1988).

Table 2. Growth and feed utilization after rearing

Parameter	Treatments of diet				
	P0	P1	P2	P3	P4
W ₀ (g)	5.31±0.34 ^a	5.33±0.09 ^a	5.48±0.18 ^a	6.17±0.19 ^a	5.43±0.13 ^a
W _t (g)	12.58±1.63 ^a	13.68±0.34 ^a	13.24±1.178 ^a	13.31±0.55 ^a	13.34±0.63 ^a
FI (g)	843.30±1.51 ^a	859.43±0.78 ^a	862.51±0.61 ^a	866.76±0.63 ^a	866.68±0.11 ^a
SGR(%)	4.04±0.38 ^a	4.24±0.03 ^a	4.09±0.13 ^a	3.83±0.14 ^a	4.08±0.22 ^a
FE (%)	89.09±8.63 ^a	95.54±1.76 ^a	92.11±6.43 ^a	92.15±3.23 ^a	92.23±3.73 ^a
PR (%)	34.62±5.24 ^b	45.45±3.25 ^a	30.84±4.28 ^b	30.80±1.31 ^b	31.49±2.25 ^b
SR (%)	100.00±0.00 ^a	100.00±0.00 ^a	100.00±0.00 ^a	100.00±0.00 ^a	98.33±2.89 ^a

Note: different superscript letters on the same line, show a significant difference (P < 0.05). W₀ = Initial weight, W_t = Final weight, FI = Feed intake, SGR = Specific growth rate, FE = Feed efficiency, PR = Protein retention, SR = Survival rate.

Water Quality

The results determined that water quality during the rearing of striped catfish was in

normal conditions that could be tolerated to support fish survival (Table 3).

Table 3. Water quality during rearing of striped striped catfish

Parameter	Results of measurement	Optimal range
Temperature (°C)	29,5 - 29,9	25 - 31 (Agriansa, 2020)
pH	6,0 - 7,9	6 - 8 (Agriansa, 2020)
Dissolved oxygen (mg.L ⁻¹)	3,97 - 6,66	> 3 (Akash et al., 2024)
Ammonia (mg.L ⁻¹)	0,03 - 0,19	<0,2 (Chen et al., 2019)

Discussion

CHF can be used as additional fish feed (Prakash & Doan, 2022). The experiment results showed that using up to 24% of CHF was not significantly different from the control treatment (P0) on the growth rate. However, there was an increase in feed consumption in all CHF treatments compared to the control. The increase in feed consumption is thought to be due to the taste of coffee that striped catfish like, which increases the fish's appetite. According to Nuraisah et al. (2013), the increase in the amount of feed consumption is caused by the palatability of the feed, both in terms of aroma and texture that fish like. Although no research is available, it is suspected that the increase in feed utilization is

due to the aroma that arises from CHF, which comes from the Maillard reaction. This reaction produces a distinctive coffee aroma from the roasting process, thus inducing the formation of aroma precursors (Cardoso et al., 2023; Tarigan et al., 2022).

The feed consumed by fish will be converted into energy. The greater the energy available, the more it will be able to meet maintenance needs while the remaining energy is used for growth (Afriansyah et al., 2023). The amount of feed given will result in growth if striped catfish can consume and digest the feed. The same study by Nuraisah et al. (2013) showed that using fermented coffee skin flour up to 20% in feed resulted in growth that was not significantly different from the control

treatment in tilapia. This energy will be used for maintenance and growth so it can be ensured to meet the needs of fish maintenance (Suprayudi *et al.*, 2017).

Growth performance did not show a significant difference between treatments. This concludes that fermented CHF has the potential to be used as an alternative raw material for rice bran and soybean flour. This can be seen from the study results, which showed that feed containing CHF up to 24% in the feed formulation was still acceptable to striped catfish and improved the growth performance of striped catfish. Afriansyah *et al.* (2023) reported that using 4% coffee skin flour positively affected growth performance and antioxidants. The use of CHF up to 24% positively affected the quality of tilapia fillets (Fitria *et al.*, 2020).

Feed efficiency refers to growth and consumption (Rodde *et al.*, 2021). Feed efficiency provides an overview of the utilization of the feed given to increase fish growth (Nuraisah *et al.*, 2013). P4 treatment with a CHF content of up to 24% produced feed efficiency no different from P0. This is likely because the fermentation results can reduce crude fiber in CHF from 33.80% to 23.1% (Nuraisah *et al.*, 2013).

Based on these results, the use of CHF up to 24% in feed can still be digested, resulting in striped catfish growth. The decrease in crude fiber is thought to be due to the role of microbes that degrade cellulose in CHF (Nuraisah *et al.*, 2013). In addition, the natural microorganisms used for this fermentation are divided into four main groups, namely photosynthetic bacteria, fermentation fungi, lactic acid bacteria and *Actinomyces* sp. all of which play a role in breaking down lignocellulose bonds, namely releasing lignin and cellulose, which then proteolytic microbes

will produce protease enzymes that function to break down proteins into amino acids (Al Barru *et al.*, 2022). The crude fiber in the control treatment feed was 6.80%, while the crude fiber in the coffee skin feed ranged from 7.21 - 10.90%.

Protein retention reflects protein saved in the body. The protein retention value in the P1 treatment (45.45%) was significantly higher compared to the P0, P2, P3, and P4 treatments ($P < 0.05$). The higher the PR value, shown the more protein in the body from diet protein (Suprayudi *et al.*, 2014). In previous studies utilizing CHF supplementation, the highest protein retention was found at a dose of 4% CHF for tilapia feed (Afriansyah *et al.*, 2023). This is thought to be due to the contribution of energy derived from higher non-protein which makes fish able to digest and absorb feed sourced from high energy for maintenance and growth needs (Van Doan *et al.*, 2022; Giri *et al.*, 2016). In addition, giving 30% fermented coffee husk feed to *Barbonymus gonionotus* showed the best intestinal villi growth in terms of height and width as viewed from its histology (Dhani *et al.*, 2023). Increased intestinal villi result in increased surface area for nutrient absorption which has a positive impact on growth performance and feed utilization in animals (Saleh *et al.*, 2022). As stated by Kpundeh *et al.* (2015), high protein retention occurs when the protein content in the diet is efficiently utilized by the fish.

Based on research, the overall water quality is within the range that can be tolerated by fish. The water temperature ranged from 29.5 - 29.9 °C, and the water pH during catfish maintenance ranged from 6.0 - 7.9. The dissolved oxygen content during maintenance ranged from 3.97 - 6.70 mg/L⁻¹, and the ammonia value ranged from 0.03 - 0.19 mg/L¹. According to Agriansa (2020), the good water

temperature and pH for catfish maintenance range from 25-31°C and 6-8. The optimal ammonia range for fish life is <0.2 mg/L⁻¹ (Chen *et al.*, 2019). According to the Akash *et al.* (2024), the optimal dissolved oxygen for catfish is 5-7 mg/L⁻¹.

CONCLUSION

Application of CHF up to 24% in feed formulation may not interfere with growth performance and feed utilization in striped catfish. However, it does not significantly affect growth performance and feed efficiency.

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AUTHORS' CONTRIBUTIONS

Each author's contribution includes among others, AA: collecting data, conceptualization, software, experimental design, data curation, manuscript writing; MA: conceptualization, software, manuscript writing, data curation; ADS: conceptualization, software, experimental studies, manuscript writing, data curation; SHD: conceptualization, software, experimental studies, manuscript writing, data curation; TBY: conceptualization, software, experimental studies, manuscript writing, data curation.

CONFLICT OF INTEREST

All authors declare that there are no conflict of interests are reported.

REFERENCES

- Afriansyah, A., Setiawati, M., Suprayudi, M. A., & Fauzi, I.A. (2023). Evaluation of dietary coffee Coffee canephora husk supplementation on the growth, blood chemicals, and antioxidative activity of red Nile tilapia *Oreochromis sp.* Jurnal Akuakultur Indonesia, 22, (1), 18-26.
- Agriansa, L., Sumantriyadi, S., & Sari, L. P. (2020). Analysis of Catfish (*Pangasius sp.*) Enlargement culture in Talang Kelapa Subdistrict, Banyuasin

- Regency. Jurnal Ilmu-ilmu Perikanan dan Budidaya Perairan, 15(1), 10-20.
- Ahmad, N., Siddiqui, P. J. A., Khan, K. M., Ali, A., Tahir, M., Akbar, N. U., ... & Boneri, I. D. (2020). Effects of partial substitution of fishmeal by soybean meal in Nile tilapia *Oreochromis niloticus* diet. The Journal of Animal and Plant Sciences, 30, 364–370.
- Akash, S., Sahoo, S., & Vijayalakshmi, M. (2024). Enhancing High-Density Fish Farming in a Biofloc System Through IoT Driven Monitoring System. In 2024 8th International Conference on Electronics, Communication and Aerospace Technology, 472-477.
- Al Barru, N. A., Lumbessy, S. Y. & Lestari, D. P. (2022). The Composition Test Of Tilapia Feed (*Oreochromis Niloticus*) With Addition Of Flour *E. Cottonii* Fermented Using Tape Yeast and EM-4. Jurnal Ilmu Perikanan dan Sumberdaya Perairan, 11(1), 1159 -1166
- Ameca, G. M., Cerrilla, M. E. O., Córdoba, P. Z., Cruz, A. D., Hernández, M. S., & Haro, J. H. (2018). Chemical composition and antioxidant capacity of coffee pulp. Cienc. e Agrotecnologia, 42(3), 307–313.
- Analinasari, A., Kenali, E. W., Berliana, D., & Yulia, M. (2022). Liquid organic fertilizer development strategy based coffee leather and raw materials to increase revenue local coffee Robusta farmers. In IOP Conference Series: Earth and Environmental Science, 1012(1), 012047.
- Association of Official Analytical Chemists [AOAC]. (2012). Official method of analysis of AOAC Intl. 19th Ed. Association of Official Analytical Chemists, Maryland (US).
- Blinová, L., Sirotiak, M., Bartošová, A., Soldán, M. (2017). Review: Utilization of waste from coffee production. Res. Pap. Fac. Mater. Sci. Technol. Slovak Univ. Technol, 25(40), 91–101.
- Bondesson E. (2015). A nutritional analysis on tea by-product coffee husk and its potential utilization in food production. Fac. Nat. Resour. Agric. Sci. - Dep. Food Sci. A, 415, 1–25.
- Cangussu, L. B., Melo, J. C., Franca, A. S., & Oliveira, L. S. (2021). Chemical characterization of coffee husks, a by-product of coffea arabica production. Foods, 10(12), 3125.
- Cardoso, W. S., Dias, S. R., Coelho, V. S., Pereira, L. L., Fioresi, D. B., & de Abreu Pinheiro, F. (2023). Maillard reaction precursors and arabica coffee (*Coffea arabica* L.) beverage quality. Food and Humanity, 1, 1-7.
- Chen, Y. Y., Cheng, Y. J., Yang, L., Liu, Y. Q., & Li, D. L. (2019). Prediction model of ammonia-

- nitrogen in pond aquaculture water based on improved multi-variable deep belief network. *Trans Chin Soc Agricult Eng*, 35, 195-202.
- Daniel, N. (2018). A review on replacing fish meal in aqua feeds using plant protein sources. *International Journal of Fisheries and Aquatic Studies*, 6(2), 164–179.
- Dhani, D. N., Fitri, L., & Firdus, F. (2024). Utilization of fermented coffee husk feed using *Aspergillus niger* on histological features of tawes (*Barbonymus gonionotus*). *Depik*, 13(3), 525-530.
- Esquivel, P., & Jiménez, V. M. (2012). Functional properties of coffee and coffee by-products. *Food Research International*, 46, 488–495.
- Fitria, P. D., Amin, M., Lokapirnasari, W. P., & Lamid, M. (2020). Supplementation of fermented coffee-peel flour to increase high-density lipoprotein (HDL) cholesterol, docosahexaenoic acids (DHA) and eicosapentaenoic acids (EPA) deposition in tilapia fillet. *Biocatalysis and Agricultural Biotechnology*, 101502.
- Food and Agriculture Organization [FAO]. (2022) The State of World Fisheries and Aquaculture 2022. FAO, Rome <https://doi.org/10.4060/cc0461en>.
- Giri, S. S., Jun, J. W., Sukumaran, V., & Park, S. C. (2016). Dietary administration of banana (*Musa acuminata*) peel flour affects the growth, antioxidant status, cytokine responses, and disease susceptibility of rohu, *Labeo rohita*. *Journal of immunology research*, 2016(1), 4086591.
- Hoque, M. S., Haque, M. M., Nielsen, M., Rahman, M. T., Hossain, M. I., Mahmud, S., ... & Larsen, E. P. (2021). Prospects and challenges of yellow flesh *Pangasius* in international markets: secondary and primary evidence from Bangladesh. *Heliyon*, 7(9), e08060.
- Hoseini, M., Cocco, S., Casucci, C., Cardelli, V., & Corti, G. (2021). Coffee by-products derived resources. A review. *Biomass and Bioenergy*, 148, 106009.
- Iriondo-Dehond A, Iriondo-Dehond M, Del Castillo MD. (2020). Applications of compounds from coffee processing by-products. *Biomolecules*, 10, 1–20.
- Kpundeh, M. D., Qiang, J., He, J., Yang, H., & Xu, P. (2015). Effects of dietary protein levels on growth performance and haemato-immunological parameters of juvenile genetically improved farmed tilapia (GIFT), *Oreochromis niloticus*. *Aquaculture International*, 23, 1189-1201.
- Ministry of Fisheries and Marine Affairs. (2024). Laporan Kinerja Kementerian Kelautan dan Perikanan. (2023). Kementerian Kelautan dan Perikanan 1: 296.
- Nahida, R., Rajesh, M., Sharma, P., Pandey, N., Pandey, P. K., Suresh, A. V., ... & Kamalam, B. S. (2025). Stocking density affects growth, feed utilisation, metabolism, welfare and associated mRNA transcripts in liver and muscle of rainbow trout more pronouncedly than dietary fish meal inclusion level. *Aquaculture*, 596, 741717.
- Nuraisah, A. S. R., Andriani, Y., & Liviawaty, E. (2013). Penggunaan kulit kopi hasil fermentasi jamur *Aspergillus niger* pada pakan terhadap laju pertumbuhan benih ikan nila (*Oreochromis niloticus*). *Jurnal Perikanan dan Kelautan*, 4(3), 21-34.
- Prakash, P., & Doan, H. V. (2022). Effect of coffee silverskin enriched diet to enhance the immunological and growth parameters of Nile tilapia (*Oreochromis niloticus*). *Archives of Razi Institute*, 77(3), 1281.
- Rahimnejad, S., Choi, J., & Lee, S. M. (2015). Evaluation of coffee ground as a feedstuff impractical diets for olive flounder (*Paralichthys olivaceus*). *Fish. Aquat. Sci.*, 18(3), 257–264.
- Rodde, C., De Verdal, H., Vandeputte, M., Allal, F., Nati, J., Besson, M., ... & McKenzie, D. J. (2021). An investigation of links between metabolic rate and feed efficiency in European sea bass *Dicentrarchus labrax*. *Journal of Animal Science*, 99(6), 152.
- Saleh, E. S., Tawfeek, S. S., Abdel-Fadeel, A. A., Abdel-Daim, A. S., Abdel-Razik, A. R. H., & Youssef, I. M. (2022). Effect of dietary protease supplementation on growth performance, water quality, blood parameters and intestinal morphology of Nile tilapia (*Oreochromis niloticus*). *Journal of Animal Physiology and Animal Nutrition*, 106(2), 419-428.
- Siddik, M. A., Julien, B. B., Islam, S. M., & Francis, D. S. (2024). Fermentation in aquafeed processing: Achieving sustainability in feeds for global aquaculture production. *Reviews in Aquaculture*, 16(3), 1244-1265.
- Stockhausen, L., Vilvert, M. P., Silva, M., Dartora, A., Lehmann, N. B., & Jatobá, A. (2023). Feed cost reduction with total replacement of fish meal by soybean meal for Nile tilapia reared in biofloc system. *Arquivo Brasileiro de Medicina Veterinaria e Zootecnia*, 75(2), 360-364.
- Suprayudi, M. A., Faisal, B., & Setiawati, M. (2014). The growth of red tilapia fed on organic-selenium supplemented diet. *Jurnal Akuakultur Indonesia*, 12(1), 48–53.

- Suprayudi, M.A, Alim S, Fauzi I, Ekasari J, Setiawati M, Junior M, Tacon A. (2017). Evaluation of hydrolysed rubber seed meal as a dietary protein source for Nile tilapia *Oreochromis niloticus* L. *Aquaculture Research*, 48(7), 3801–3808.
- Tarigan, E. B., Wardiana, E., Hilmi, Y. S., & Komarudin, N. A. (2022). The changes in chemical properties of coffee during roasting: A review. In IOP conference series: Earth and environmental science, 974(1), 012115.
- Tola, S., Adepoju, M. S. K., Yuangsoi, B., Charoenwattanasak, S., Jatuwong, K., & Seelaudom, M. (2025). Effects of partial and complete replacement of fish oil with perilla oil on growth performance, feed efficiency, health status, and fatty acid accumulation in flesh of Asian seabass (*Lates calcarifer*) reared in freshwater. *Animal Feed Science and Technology*, 323, 116277.
- Van Doan, H., Lumsangkul, C., Hoseinifar, S. H., Harikrishnan, R., Balasundaram, C., & Jaturasitha, S. (2021). Effects of coffee silverskin on growth performance, immune response, and disease resistance of Nile tilapia culture under biofloc system. *Aquaculture*, 543, 736995.
- Van Doan, H., Lumsangkul, C., Hoseinifar, S. H., Jaturasitha, S., Tran, H. Q., Chanbang, Y., ... & Stejskal, V. (2022). Influences of spent coffee grounds on skin mucosal and serum immunities, disease resistance, and growth rate of Nile tilapia (*Oreochromis niloticus*) reared under biofloc system. *Fish & Shellfish Immunology*, 120, 67-74.
- Vivas, E. A., Castillo, H. S. V., & Acosta, E. G. (2025). Physicochemical and Structural Characterization of Coffee Husks for Sustainable Applications in Biodegradable Materials. *Journal of Natural Fibers*, 22(1), 2453489.
- Warasto, Y., & Fitrani, M. (2013). Fermented giant salvinia (*Salvinia molesta*) meal as feed ingredient for tilapia (*Oreochromis niloticus*). *Jurnal Akuakultur Rawa Indonesia*, 1(2), 173-183.
- Watanabe, T. (1988). *Fish Nutrition and Mariculture, the General Aquaculture Course*. JICA, Japan.
- Yafetto, L., Odamtten, G. T., & Wiafe-Kwagyan, M. (2023). Valorization of agro-industrial wastes into animal feed through microbial fermentation: A review of the global and Ghanaian case. *Heliyon*, 9(4), e14814.
- Zannat, M. M., Hossain, F., Rahman, U. O., Rohani, M. F., & Shahjahan, M. (2023). An overview of climate-driven stress responses in striped striped catfish (*Pangasianodon hypophthalmus*)—prospects in aquaculture. *Asian Journal of Medical and Biological Research*, 9(3), 70-88.