Effect of fermented local agricultural waste on the survival and growth of Asian redtail catfish (*Hemibagrus nemurus*) fry: a new sustainable approach for advancing Indonesia's aquaculture

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Abstract. This study aims to determine the effect of giving fermented feed originating from different agricultural wastes combined with anchovy head meal to increase the survival and growth of Asian redtail catfish (*Hemibagrus nemurus*) seeds. The materials used in this study were Asian redtail catfish seeds, fermented sago (*Metroxylon sagu*) waste, fermented kepok banana (*Musa paradisiaca*) peel flour, fermented pineapple (*Ananas comosus*) peel flour, fermented palm (*Elaeis guineensis*) oil solid waste, effective microorganism 4 (EM4), and anchovy (*Stolephorus* sp.) head flour. The method used was a completely randomized design with five treatments and three replications. The results showed that the best results in utilizing different agricultural wastes were found in the fermentation of kepok banana peels (P3), with details of the survival rate of 67%, and the weight gain of 0.313 g. The length gain was 1.34 cm, and the specific growth rate was 1.57%. The best feed conversion ratio was 1.70. Water quality parameters were very supportive, with a temperature range of 25-31°C, pH 6-7, dissolved oxygen 6.4 mg L^{-1}, and ammonia 1.92 ppm. After the variance analysis, the results showed a significant effect on survival, weight gain, and specific growth rate. However, the results were similar to the length gain.

Key Words: agricultural waste, Asian redtail catfish seeds, fermentation, growth, pass life.

Introduction. The rising global population has placed immense pressure on food security, particularly aquatic food resources. From an economic perspective, fish farming offers an efficient and sustainable solution to help meet the growing global demand for food (Rao & Joshep 2013; Balindo & Otadoy 2024). For instance, fish farming can convert one ton of feed into nearly one ton of fish, whereas the same amount of feed yields only 150 kg of beef, 300 kg of pork, or 500 kg of chicken. In addition to supplying nutritious food, fish farming contributes to national country's economic growth and generates employment opportunities. With a wide variety of commodities available, aquaculture is a cornerstone of the global food supply, which is vital in addressing food security challenges (Benoit et al 2023; Sampathkumar et al 2023).

One promising fishery commodity for development is the Asian redtail catfish (*Hemibagrus nemurus*), a freshwater species with high economic value. It has emerged as a potential candidate to diversity aquaculture businesses in Indonesia (Radona et al 2019; Hadi et al 2024; Leung et al 2024). However, its intensive cultivation remains limited due to the low availability of quality fish seed (Suhenda et al 2010; Tamale et al 2017; Agusnimar et al 2023). A major constraint in seed production is the low larvae or fry survival rate (Herawati et al 2024).

Studies have shown that the survival and growth of *H. nemurus* fry can be improved through feeding with silkworms and formulated diets (Mokolensang et al 2023). Unfortunately, sourcing silkworms in significant and consistent quantities remains challenging, as they are still primarily harvested from the wild and are only seasonally available (Armbrecht et al 2023; Fernández-Bautista et al 2024). Moreover, the mass cultivation of silkworms by hatchery owners and fish farmers has not been widely adopted. As a result, farmers often resort to using manufactured feeds.

The increased reliance on artificial feed to meet aquaculture demands has led to a surge in the need for fish meal and fish oil - key components typically derived from increasingly limited marine resources (Jinadasa et al 2016; Renchen et al 2024). This dependency increases feed costs, making fish farming less economically viable. To address this issue, there is a growing need to formulate feed from raw materials that are both affordable and readily available (Diwan et al 2023).

The high cost of commercial feed has encouraged the development of alternative artificial feeds that farmers can produce independently. This initiative reduces production costs and creates new business opportunities for local communities. One widely adopted solution uses locally sourced ingredients such as soybean waste, cornmeal, rice bran, cassava pulp, and tofu residue (Wong et al 2016).

As a tropical agricultural nation, Indonesia possesses vast potential in the agriculture, plantation, and fisheries sectors across its regions. However, increased productivity in these areas also generates significant amounts of waste. To prevent environmental issues, a sustainable solution is needed. One such approach is repurposing agricultural waste as a raw material for fish feed. Agricultural by-products have nutritional properties comparable to commercial feed and can be processed easily and affordably. Moreover, their protein content can be further enhanced through fermentation (Zheng et al 2021; Britton et al 2023; Mazoudier et al 2023). Based on this background, this study aims to evaluate the effects of fermenting different types of agricultural waste on the survival and growth performance of *H. nemurus* fry.

Material and Method. This study was conducted at the Fish Hatchery Center, Faculty of Agriculture, Universitas Islam Riau, Pekanbaru, Riau, Indonesia, from January to February 2024.

***Description of the study**.* This study aims to evaluate the effects of fermented feed derived from various agricultural wastes - pineapple (*Ananas comosus*), kepok banana (*Musa paradisiaca*), palm oil (*Elaeis guineensis*), and sago (*Metroxylon sagu*) waste - on the survival and growth of *H. nemurus* fingerlings. Sago waste, a byproduct of sago processing, yields both sago flour and fibrous residue and is notably rich in carbohydrates. Sago has long been a traditional staple food in the Meranti Archipelago Regency of Riau Province, Indonesia, serving as the primary dietary source before the widespread introduction of rice.

***Experimental fish**.* The *H. nemurus* fingerlings used in this study were 21 days old, with an average total length of 2.4 cm and an average weight of 0.17 g. A total of 400 fingerlings were sourced from the Fish Seed Center of the Integrated Agricultural Unit at Universitas Islam Riau, located on Kasang Kulim, Teropong village, Kubang Raya, Siak Hulu, Kampar District.

Ingredients and preparation of experimental diets. The test feed used in this study was produced through fermentation and consisted of raw agricultural waste materials mixed with anchovy head meal in a 1:1 ratio. The raw materials were sourced from various regions. Sago dregs were obtained from a Tanjung Darul Ikhsan village processing factory in Meranti Islands, Riau Province. Pineapple peels were collected from the Sharia market on street Pasir Putih, Kampar district. Kepok banana peels were sourced from a banana chip production site on street Kartama, Marpoyan Damai, Pekanbaru City. Palm oil solid waste (called “solid”) was obtained from the palm oil mill PKS PT. Johan Sentosa, located in Sei Jernih village, Bangkinang District, Kampar Regency, Riau. Anchovy heads were acquired from Pambang village, Bantan District, Bengkalis Regency, directly from a salted anchovy processing facility, and then transported to Pekanbaru. Meanwhile, the materials used to make the fermentation solution consist of agricultural effective microorganisms 4 (EM4), cane sugar, and water.

Before use, all raw test materials were ground using a chopping machine and sieved into fine flour. The resulting material was then fermented with EM4 solution at a ratio of 1 kg of raw material to 1 liter of EM4 solution and allowed to ferment for 15 days. The EM4 solution was prepared by mixing equal parts of EM4, clean water, and cane sugar (molasses) and left to activate for three days before application. The proximate composition of the fermented test feed was analyzed at the Fisheries Products Laboratory, Faculty of Fisheries and Marine Sciences, Universitas Riau, and the results are presented in Table 1.

Table 1

Proximate analysis results for each test feed

Treatments	*Parameters*				
	Moisture (%)	*Ash (%)*	*Protein (%)*	*Fat (%)*	*Crude fiber (%)*
P1	14.41	32.52	44.31	3.26	5.50
P2	35.18	20.05	28.42	1.92	14.43
P3	28.05	25.82	34.82	4.21	7.10
P4	16.46	44.30	29.36	0.32	9.56
P5	24.90	25.22	31.80	3.14	14.94

Research instruments. The tools used in this research were electric scales, analog scales, a grinding machine, a small weir, a mercury thermometer, pH indicator litmus paper, a DO meter, MR ammonia, a millimeter block, a blower, zinc, a 15-liter tray, an aeration hose, aeration stone, breaker glass, stationery, and cellphones.

Method. This research used an experimental method with a completely randomized design with five treatments and three replications:
P1 = 100% anchovy head meal;
P2 = 50% pineapple peel fermentation + 50% anchovy head meal;
P3 = 50% kepok banana peel fermentation + 50% anchovy head meal;
P4 = 50% fermentation of palm oil solid waste (solid) + 50% anchovy head meal;
P5 = 50% fermentation of sago dregs + 50% anchovy head meal.

The frequency of feeding was 4 times a day, namely in the morning at 08.00 am, in the afternoon at 11.59 am, in the afternoon at 04:00 pm and in the evening at 08:00 pm.

Survival rate. The percentage of survival was calculated using the Wirabakti (2006) formula, namely:

$$SR = \frac{Nt}{No} x\, 100$$

where: SR = survival of test fish (%);
Nt = number of fish at the end of the study (fish);
No = number of fish at the start of the study (fish).

Growth. The growth observed in this study was the growth in weight gain and length gain. The growth formulas for weight, length, and specific growth rate of fish is calculated based on the formulae according to Zonneveld et al (1991) that are:
Weight gain:

$$WG = Wt - Wo$$

where: WG = weight gain (g);
Wt = average weight of individual fish at the end of the study (g);
Wo = average weight of individual fish at the start of the study (g).

Length gain:

$$LG = Lt - Lo$$

where: LG = length gain (cm);
Lt = average length of individual fish at the end of the study (cm);
Lo = average length of individual fish at the start of the study (cm).

Specific growth rate:

$$SGR = \sqrt[t]{\frac{wt}{w0}} - 1 \, x \, 100$$

where: SGR = specific growth rate;
Wt = average weight of individual fish at the end of the study (g);
Wo = average weight of individual fish at the start (g).

***Data analysis**.* The data observed during the research included the response of fish seeds to feed, survival rate, weight gain, length gain, and specific growth rate *of H. nemurus* fry, and the water quality of the cultivation media. The collected data are presented as tables to facilitate interpretation. Data analysis was conducted using analysis of variance (ANOVA), followed by Duncan's multiple range test for further comparison using SPSS version 24.

Results and Discussion. The research results indicated that the survival rate, weight gain, length gain, and specific growth rate of *H. nemurus* fry varied across treatments. These differences are presented in Table 2.

Table 2

Average survival rate, weight gain, length gain, and specific growth rate of *H. nemurus* fry fed with different fermented agricultural wastes

Treatments	*SR (%)*	*WG (g)*	*LG (cm)*	*SGR (% day^{-1})*
P1	55.00 ± 5.00^a	0.23 ± 0.05^a	1.25 ± 0.05^{ab}	1.10 ± 0.24^a
P2	50.00 ± 0.00^a	0.20 ± 0.03^a	1.22 ± 0.03^a	0.97 ± 0.12^a
P3	66.67 ± 2.88^b	0.31 ± 0.02^b	1.34 ± 0.10^b	1.49 ± 0.07^b
P4	50.00 ± 5.00^a	0.23 ± 0.01^a	1.18 ± 0.03^a	1.08 ± 0.03^a
P5	55.00 ± 5.00^a	0.24 ± 0.01^a	1.28 ± 0.02^{ab}	1.13 ± 0.05^a

Note: Different superscript letters in the column indicate statistically significant differences between treatments ($p < 0.05$).

Based on the research results regarding the use of agricultural waste as a fermentation substrate to improve the survival of *H. nemurus* fry, survival rate data were obtained, as presented in Table 2. The survival rate of *H. nemurus* under the P3 treatment was significantly higher than the other treatments ($p < 0.05$). This indicates that different types of agricultural waste used as fermentation substrates significantly affected the survival rate of *H. nemurus* fry.

The highest survival rate for *H. nemurus* fry was obtained in the P3 treatment, reaching 67%. This treatment utilized a paste-form feed of 50% fermented kapok banana peel flour and 50% anchovy head meal. The high survival rate is attributed to the improved digestibility of the feed, as banana peel flour contains lower fiber content than other agricultural waste materials (Table 1). Fish generally do not have the ability to digest fiber (Jinadasa et al 2016; Fernández-Bautista et al 2024).

In contrast, the P2 and P4 treatments had the lowest survival rates. The feed used in these treatments consisted of fermented pineapple peel flour mixed with anchovy head meal (P2), and a solid fermentation product combined with anchovy head meal (P4). These feeds had relatively high fiber contents, 17.20% and 12.08% respectively. Although both pineapple peel flour and the solid fermentation product were fermented, they still contained high levels of crude fiber, making them difficult for *H. nemurus* fry to digest. Fish feed should ideally contain no more than 5-6% crude fiber (Aryani et al 2014; Cao et al 2015).

The excessive crude fiber in feed reduces its digestibility, leaving a significant portion of the feed uneaten and accumulating at the bottom of the rearing containers. This leads to a deterioration in water quality due to increased turbidity and elevated ammonia levels. Poor water quality stresses the fish (Fuller 2004; Wang et al 2023), disrupting physiological functions, inhibiting metabolic processes, decreasing appetite, and ultimately increasing mortality.

Weight gain of H. nemurus fry. As shown in Table 2, the statistical test results indicated that the fermentation of different types of agricultural waste had a highly significant effect on the weight gain of *H. nemurus* fry ($p < 0.05$). The highest weight gain in this study was also observed in the P3 treatment, reaching 0.31 g. This treatment used a pasta feed composed of 50% fermented kapok banana peel flour and 50% anchovy head meal, with a protein content of 34.82%, which is lower than the protein content in the P1 treatment (44.31%), which consisted solely of anchovy head meal. This finding suggests that higher protein content in feed does not necessarily correlate with greater weight gain in fish. The quality of fish feed is determined not only by its nutritional composition but also by the extent to which these nutrients can be digested and absorbed by the fish (Undeland et al 2004; McAuley et al 2018). Therefore, feed with a high price or protein content is not automatically of superior quality. It is essential to explore alternative feed ingredients that enhance digestibility. One such option is the use of crude base-rate feed ingredients, which have been shown to support improved digestion (Megawati et al 2012).

Crude fiber plays a role in facilitating the excretion of undigested feed through the digestive tract. However, crude fiber alone is insufficient to support optimal feed digestibility. In this study, the crude fiber content in treatment P3 was 7.83%, which was higher than that in treatment P1 (5.50%) but lower than the fiber content in treatment P2 (4.75%), P4 (3.76%), and P5 (3.60%).

The weight gain of *H. nemurus* fry in treatment P3 was higher than that observed in the other treatments. This improvement is attributed to the fermented banana peel flour used in P3, which contained a moderate fiber level (7.83%) within the digestible range for the fish. Additionally, fermented banana peel flour emits a strong aroma, which can stimulate the fish's appetite. Feed ingredients with a distinctive smell are generally more palatable to fish and can encourage greater feed intake (Asiedu et al 2023; Biswas et al 2023).

In contrast, treatment P5, which used a feed mixture of 50% fermented sago dregs flour and 50% anchovy head flour, resulted in a lower weight gain of 0.240 g than P3. Although the proximate composition of the feed in P5 showed better nutritional values - higher protein content (31.12%) and lower fiber content (2.56%) than P3 - growth was suboptimal. This may be attributed to the lower palatability of sago dregs-based feed for *H. nemurus*, a carnivorous species that tends to reject sago-based ingredients (Gunawan et al 2018; Mphande et al 2023).

Treatment P2, which included 50% fermented pineapple peel flour and 50% anchovy head flour, also exhibited low weight gain. This was likely due to the high fiber content in the pineapple peel flour (17.20%), which made the feed less digestible for *H. nemurus* fry. Poor digestibility hampers nutrient absorption and subsequently slows growth. Factors affecting feed utilization and growth include digestibility, metabolic rate, and individual physiological responses, which vary among fish (Gao et al 2012; Mehta et al 2023).

Length gain of H. nemurus fry. The study's results examining the impact of fermented agricultural waste as a feed ingredient on the length gain of *H. nemurus* fry are presented in Table 2. Based on the analysis of variance, a statistically significant effect of fermented agricultural waste-based feed on the absolute length gain of *H. nemurus* fry ($p < 0.05$).

As shown in Table 2, there were notable differences in the growth patterns among treatments. The highest length gain was observed in treatment P3. This superior performance is attributed to the formulation of the feed, which consisted of 50% fermented banana peel flour and 50% anchovy head flour. The banana peel flour, known for its pungent aroma, likely enhanced the palatability of the feed, stimulating the fish's appetite and feed intake. Moreover, the nutritional properties of fermented banana peel flour may contribute to efficient energy conversion and metabolism, which supports linear growth. Aromatic feed ingredients are known to facilitate digestion and improve the excretion of waste (Asiedu et al 2023).

Conversely, the lowest length gain was observed in treatment P4, which consisted of 50% fermented palm oil solid waste (solid) and 50% anchovy head flour. The limited growth in this treatment is likely due to the high fiber content of the solid waste (12.08%) and its low-fat content (only 0. 31%). Elevated fiber levels can hinder nutrient absorption and reduce feed utilization efficiency. High dietary fiber slows digestive transit and decreases digestibility, ultimately suppressing growth performance in fish (Agneeswaran et al 2023; Bi et al 2023).

Specific growth rate. Results indicated that treatment P3 yielded the highest specific growth rate at 1.57%, outperforming all other treatments ($p < 0.05$). This suggests that the feed formulation consisting of 50% fermented banana peel flour and 50% anchovy head flour was highly effective in promoting growth. The superior performance of P3 is likely due to the feed's palatability, digestibility, and nutrient content, which aligned well with the nutritional needs of *H. nemurus* fry. This finding is consistent with the statement by Panggabean et al (2016), which noted that optimal fish growth occurs when the feed provided meets the species' dietary requirements.

As shown in Table 2, the lowest specific growth rate was recorded in treatment P2, at 1.02%. This treatment used 50% fermented pineapple peel flour and 50% anchovy head flour. The poor performance is attributed to the high fiber content in pineapple peel flour, which impairs digestibility and limits nutrient absorption in young fish. The specific growth rate is directly linked to weight gain, which depends on the amount and quality of feed consumed (Song et al 2022).

Water quality. The results of water quality measurements during the research can be seen in Table 3.

Table 3

Results of water quality measurements during the research

Treatments	*Water quality parameters*				
	Temperature (°C)	*pH*	*DO (mg L^{-1})*	*Ammonia (mg L^{-1})*	
				Initial	*Final*
P1	25-31	6-7	6.4	0.12	2.30
P2	25-31	6-7	6.8	0.12	2.38
P3	25-31	6-7	6.4	0.12	1.92
P4	25-31	6-7	6.5	0.12	2.12
P5	25-31	6-7	6.3	0.12	1.87
Tolerance limits	25-32	5-7	5-9	0.6-5	

As shown in Table 3, the water temperature during the research ranged from 25 to 31°C. This range falls within the optimal temperature for rearing *H. nemurus*, as tropical aquatic organisms generally thrive within a temperature range of 25-32°C. Temperature plays a crucial role in fish metabolism; excessively low temperatures can suppress appetite and slow growth. The observed temperature variation was due to differences in measurement times - typically, the lowest readings occurred in the early morning, while the highest was recorded in the afternoon (Cao et al 2015; Agneeswaran et al 2023). These fluctuations are commonly associated with specific weather changes (Ahmad et al 2016).

The pH levels recorded in this study ranged between 6 and 7, which is considered suitable for the growth and development of *H. nemurus* fry. According to Zulfahmi et al (2022), the optimal pH range for freshwater aquaculture is between 5 and 9. Extremes in pH - either too acidic or too alkaline - can adversely affect fish physiology (Daelami 2001; Bi et al 2023). In general, most aquatic organisms grow best under neutral pH conditions.

Dissolved oxygen (DO) levels in the rearing media were observed between 6.3 and 6.8 mg L^{-1}. Oxygen is a vital factor influencing the health and growth of *H. nemurus* fry. Insufficient DO levels can lead to fish stress and force them to surface frequently to breathe. In this study, the DO levels remained within a favorable range. The minimum oxygen tolerance limit for *H. nemurus* is reported to be 2.0 mg L^{-1} (Radona et al 2019), indicating that the oxygen conditions throughout the experiment were well within the acceptable threshold.

Ammonia levels ranged from 1.87 to 2.38 mg L^{-1}, with initial concentrations at 0.12 mg L^{-1}. Ammonia is a byproduct of metabolic processes and can accumulate due to uneaten feed and waste from the fish. Elevated ammonia concentrations can become toxic, particularly when sudden changes damage gill tissues. Although *H. nemurus* can tolerate certain ammonia levels, it is generally recommended that concentrations in freshwater systems not exceed 2.0 mg L^{-1} (Undeland et al 2004; Mphande et al 2023). Ammonia levels are significantly influenced by water temperature and pH. The increased ammonia concentration observed during the study was primarily attributed to fish metabolism and organic matter breakdown, which produced acidic compounds over time.

Conclusions. This study demonstrates that fermented agricultural waste-based feed significantly enhances the survival, weight gain, and specific growth rate of *Hemibagrus nemurus* fry. The most effective formulation was P3, combining 50% fermented banana peel flour with 50% anchovy head flour. Water quality remained within optimal ranges throughout the experiment. These findings highlight the promising potential of transforming local agricultural waste into sustainable, cost-effective aquaculture feed. This approach offers not only improved fish performance but also contributes to waste reduction and eco-friendly farming practices. This approach could be scaled and adapted for broader aquaculture applications in the future.

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Conflict of interest. The authors declare that there is no conflict of interest.

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