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Turning Waste into Nutrition: Harnessing Tannery Waste for Black Soldier Fly Larvae Cultivation as Sustainable Catfish Feed Alternatives

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ABSTRACT

This study aimed to help reduce the lime fleshing solid waste problem by implementing utilization as feed for Black Soldier Fly (BSF) larvae. The BSF larvae were analyzed as a sample to determine whether it is safe to be eaten by other living species, especially catfish. The raw material used is lime fleshing cowhide waste from a leather tannery. The process included fermentation of lime fleshing waste with a formulation of waste: bran: water (8:1:2) for three days, hatching BSF larvae eggs for six days, and feeding fermented waste to BSF larvae (1000:1) for nine days, then baby BSF larvae dried, and BSF larvae were applied to catfish in a ratio (BSF larvae weight = 9: 5) for 12 days. Then, they analyzed the protein, calcium, and sulfur contents on the sample BSF larvae and catfish. We used the fermentation of lime fleshing waste with bran and water variables, which are well water, catfish pond water, and rice washing water, for three days. Then, hatching BSF larvae eggs for six days, BSF larvae cultivation for nine days, and application of the BSF larvae on catfish for 12 days. Data were analyzed by one-way ANOVA, then continued using the Duncan Multiple Range Test (DMRT). The result of fermented lime fleshing waste was used on the BSF larvae, and the cultivation contents were analyzed for protein, calcium, and sulfur. The analysis result of the three variables has an average value of protein at around 6.06%, calcium at 0.041%, and sulfur at around 0.016%. The study concludes that BSF larvae, when combined with commercial feed and suitable formulation, could be an effective and efficient alternative feed for catfish while addressing the lime fleshing waste problem.

Keywords:
Aquaculture; black soldier fly larvae; catfish feed; fermentation; tannery waste

1. Introduction

As the global population grows, the demand for sustainable and efficient food production methods has become increasingly urgent. The aquaculture industry faces the challenge of finding alternative and eco-friendly feed sources to reduce its dependence on conventional fishmeal and decrease the environmental impact (Hoerterer et al., 2022). Over the past few decades, relying on fishmeal as a primary protein source in aquafeeds has raised concerns regarding overfishing, biodiversity loss, and the sustainability of marine resources (Jannathulla et al., 2019). Therefore, finding a viable and environmentally responsible alternative is crucial for ensuring the long-term growth of the aquaculture sector while mitigating ecological damage.

One promising solution lies in the innovative concept of utilizing BSF larvae (*Hermetia illucens*) cultivation as a sustainable aquafeed alternative (Aisyah et al., 2022; Mohan et al., 2022; Rawski et al., 2020; Yildirim-Aksoy et al., 2020; Zulkifli et al., 2022; Lu et al., 2022). It has also gained significant attention due to its ability to efficiently convert organic waste into high-protein biomass, making it a suitable substitute for traditional fishmeal (Mohan et al., 2022).

Recently, researchers have demonstrated the efficacy of BSF larvae in promoting healthy growth in various fish species, thus reinforcing the potential of BSF larvae as a sustainable and environmentally friendly feed option for the future of aquaculture. Their nutrient composition is rich in protein, lipids, and essential amino acids, making them comparable to conventional protein sources used in aquaculture feeds (Spranghers et al., 2017). In addition to its nutritional benefits, BSF larval culture presents a promising approach to waste valorization by converting various types of organic waste into valuable protein sources. Previous studies have successfully incorporated BSF larvae reared on agricultural and food processing waste into aquafeed, which showed improved growth performance and feed conversion efficiency in fish species such as tilapia (*Oreochromis niloticus*) and catfish (*Clarias gariepinus*) (Bokau & Basuki, 2020; Romano et al., 2023; Widigdyo & Arifah, 2022). In addition, the environmental footprint of BSF larval production is significantly lower compared to conventional fishmeal, as it requires minimal land, water, and energy inputs and contributes to waste reduction and nutrient recycling (Beesigamukama et al., 2021).

An innovative approach to addressing waste management issues in the leather industry involves repurposing tannery waste to cultivate Black Soldier Fly (BSF) larvae, which can serve as a sustainable feed alternative for catfish (Widigdyo & Arifah, 2022). Generate significant amounts of organic waste, often leading to environmental pollution and posing disposal challenges, such as the waste from the fleshing process (Wibowo & Yuliatmo, 2020). However, by transforming this waste into high-quality protein from BSF larvae, it is possible to reduce waste while simultaneously providing a nutritious and cost-efficient feed option for catfish aquaculture (Mohan et al., 2022).

Despite its potential, there are still challenges associated with integrating BSF larvae into aquatic feeds. Factors such as soaking materials, the chemical composition of the larval substrate, processing methods, and the presence of anti-nutritional factors can affect the digestibility and acceptability of BSF larvae-based feeds (Barroso et al., 2014).

This study explores the potential of transforming tannery waste into a valuable resource for BSF larvae cultivation and its benefits as a protein-rich and sustainable feed option for catfish. By evaluating the nutritional composition of the BSF larvae and conducting feeding trials with catfish, we aimed to determine the feasibility of this in terms of physical and chemical characteristics. The outcomes of this research could support implementing a more sustainable aquaculture system, minimizing dependency on conventional fishmeal, and mitigating environmental issues linked to industrial waste. With the prospect of turning waste into nutrition, this research promises to address environmental concerns and contribute to the aquaculture industry's sustainable growth and development.

2. Materials and Methods

2.1. Materials

Materials used in this study are 12 kilograms of sludge from the fleshing process in Magetan Tannery Industry, Indonesia, 12 grams of BSF larvae eggs, 3 kilograms of bran, three types of soaking water (well water, rice washing water, and catfish pond water) of 500 mL each, and 80 catfish.

2.2. Research Methodology

2.2.1. Sludge fermentation

Fermentation of sludge was adopted from Fitriana et al. (2023) with slight modification. Fleshing sludge was fermented with bran and soaking water by 8:2:1 for 3 days. The treatment is different for soaking water, i.e., natural water, rice water, and pond water.

2.2.2. Hatching BSF larvae Eggs

The process of preparing for larvae egg hatching was followed by Rahmawati et al. (2022) with slight modification. Three plastic boxes (50 x 30 x 20 cm) containing 50 ml of soaking water for each treatment were poured with 100 grams of rice bran—two grams of BSF larvae eggs were placed on top of the mixture. Every day for 6 days, the mixture is sprayed with soaking water according to the treatment to maintain humidity. After 6 days, the BSF larvae' eggs hatch and are ready to be cultivated.

2.2.3. BSF larvae cultivation

The cultivation of BSF larvae in this study followed the method outlined by (Yunianta et al., 2023), with several modifications to optimize fermented fleshing sludge as the primary substrate. Five hundred grams of fermented fleshing sludge mixed with the young BSF larvae. After cultivating for 10 days, BSF larvae were harvested by separating the BSF larvae from the cultivation material by sieving.

Figure 1. BSF Larvae cultivation

2.2.4. Drying

Two hundred and fifty grams of sand were poured into a hot pan. Then, BSF larvae were poured over heated sand. BSF larvae roasted for 15 minutes until dry. Next, the BSF larvae are sieved to separate the magot from the sand. The dried BSF larvae were then stored for further processing.

2.2.5. BSF larvae application as catfish feed

The feeding experiment for catfish in this study was adapted from the method described by Budiharjo et al. (2022), with several modifications to evaluate the effects of BSF larvae treated with different soaking water treatments as a dietary component. Three ponds containing 10 catfish aged 1 month, each were given 3 grams of dry BSF larvae feed according to treatment. Feed was given 2 days every morning at 10 o'clock for 12 days. After 12 days, catfish are harvested for further processing. The control treatment was catfish meat derived from catfish fed with commercial feed. This control group was used to establish a basis for comparison with catfish fed with BSF larvae with soaking water treatment.

2.3 Evaluation of BSF larvae and catfish characteristic

BSF larvae were evaluated for physical (wet and dry weight) and chemical characteristics (protein, calcium, sulfur content). Meanwhile, catfish were evaluated for chemical characteristics (protein, calcium, sulfur content).

2.4 Data Analysis

Data analysis was performed using one-way ANOVA to determine significant differences between treatments. If there was a significant difference ($p<0.05$), the analysis was continued with Duncan's multiple range test to determine differences between treatment groups.

3. Results and Discussion

3.1. Wet and dry weight of BSF larvae

The weight of BSF larvae is crucial in production as it directly impacts factors such as physical characteristics, cost production, material usage, and overall efficiency. Table 1 shows the results of measuring BSF larvae's wet and dry weight after hatching with three types of soaking water. The weight of BSF larvae with rice water treatment as soaking water significantly produced the highest wet weight ($P<0.05$). Meanwhile, the best BSF larvae colony dry weight was significantly ($P<0.05$) produced from pond water treatment as soaking water. The difference in weight level between wet weight (with rice water) and dry weight (with pond water) could be due to the nature of rice, which can bind water, causing the water content in BSF larvae to be higher compared to other soaking water treatments (Lapčíková et al., 2021).

Table 1. Wet and dry weight of BSF larvae after hatching process

Soaking water	Wet weight (mg)	Dry weight (g)
Groundwater	613.0±2.82[a]	323.5±3.53[a]
Pond Water	611.0±0.83[a]	330.0±2.82[b]
Rice water	616.5±2.12[b]	325.0±2.82[a]

Results are given as mean ± standard deviation

[ab]Different letters within the same row indicate statistical significance at $p<0.05$ level

3.2. Chemical content of BSF larvae

The chemical content of a product is of utmost importance in production as it determines its functionality, safety, and compliance with regulations. Accurate regulation and tracking of chemical composition guarantee uniform product quality, reduce potential risks, and foster trust between consumers and regulatory authorities (Spranghers et al., 2017). The chemical content of BSF larvae is shown in Table 2, while the chemical content is shown in Table 3.

Table 2. Chemical content of BSF larvae

Soaking water	Protein content (%)	Calcium content (%)	Sulfur contents (%)
Groundwater	28.36±0.03[a]	0.71±0.016[b]	0.025±0.009
Pond Water	38.54±0.12[b]	0.85±0.036[c]	0.040±0.006
Rice water	38.56±0.56[b]	0.58±0.030[a]	0.036±0.006

Results are given as mean ± standard deviation

[abc]Different letters within the same row indicate statistical significance at $p<0.05$ level

Soaking water from pond water and rice water significantly produced the highest protein content (38.56±0.56%), whereas the groundwater treatment produced the lowest (28.36±0.03%). This result was higher than Yildirim-Aksoy et al. (2020), which found 21.6 % of the black soldier fly larvae protein content. It can be caused by groundwater's lack of nutrition, such as protein. However, the protein content meets the requirements for catfish feed, at least 26-32% (Robinson & Li, 2015). The higher protein content in BSF larvae treated with pond and rice water, as compared to groundwater, aligns with findings by Barragan-Fonseca et al. (2017), highlighting the nutritional potential of BSF larvae as a valuable animal feed ingredient, especially concerning protein and mineral content.

Based on the results, pond water treatment generated the highest calcium content. Fleshing waste is a byproduct of the leather tanning process, particularly from the liming stage, where lime is used to remove hair and proteins from hides (Wang et al., 2016). Fleshing waste contains lime (CaOH) that can be oxidized, which can cause the release of calcium bonds and radicals in water. While there were no significant differences ($P>0.05$) in the sulfur content of BSF larvae. It was lower than the sulfur content of larvae BSF frass in an aquaponic system found by (Romano et al., 2023).

3.3. Chemical Content of Catfish

Table 3. Chemical content of Catfish meat

Soaking water	Protein content (%)	Calcium content (%)	Sulfur content (%)
Groundwater	6.62±0.29[b]	0.036±0.020[a]	0.022±0.006[b]
Pond Water	6.51±0.47[b]	0.046±0.003[a]	0.015±0.002[ab]
Rice water	5.05±0.12[a]	0.045±0.003[a]	0.013±0.001[ab]
Control	6.24±0.07[b]	1.436±0.013[b]	0.008±0.002[a]

Results are given as mean ± standard deviation

[ab]Different letters within the same row indicate statistical significance at $p<0.05$ level

The protein content in catfish fillets treated with groundwater and pond water has a significantly higher value than rice water, and they have protein content that exceeds the control. However, this protein content was lower than catfish from Mozambique, which was found at 15.72% (Yildirim-Aksoy et al., 2020). The different treatments in soaking water did not provide a significant difference (P>0.05) in the calcium content of catfish fillets. However, they significantly differed (P<0.05) from the control with higher calcium content. Groundwater as a soaking water treatment resulted significantly in sulfur content (P<0.05) than the control. Yildirim-Aksoy et al. (2020) reported that the whole body of catfish has a higher calcium (3.59±0.17%) and sulfur (0.69±0.005%) content than the values in this study. The high calcium and sulfur content is understandable because the samples analyzed by Yildirim-Aksoy et al. (2020) were whole parts of the body, including bones or spines, while the samples analyzed in this study were only in the catfish fillet even though bones or spines are part of the body that has the highest calcium content (Ratri et al., 2023).

4. Conclusion

This study demonstrates that pond water as a soaking treatment for BSF larvae can enhance their dry weight and nutritional content, particularly in terms of protein, calcium, and sulfur. The findings suggest that pond water improves the yield and quality of BSF larvae and supports their potential use as a sustainable feed alternative. Although the calcium content in catfish fillets fed with BSF larvae were lower compared to the control, the overall protein and sulfur levels were comparable. These results imply that BSF larvae, especially those treated with pond water, can be an effective and environmentally friendly feed option, contributing to more sustainable aquaculture practices.

Pond water as a soaking treatment for BSF larvae hatching produced the highest dry weight (330.0±2.82 g) along with the highest protein (38.54±0.12%), calcium (0.85±0.036%), and sulfur (0.040±0.006%) content in dried larvae. Catfish fillet-fed BSF larvae with a variety of soaking water were also analyzed for chemical content and were compared with the control. Protein and sulfur content in catfish fillets fed with larvae was almost the same as control. However, the calcium content of the control still had a higher value than the other treatments. BSF larvae treated with pond water offer a sustainable and eco-friendly feed option for aquaculture.

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