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Fermentation of Livestock Blood Waste as Fish Feed Ingredient

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ABSTRACT

Livestock blood waste has significant potential to be utilized as an alternative feed ingredient due to its high protein content, reaching up to 80%, and abundant availability. However, blood waste is known to contain high levels of iron and an imbalanced amino acid profile. Based on these issues, one potential solution is to ferment livestock blood waste to enhance its nutritional value. This review article aims to compile and analyze various effective fermentation methods and identify best practices in the fermentation process of livestock blood waste. Fermentation can be carried out using various microbes, mainly lactic acid bacteria. Fermentation treatment of livestock blood waste with lactic acid bacteria using lactic acid concentrations ranging from 3% to 6% produces blood waste with a well-balanced nutritional profile. Meanwhile, the optimal use of blood waste as an alternative feed ingredient for fish is achieved by adding formic and propionic acids at doses of 1.5%–3%, improving fish protein digestibility by 94.66%. This indicates that livestock blood waste can be an alternative raw material in fish feed production.

Keywords: Animal Blood, Fish Feed, Lactic Acid Fermentation, Fish Feed, Microbes

1. INTRODUCTION

Livestock blood waste is one of the liquid wastes commonly produced from slaughterhouses and has significant potential for reuse as an alternative animal feed ingredient. According to Sutrisman et al. (2016), each cattle slaughter process can produce blood equivalent to 7-9% of live weight or approximately 20-28 liters per head. The study also revealed that daily blood waste could reach up to 1,000 L. Annually, blood waste explicitly produced from cattle in Indonesia can reach 11.9 million liters (Ramadhan et al., 2017). Blood can be processed into blood meal, a protein-rich feed ingredient containing 79.3% crude protein and 0.31% crude fiber. Fresh blood has a moisture content of about 80%, while blood meal contains approximately 16.5% moisture (Setiowati et al., 2014).

On the other hand, aquaculture faces challenges, particularly in feed production costs, which can account for 60-70% of total production costs. This is mainly because fish meal, a primary protein source in fish feed, is becoming increasingly scarce and expensive. Therefore, exploring cheaper alternative feed ingredients with high protein content that meet fish's nutritional needs is essential (Prajayati et al., 2018). Although blood and blood meals can potentially be fish-feed ingredients, several challenges prevent their direct application. The high protein content in blood meal limits its digestibility by fish. Moreover, blood waste contains high iron levels and an imbalance of amino acids, which can disrupt fish digestion (Ramadhan et al., 2015). To address these challenges, processing blood waste or blood meal to improve its quality for fish feed is necessary. One effective method is fermentation (Palinggi et al., 2013).

Fermentation is a biochemical process involving microorganisms such as bacteria, yeast, and fungi to break down organic matter into more straightforward and more digestible products. Fermentation aims to enhance nutritional value, extend shelf life, and improve digestibility by producing fish feed derived from livestock blood. Lactic acid fermentation, in particular, uses lactic acid bacteria (LAB) to enhance feed quality. LAB plays a role in breaking down carbohydrates into lactic acid, lowering environmental pH, and creating conditions unsuitable for pathogenic microorganisms. This fermentation process enhances feed digestibility and nutritional profiles by increasing protein availability and reducing anti-nutritional factors (Oktaviani et al., 2021). Therefore, it is essential to process blood waste through lactic acid fermentation before using it as an alternative ingredient in fish feed.

This journal aims to evaluate the potential use of livestock blood waste fermented with lactic acid bacteria as an alternative raw material in fish feed formulation. Specifically, this review discusses the nutritional characteristics and potential of livestock blood waste, the principles and applications of lactic acid fermentation technology in blood waste processing, and the evaluation of fermented blood waste quality as fish feed. The findings of this review are expected to provide scientific information on optimizing livestock blood waste utilization through fermentation processes to support the sustainable development of the fish feed industry.

2. RESEARCH METHOD

The method used in this study is descriptive, collecting literature review studies from various sources such as Google Scholar, ScienceDirect, and ResearchGate using keywords such as fermentation, blood waste fermentation, lactic acid fermentation, and fish feed. The journals or literature reviewed focus on studies related to feed ingredients used as substitutes or additives that can affect fish growth and improve digestibility. Specifically, the reviewed studies include blood waste from livestock processed through fermentation using lactic acid bacteria (LAB). The test subjects discussed involve various fish species. The results from the journal review are grouped according to topics derived from the analyzed journals and are further examined based on those topics.

3. RESULT AND DISCUSSION

Livestock Blood Waste

Blood is one of the local resources commonly obtained from slaughterhouses or poultry processing plants. Typically, blood waste is discarded without prior treatment, posing a potential environmental pollution risk. According to Ramadhan et al. (2017), blood waste from cattle in Indonesia reaches approximately 11.9 million liters per year. To utilize this resource effectively, blood is dried and processed into blood meal, which can be used as an environmentally friendly feed ingredient (Figure 1).

Figure 1. Blood meal
Source: Haryanta et al. (2022)

Blood waste can be processed into fish feed or livestock feed in the form of blood meal. Halimatusadiah (2009) stated that blood meals contain high protein levels, reaching 88.45% of their dry weight, making them a highly potential protein source for fish feed. Using blood meal as an alternative feed ingredient helps reduce environmental pollution caused by unused blood waste. Blood meal generally has characteristics of low potassium and phosphorus content. Another characteristic is that this blood meal contains very high crude protein, which can reach up to 80%, and also contains crude fiber, moisture content, and crude fat. Blood meals generally have the following nutritional characteristics (Table 1).

Table 1. Nutritional composition of blood meal

Crude Protein	Crude Fiber	Moisture Content	Crude Fat	Reference
79,3%	0,31%	16,5%	-	Ramadhan et al. (2021)
80%	1%	-	1,6%	Ananda et al. (2024)

The nutritional content of blood waste must be enhanced and adjusted to fish digestibility. Although the protein value is exceptionally high, blood waste contains high iron levels and an imbalance of amino acids, making it less effective for direct fish feed applications (Ramadhan et al., 2015). Additionally, blood meal has low digestibility, around 55.2% (Halimatusadiah, 2009). Therefore, treatment such as lactic acid fermentation is essential to optimize the nutritional value of blood waste for use as fish feed. This ensures that the feed does not negatively impact fish health and growth while serving as an effective alternative feed ingredient in aquaculture.

3.2. Fermentation

Fermentation aims to improve, reduce, or enhance the nutritional quality of feed ingredients by utilizing enzymes produced by specific microorganisms (Surianti et al., 2020). Microorganisms commonly used in fermentation include bacteria, fungi, and yeast. One of the most effective bacteria for fermenting livestock blood into fish feed is lactic acid bacteria (LAB). LAB significantly reduces environmental pH, effectively inhibiting the growth of pathogenic microorganisms. During fermentation, LAB enzymes break down proteins and fats into simpler forms, making them more digestible for fish (Pamungkas, 2011). An example of commonly used lactic acid bacteria is *Lactobacillus plantarum* (Figure 2).

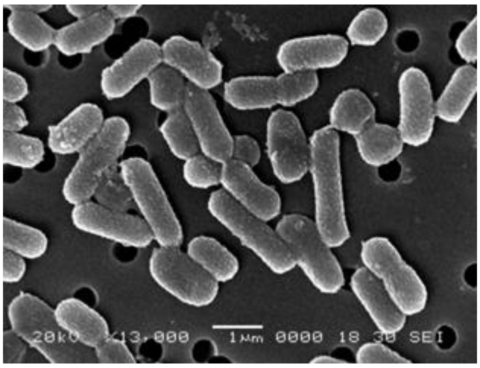

Figure 1. *Lactobacillus plantarum*
Source: Arasu et al. (2016)

The fermentation process with lactic acid bacteria can improve the efficiency of nutrient absorption by fish because the fish's body more readily absorbs simpler molecules. The degradation of fats will produce fatty acids, which bacteria can later use for their growth. Glucose, produced from cellulose breakdown, is processed by Lactobacillus into lactic acid. Lactic acid production decreases when sugar levels are low and increases when sugar levels are still high. This indicates that the more sugar present, the more lactic acid is produced, lowering the environmental pH (Pamungkas, 2011). The amino acids produced from protein breakdown can be converted into CO_2, H_2O, lactic acid, acetic acid, ethanol, and nitrogen-containing compounds such as ammonia (NH_3). The presence of NH_3 can slightly raise the pH during the fermentation process, but if the molasses concentration is too high, the production of NH_3 also increases and can kill some types of lactic acid bacteria, reducing their ability to break down proteins (Setyawan et al., 2014).

Lactic acid bacteria such as Lactobacillus convert carbohydrates into lactic acid through a series of biochemical reactions that begin with glycolysis, where glucose is broken down into pyruvate. The pyruvate is then converted into lactic acid under anaerobic conditions, which also helps regenerate NAD+ to continue glycolysis. Several factors, including environmental conditions such as pH and temperature, the quality of raw materials, and fermentation time, influence the success of fermentation. The optimal temperature for the growth of lactic acid bacteria ranges from 30°C to 40°C, while lower pH (around 4-5) can inhibit the growth of pathogenic microbes and enhance product stability. The correct fermentation time is also crucial, as more extended fermentation periods can increase the number of lactic acid bacteria and bioactive components in the feed (Rinto et al., 2022).

Lactobacillus can be classified into two types of fermentation: homofermentative, which produces almost entirely lactic acid, and heterofermentative, which produces lactic acid and other products such as acetic acid and carbon dioxide gas. *Lactobacillus* in the fish digestive system acts as a probiotic, helping to balance the gut microbiota and improve digestive tract health. Moreover, the lactic acid produced can lower the environmental pH, thereby inhibiting the growth of harmful microorganisms that could cause disease in fish (Setyawan et al., 2014). Other factors affecting fermentation include the substrate (medium), oxygen, and water activity (Kusuma et al., 2020).

3.3. Improving Blood Waste Quality through Fermentation

Livestock blood waste can be used as fish feed, with fish blood waste containing very high crude protein levels, reaching up to 80% (Ananda et al., 2023). Blood requires further processing to be utilized as fish feed. One way to improve the nutrition or quality of blood waste for fish feed is by fermenting it using lactic acid bacteria, specifically *Lactobacillus* sp. These bacteria have a proteolytic system capable of hydrolyzing dietary proteins into peptides and amino acids. *Lactobacillus* sp contains key components, such as serine protease enzymes, which break down proteins. Fermentation with these lactic acid bacteria can increase the crude protein content. The increase in crude protein is due to the bacteria contained in the probiotic, which can hydrolyze the feed, as fermentation helps cut the peptide chains from long protein chains (Haryasakti et al., 2019).

According to Prasetyo et al. (2023), the fermentation process with lactic acid, specifically *Lactobacillus* sp, requires 21 days to increase the crude protein content. Laining & Rahmansyah (2002) showed that fermentation can improve the digestibility of blood meal by breaking down complex components in the blood, making it easier for fish to digest. Fermentation enhances nutritional value and helps reduce potential environmental issues that may arise from using this animal by-product. The following table presents other research related to the fermentation of blood meal with lactic acid (Table 2).

Table 2. Fermentation research results with lactic acid bacteria

Treatment	Results	Reference
Fermentation with *L. acidophilus*	Improved protein quality and amino acid availability	Samaddar & Kaviraj (2014);
Fermentation with *L.plantarum* (120 hours)	Increased digestibility of 36.51% NDF, 24.57% ADF, 12.15% cellulose, 11.94% hemicellulose, and 5.53% lignin. This BMOPFA has a DM digestibility rate of 78.10%, an OM digestibility rate of 73.56%, a CP digestibility rate of 67.33%, and a rumen N-NH concentration of 32.67 mM.	Imsya et al. (2023)
Indirect Fermentation (Various Substrates) Substrates used: 6% sugar cane, 6% dry whey, 10% liquid molasses, 13% dry molasses, 15% Brewer's solubles.	Brewer's Solubles (15%) showed the best results compared to other substrates. Stability was achieved with a final pH of 4.3, which preserved blood materials for up to 60 days. This fermentation also produced a more stable product compared to liquid molasses (10%) or whey products (6%), reducing ammonia nitrogen (NH3-N < 0.3%), indicating minimal protein decomposition.	Cai et al. (1994)
Fermented with 6% *L.plantarum* and *Bacillus subtilis*, a mixture of 70% rapeseed and 25% blood meal was inoculated with 6% *L.plantarum* and *B. subtilis* and then fermented for 3 weeks.	Fermented blood meal becomes an alternative protein source and can replace soybean meal in duck rations. Crude protein and crude fat increased after fermentation, with the protein increase possibly due to the reduction of some carbohydrates.	Xu et al. (2011)

The use of blood meal processed through fermentation offers a significant opportunity to reduce reliance on increasingly expensive fishmeal while improving the sustainability of aquaculture feed production. Based on Table 2, it can be seen that the best fermentation treatment with lactic acid is at a dose of 3-6%. The application of fermentation technology to improve the quality of blood meal as fish feed aligns with efforts to utilize organic waste more efficiently, supporting a more environmentally friendly and economical fishing industry.

3.4. Use of Blood Waste for Fish Feed

Blood meal, produced through the drying process of animal blood, is an alternative protein source that can replace fishmeal. Halimatusadiah (2009) stated that the protein content of blood meal is very high, reaching 88.45% of its dry weight, making it a potential protein source for fish feed. However, the main challenge in using blood meal as fish feed is its low digestibility, which is only around 55.2%. This limits its widespread use in feed formulations.

To address this digestibility issue, fermentation has been identified as one of the methods that can improve the quality of blood meal. Laining & Rahmansyah (2002) showed that fermentation can improve the digestibility of blood meal by breaking down complex components in the blood, making it easier for fish to digest. Fermentation enhances nutritional value and helps reduce potential environmental problems that may arise from using this animal by-product. The following are several studies that use blood as fish feed in the form of unfermented and fermented blood meal (Table 3)

Table 3. Effect of blood waste utilization in fish feed

Processing Method	Organism	Dosage	Results	Reference
Fermented with formic and propionic acids	Nile Tilapia (*Oreochromis niloticus*)	1.5% (1:1 ratio of formic and propionic acids)	Improved protein digestibility (94.66%), fat digestibility (88.71%), and total digestibility (90.27%)	Rosmawati & Samsudin (2016)
Fermented with formic and propionic acids	Tiger Grouper (*Epinephelus fuscoguttatus*)	3% blood meal	High digestibility: protein (84.4–88.1%), lipid (93.3–94.7%)	Usman et al. (2007)
Blood meal substitution	Humpback Grouper (*Cromileptes altivelis*)	12% blood meal substitution	Optimized Fe bioavailability, increased growth, and improved immunity	Setiawati et al. (2009)
Blood meal substitution	Nile Tilapia (*O.niloticus*)	20% blood meal substitution	Highest growth rates, feed efficiency, and survival rate	Takou et al. (2021)

Based on research, fermentation using a mixture of formic acid and propionate at doses of 1.5-3% (1:1 ratio) has been shown to effectively improve nutrient digestibility in tilapia and tiger grouper, with protein digestibility reaching 94.66% and lipid digestibility up to 94.7%. Meanwhile, the substitution of blood meal in feed showed the best results at 20% for tilapia, supporting growth and the highest feed efficiency, and 12% for duck grouper, which increased iron bioavailability, growth, and immunity. Thus, the optimal dose for fermentation or substitution depends on the fish species and the intended purpose.

The use of blood meal processed through fermentation offers significant opportunities to reduce reliance on increasingly expensive fishmeal while improving the sustainability of aquaculture feed production. The application of fermentation technology to improve the quality of blood meal as fish feed is also in line with efforts to utilize organic waste more efficiently, supporting a more environmentally friendly and economical fishing industry

4. CONCLUSION

Based on the reviewed literature, the nutritional quality of livestock blood waste significantly improves through fermentation using lactic acid bacteria (LAB). The findings highlight that fermented blood waste exhibits more stable dietary properties, including increased protein content, enhanced essential amino acid availability, and reduced crude fiber levels, making it suitable as an alternative ingredient for fish feed. In practical applications, fermented and non-fermented blood waste can be used in fish feed formulations, particularly for Nile tilapia and humpback grouper. However, fermented blood meal significantly improves fish digestibility efficiency, especially for protein absorption, reaching 94.66% digestibility levels. Using fermented blood meal reduces reliance on fish meal, which is becoming increasingly scarce and expensive. Furthermore, it supports sustainable aquaculture practices by minimizing environmental pollution from untreated slaughterhouse blood waste.

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