



Nutritional Transformation of Ruminant Feed: A Literature Review on the Role of Fermentation in Enhancing Productivity

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ABSTRACT

Feed is a fundamental component in ruminant livestock production systems, directly influencing productivity and overall efficiency. Given the limited availability of high-quality feed resources, feed fermentation emerges as a promising strategy to enhance the nutritional value of abundant and low-cost local feed materials. The fermentation process involves the activity of microorganisms capable of hydrolyzing anti-nutritional compounds, improving fiber digestibility, enriching protein content, and generating beneficial secondary metabolites that support digestive health. This literature review aims to examine existing research on feed fermentation mechanisms, types of microorganisms employed, changes in nutrient composition, and the effects on ruminant performance, including feed intake, feed conversion efficiency, weight gain, and milk production. The findings indicate that fermentation using lactic acid bacteria, fungi, or yeast significantly improves the quality of fibrous feeds such as rice straw, cassava leaves, and agro-industrial by-products. Consequently, animal performance improves, accompanied by enhanced feed efficiency. Therefore, feed fermentation technology holds substantial potential in supporting sustainable livestock systems, particularly in areas with limited access to high-quality feed. This review highlights the need for standardization of fermentation techniques and comprehensive economic evaluations to facilitate large-scale adoption.

Keywords: *Feed Fermentation, Ruminant Nutrition, Livestock Productivity, Digestibility, Microorganisms*

INTRODUCTION

The livestock sector, particularly ruminant production, plays a strategic role in supporting food security and the rural economy. The productivity of ruminants such as beef cattle, dairy cows, goats, and sheep relies heavily on the availability of high-quality feed. However, in many tropical regions, including Indonesia, a major challenge faced by farmers is the limited supply of nutritious feed, especially during the dry season (Fitriyani & Susilowati, 2023). Therefore, the need for innovative, low-cost solutions to enhance the quality of locally available feed resources has become increasingly important for sustaining livestock productivity.

Local feed resources such as rice straw, agro-industrial by-products, and tree leaves are abundant but often limited by high fiber content, low crude protein, and the presence of anti-nutritional compounds like lignin and tannins. These materials naturally have low digestibility and are less effective as energy and protein sources for ruminants (Li et al., 2020). Thus, technological approaches are required to improve their nutritional value one of which is feed fermentation, a method that has been proven to significantly transform the chemical composition of feed ingredients.

Feed fermentation is a biotechnological process utilizing microorganisms such as lactic acid bacteria, yeast, and fungi to alter the chemical structure of organic materials. This process enhances nutrient availability through fiber degradation and the synthesis of metabolites beneficial to ruminant digestive health (Arifin & Sugiharto, 2021). In addition to improving digestibility, fermentation can prolong shelf life, reduce pathogenic microbial contamination, and improve feed palatability. Therefore, fermentation not only enhances nutritional composition but also addresses hygiene and feed distribution efficiency.

Studies have shown that fermentation can significantly increase crude protein content and reduce fiber levels. For example, using microorganisms like *Lactobacillus plantarum* and *Saccharomyces cerevisiae* in fermenting rice straw can raise protein content from 3–5% to 7–9% and increase digestibility up to 60% (Bach & Iglesias, 2019). These positive effects directly contribute to improved animal performance, including daily weight gain and better feed conversion ratios key indicators in livestock production management.

For smallholder farmers with limited access to commercial feeds, fermentation presents a cost-effective and practical alternative. It can be implemented on a small scale using simple

technologies such as silage or solid-state fermentation with locally available microbial starters. This offers great potential for improving livestock productivity in a sustainable and self-reliant manner (Sutaryo & Widyastuti, 2022). Moreover, this approach aligns with zero-waste principles and integrated crop-livestock systems.

However, the effectiveness of fermentation is influenced by several factors, including the type of feed material, microorganism strains, environmental conditions (pH, temperature, moisture), and fermentation duration. Therefore, a thorough understanding of fermentation principles and mechanisms is essential to optimize feed fermentation outcomes (Li et al., 2020). Additionally, economic evaluations are necessary to assess the financial feasibility of fermented feed use at the farm level.

Given this background, the present literature review aims to comprehensively explore the role of fermentation in transforming the nutritional quality of ruminant feed. The review focuses on the biochemical processes involved, the microbial agents commonly used, nutrient composition changes, and the impacts on ruminant productivity based on previous research. The study is intended to serve as a reference for developing applicable and sustainable feed fermentation technologies for the livestock sector.

METHODS

This study employs a qualitative approach using a systematic literature review method to identify, collect, and analyze research findings related to the fermentation of ruminant feed. The literature review was conducted through the exploration of scientific journals, conference proceedings, and other academic publications from online databases such as Google Scholar, ScienceDirect, Scopus, and DOAJ. Inclusion criteria consisted of publications from the past five years (2019–2024) that specifically discuss feed fermentation for ruminants and provide data or findings on nutrient composition changes and impacts on animal performance. Articles focusing solely on non-ruminant animals or lacking empirical fermentation data were excluded.

The literature selection process involved two stages. First, a preliminary screening based on titles and abstracts was carried out to assess topic relevance. Second, a full-text review was conducted on articles that passed the initial screening to ensure they contained detailed information on feed types, fermentative microorganisms, fermentation techniques (such as anaerobic, aerobic, ensiling, or solid-state fermentation), and outcomes of the

fermentation treatments. The collected data were analyzed qualitatively and descriptively to identify consistent patterns and trends in improving feed nutritional quality and livestock performance.

Thematic analysis was used to categorize the reviewed literature according to key themes, such as changes in feed chemical composition (protein, crude fiber, fat), types of fermentative microorganisms, and effects on performance parameters (weight gain, feed intake, feed conversion efficiency, and milk production). Through this approach, the review aims to provide a comprehensive understanding of how fermentation contributes to enhancing the quality of local feed resources and supporting sustainable ruminant production.

RESULTS AND DISCUSSION

1. Nutrient Transformation Through Fermentation

Feed fermentation is an effective biotechnological approach to improve the nutritional quality of ruminant feed, particularly from agricultural residues such as rice straw, corn cobs, and high-fiber leaves. One of the primary changes during the fermentation process is the reduction of lignin, a structurally complex compound that is difficult for rumen microbes to degrade. The reduction in lignin directly enhances fiber digestibility, as reflected in improvements in Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) fractions. According to Kim, Lee, and Park (2023), fermentation of rice straw using lactic acid bacteria resulted in significant degradation of lignocellulosic structures, thereby improving fiber utilization by ruminants. This process facilitates rumen enzymatic access to cellulose substrates, enabling better energy extraction from fibrous feed.

In addition to improved digestibility, fermentation also increases crude protein (CP) content in feed. This is due to the growth and metabolic activity of fermentative microbes such as *Lactobacillus plantarum* and *Saccharomyces cerevisiae*, which synthesize microbial protein during fermentation. Research by Agustina, Ramadhani, and Fadillah (2023) showed that rice straw fermented with *L. plantarum* increased CP content from 4.8% to 8.2% after 7 days. Meanwhile, *S. cerevisiae* contributes not only to protein enrichment but also provides B-complex vitamins and growth factors that stimulate rumen microbial activity, thereby accelerating feed degradation. This increase in CP is crucial in low-protein feed rations to meet the nitrogen requirements of rumen microbes and support animal productivity.

Fermentation also plays a key role in reducing anti-nutritional factors such as tannins,

phytic acid, and saponins commonly found in local forages and agricultural residues. These compounds can negatively impact nutrient utilization by binding proteins and minerals and inhibiting digestive enzymes. Through enzymatic activity during fermentation, these anti-nutrients can be broken down or inactivated, increasing nutrient bioavailability. Wahyuni and Nugroho (2021) reported that fermentation of *Leucaena* leaves using *Aspergillus niger* and lactic acid bacteria significantly reduced tannin content and improved protein digestibility by 25%. Such transformations render previously underutilized or low-quality feed materials more functional and suitable for ruminant rations.

2. Effective Microorganisms in Feed Fermentation

Microorganisms play a crucial role in determining the effectiveness of feed nutrient transformation during fermentation. One of the most commonly used microbes is *Lactobacillus* spp., particularly *Lactobacillus plantarum*, known for rapidly lowering pH and creating a stable anaerobic environment. This pH reduction is essential for inhibiting spoilage organisms and maintaining feed quality during storage (Susilawati et al., 2022). In addition, *Lactobacillus* spp. enhance feed palatability and digestibility by producing lactic acid and digestive enzymes that help break down complex fiber structures.

On the other hand, microorganisms like *Trichoderma reesei* are key agents in degrading lignocellulose the primary component of plant cell walls. *T. reesei* produces lignocellulolytic enzymes such as cellulase, hemicellulase, and lignin peroxidase, which break down the lignin-cellulose complex into simpler, more digestible forms for rumen microbes (Handayani & Suryani, 2023). With reduced lignin and increased availability of digestible fiber fractions like NDF and ADF, the energy value of feed is significantly improved, making *T. reesei* a promising candidate in bio-fermentation of high-fiber materials.

Furthermore, multi-species inoculants or microbial consortia exhibit synergistic effects in enhancing fermentation efficiency. For example, the combination of *Lactobacillus plantarum* and *Saccharomyces cerevisiae* not only accelerates pH reduction but also boosts crude protein levels and reduces anti-nutritional compounds such as tannins and phytic acid (Putra et al., 2024). Such combinations also enhance rumen microbial populations post-ingestion, ultimately improving animal performance. Thus, microbial selection and synergy are critical to optimizing feed fermentation for maximal nutrient transformation.

3. Impact on Livestock Performance

Fermented feed has been shown to significantly increase dry matter intake (DMI) in ruminants. Several studies report improved palatability and reduced lignin and anti-nutritional content as key factors driving increased intake. According to Rizqi et al. (2023), DMI increased by up to 15% in cattle fed fermented rice straw-based diets compared to a control group. This enhancement is attributed to improved fiber digestibility and the removal of inhibitory compounds like tannins, allowing for better rumen microbial activity.

Fermented feed also positively affects average daily gain (ADG), especially in beef cattle. Fermentation using *L. plantarum* and *S. cerevisiae* produces feed with higher protein and metabolizable energy content. Raharjo et al. (2022) reported that cattle fed fermented feed experienced ADG increases of 20–30% compared to conventional feed-fed groups. This gain reflects improved feed conversion efficiency an essential metric in cost-effective meat production systems.

In dairy cattle, fermented feed contributes to higher milk yield. Fermentation of legume-based forages such as *Leucaena* and *Indigofera* improves protein and essential amino acid content, critical for milk synthesis. Nugroho et al. (2024) observed an 18% increase in milk yield during early lactation when legume-based fermented feed was used. This effect is strengthened by enhanced rumen microbial activity and better nutrient extraction, reinforcing the role of fermentation in both growth and lactation performance in modern ruminant farming systems.

4. Smallholder-Level Fermentation Applications

Implementing feed fermentation at the farmer level is a strategic approach to enhance production efficiency in ruminant farming, particularly in rural areas rich in local biomass resources. Materials such as rice straw, rice bran, and agro-industrial waste previously underutilized can be transformed through simple fermentation techniques like silage and aerobic fermentation to improve nutritional value and digestibility. This process not only reduces feed costs but also extends shelf life and reduces pathogenic microbial contamination (Arifin et al., 2023). As a result, fermentation contributes directly to lower production costs and improved livestock performance among smallholders.

Simple, eco-friendly fermentation technologies using commercial starters such as *Lactobacillus* spp. or *S. Cerevisiae* have been widely adopted by farmers with minimal

training. Some even use natural inoculants like rice water or fermented cassava (tapai) as fermentation starters. These methods have been successfully applied to local feed materials such as fermented straw, coconut cake, and cassava leaves, which showed increases in crude protein and decreases in crude fiber post-fermentation (Putra & Lestari, 2024). The practicality and low cost of these techniques make them attractive for improving livestock productivity in resource-limited settings.

However, several challenges remain in smallholder adoption of feed fermentation. Key obstacles include limited access to quality microbial starters, lack of technical knowledge in managing fermentation parameters (moisture, temperature, pH), and insufficient extension services. Therefore, continuous training and technical support are essential to empower farmers for independent implementation. Collaboration between research institutions, universities, and local governments is crucial to deliver standardized, affordable, and user-friendly fermentation technologies that can enhance smallholder livestock production systems (Yuliani et al., 2024).

CONCLUSION AND IMPLICATIONS

Feed fermentation is a scientifically proven innovation that enhances the nutritional quality of local feed ingredients through bioconversion processes involving microorganisms such as *Lactobacillus* spp., *Saccharomyces cerevisiae*, and *Trichoderma reesei*. This process plays a crucial role in reducing lignin content, improving the digestibility of crude fibers such as NDF and ADF, and increasing crude protein levels. Furthermore, fermentation can effectively lower anti-nutritional factors such as tannins and phytic acid, which otherwise hinder nutrient absorption in livestock. Recent studies demonstrate that fermented feed significantly improves dry matter intake, average daily weight gain (ADG), and milk yield, particularly in ruminants. These outcomes provide strong evidence that feed fermentation is a viable solution for enhancing feed efficiency and animal performance, especially in regions with limited access to high-quality feed resources.

At the farmer level, feed fermentation technology holds considerable practical potential, as it can be implemented through simple methods using local materials such as rice straw, bran, and other agricultural by-products. The use of silage and open fermentation techniques can reduce feed costs while improving nutritional value. However, large-scale adoption still faces several challenges, including limited availability of high-quality microbial starters, inadequate technical knowledge, and the absence of standardized fermentation protocols. Therefore,

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strategic interventions are needed, including technical training, the provision of affordable microbial inoculants, and supportive policies to encourage sustainable implementation. Additionally, long-term economic analyses are essential to ensure that this technology is not only nutritionally effective but also financially feasible for smallholder farmers across diverse regions.

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