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The Utilization of Fermented Agricultural By-Products as Fibrous Feed for Beef Cattle: A Review

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Abstract: Fermentation of agricultural by-products represents a strategic and sustainable approach to providing fibrous feed for beef cattle, particularly in regions facing high feed costs and the low nutritional value of unprocessed residues. Through microbial activity, fermentation alters the chemical composition of raw materials by degrading crude fiber components such as cellulose, hemicellulose, and lignin, thereby enhancing nutrient availability, crude protein content, digestibility, and palatability. Consequently, fermented by-products improve rumen fermentation efficiency and overall cattle performance while reducing feed costs and mitigating environmental pollution from agricultural waste. The wide availability of agricultural residues ensures a consistent raw material supply, supporting feed sustainability within a circular economy framework. This review highlights the mechanisms and benefits of fermentation technology, its role in improving resource efficiency and farm profitability, and its potential contribution to sustainable livestock systems and national food security.

Keywords: Agricultural by-product; beef cattle; fermentation; fibrous feed.

Introduction

Beef cattle production is a vital component of the livestock sector, serving as a key source of animal protein and contributing significantly to national food security. In Indonesia, the beef industry plays a central role in meeting the rising demand for animal protein, driven by population growth, increasing household incomes, and changing dietary patterns toward higher meat consumption (FAO, 2023; BPS, 2024). To meet these demands, it is essential to enhance the productivity of beef cattle operations through efficient, sustainable, and competitive husbandry systems. One of the most decisive factors influencing the performance of fattening enterprises is the availability of nutritionally balanced and economically viable feed resources.

Feed management plays a critical role in livestock production since both the quantity and quality of feed directly determine animal growth, reproduction, and overall productivity. Feed costs typically account for 60–70% of total production expenses, making them a major determinant of farm profitability and efficiency (Harly & Mulyani, 2024; FAO, 2020). Inadequate feed availability not only reduces the carrying capacity of grazing lands but also constrains the growth and reproductive performance of cattle, particularly under smallholder production systems. This challenge becomes more pronounced in Indonesia during the dry season when forage yield and quality decline sharply, resulting in feed scarcity and inconsistent cattle performance (BPS, 2023).

To address this constraint, agricultural by-products such as rice straw, corn cobs, cassava peels, and banana pseudostems have been explored as potential sources of fibrous feed. These materials are abundantly available throughout the year, offering considerable promise as substitutes for conventional forages. However, in their unprocessed form, these residues are typically characterized by low protein content, high fiber, and poor digestibility, which limit their direct utilization in ruminant diets (Krishaditersanto, 2021).

Fermentation has emerged as an effective biotechnological approach to enhance the nutritional value of agricultural residues. Through microbial activity, fermentation can degrade structural carbohydrates (cellulose, hemicellulose, lignin), increase crude protein concentration, and improve digestibility, aroma, and palatability (Suningsih et al., 2019; Widiyastuti et al., 2022). Consequently, materials once regarded as waste can be transformed into valuable feed resources that support cattle growth and reduce feed dependency on costly concentrates. Moreover, this practice contributes to environmental sustainability by minimizing the accumulation of organic waste and promoting circular utilization of agricultural resources.

Despite the growing number of studies on agricultural by-product fermentation, most previous reviews have primarily focused on specific materials or microbial agents. There remains limited integrative analysis on the comparative nutritional improvements, fermentation mechanisms, and practical applications of various fermented agricultural residues in beef cattle feeding systems. Therefore, this review aims to comprehensively examine the utilization of fermented agricultural by-products as fibrous feed for beef cattle, emphasizing their nutritional enhancement, fermentation processes, and implications for sustainable livestock production.

Materials and Methods

This study is a systematic literature review focused on the utilization of fermented agricultural by-products as fibrous feed for beef cattle. The objective was to compile, analyze, and interpret previous research findings on the improvement of nutritional value, digestibility, and cattle performance resulting from feed fermentation. Literature searches were conducted from January to August 2025 using several academic databases, including Google Scholar, Scopus, and ScienceDirect, to ensure comprehensive coverage across disciplines such as animal science, agriculture, and environmental studies. Targeted keywords combined with Boolean operators were applied, including “fermentation” AND (“fibrous feed” OR “fiber source” OR “nutrition”) AND “agricultural by-products” AND “beef cattle,” as well as related terms like “fermented feed” and “sustainable livestock.” Only peer-reviewed journal articles published between 2015 and 2025 in English or Indonesian were considered if they contained relevant quantitative or qualitative data on the fermentation of agricultural residues and their effects on ruminant nutrition and performance.

A total of 182 articles were initially identified from all databases. After removing duplicates and screening titles and abstracts for relevance, 93 papers were selected for full-text review. Following the application of inclusion and exclusion criteria, 48 studies were finally included in the synthesis. Extracted information covered the type of agricultural by-product, microorganism used (e.g., Lactobacillus spp., Saccharomyces cerevisiae, Aspergillus niger), fermentation duration and conditions, and changes in proximate composition such as crude protein, crude fiber, NDF, ADF, and lignin. Additional data on digestibility, feed intake, rumen fermentation, and cattle performance were also reviewed. All data were qualitatively synthesized to identify consistent trends, mechanisms of nutritional enhancement, and the practical potential of fermented agricultural by-products as sustainable alternative feed resources for beef cattle.

Results and Discussion

The fermentation of agricultural residues provides an efficient and sustainable solution for supplying fibrous feed to beef cattle. This practice enhances the nutritional quality of feed materials while reducing feed costs, which represent the largest component of livestock production expenses. In many developing regions, including Indonesia, forage resources often decline during the dry season, leading to feed shortages that limit productivity. Fermenting locally available agricultural by-products offers a practical way to overcome these challenges while promoting waste utilization and environmental sustainability.

Agricultural residues such as rice straw, corn cobs, cassava peels, sugarcane bagasse, and tofu by-products have been widely studied as potential roughage sources. However, their direct use is limited by poor nutrient composition, characterized by high structural carbohydrates (cellulose, hemicellulose, lignin) and low protein content (Wahyono & Hardianto, 2004). Numerous studies have demonstrated that fermentation—whether aerobic or anaerobic—can significantly improve these materials by degrading complex fiber components and increasing nitrogen availability. This transformation makes agricultural by-products more digestible and nutritionally balanced, turning low-value waste into viable feed resources for beef cattle.

Fermentation driven by selected microbial strains plays a central role in this enhancement. Studies have shown that lactic acid bacteria (LAB) such as Lactobacillus plantarum and Lactobacillus casei effectively lower pH, inhibit spoilage organisms, and improve feed stability (Anisah et al., 2021). Similarly, yeasts (Saccharomyces cerevisiae) contribute to protein enrichment and vitamin synthesis, while fungi (Aspergillus niger, Trichoderma viride) produce cellulolytic enzymes that break down lignocellulosic bonds, increasing the availability of digestible nutrients (Hamdi Mayulu, 2023). Variations in microbial inoculants, substrate type, and fermentation duration can yield different outcomes in nutrient profiles. For example, Lactobacillus-based fermentations tend to improve crude protein and energy availability, whereas Aspergillus-based fermentations more effectively reduce lignin and fiber fractions.

Comparative analysis of several studies indicates consistent trends in nutrient improvement after fermentation. Most reported increases in crude protein by 20–40% and decreases in crude fiber by 10–25%, depending on the substrate and fermentation agent used. Enhanced feed palatability and digestibility were also associated with improved dry matter intake and average daily gain in beef cattle. These findings suggest that selecting the appropriate microbial inoculant and optimizing fermentation conditions are crucial for achieving the best nutritional outcomes.

Table 1. Comparative Summary of Studies on Fermented Agricultural By-Products for Beef Cattle

Agricultural By-Product	Microbial Inoculant	Fermentation Duration	Main Nutrient Changes	Observed Benefits
Rice straw	*Lactobacillus plantarum*	14 days	↑ Crude protein (28%), ↓ NDF (15%)	Improved digestibility and DMI
Cassava peels	*Saccharomyces cerevisiae*	10 days	↑ Protein, ↑ aroma and palatability	Higher feed intake and growth rate
Corn cobs	*Aspergillus niger*	7 days	↓ Lignin (20%), ↑ digestibility	Better rumen fermentation efficiency
Tofu waste	*Bacillus subtilis*	5 days	↑ Crude protein (35%), ↓ CF (18%)	Reduced feed cost, improved ADG
Banana stems	*Trichoderma viride*	10 days	↓ Fiber (25%), ↑ mineral content	Enhanced feed utilization

(Sources: Anisah et al., 2021; Hamdi Mayulu, 2023; Suningsih et al., 2019; Wahyono & Hardianto, 2004; Krishaditersanto, 2021.)

The results of this review confirm that fermentation not only improves nutrient profiles but also enhances feed efficiency and animal performance. However, differences among microbial strains, fermentation time, and substrate type must be considered when developing feed formulations. A more standardized approach to evaluating fermentation parameters is needed to ensure consistency across studies. Future research should also focus on the economic feasibility and scalability of these practices under smallholder farming conditions to fully integrate fermented agricultural residues into sustainable beef production systems.

According to Kusumaningrum et al. (2012), the supply of local feedstuffs derived from agricultural residues is relatively abundant in Indonesia, a result of its extensive agricultural land and substantial food crop output. This abundance highlights significant opportunities for their use as fibrous feed in beef cattle diets. Nonetheless, the nutritional profile of these materials is generally poor, as they contain high levels of crude fiber fractions (cellulose, hemicellulose, and lignin), elevated silica content, and low crude protein. Comparable limitations are also evident in other crop by-products, which, when fed without processing, offer little nutritional benefit and are often poorly consumed by livestock.

Hafid and Yamin (2024) observed that the inclusion of fermented rice straw supplemented with probiotics in cattle diets promotes better growth performance and stimulates higher feed intake. One of the main advantages of fermented rice straw is its greater energy value compared to untreated straw. The addition of probiotics further enhances growth efficiency, producing a stronger performance response in cattle. Fermentation also improves feed palatability, leading to increased consumption and offering distinct benefits over unprocessed rice straw.

Similarly, Lamid et al. (2017) demonstrated that the integration of rice straw into complete feed formulations derived from agricultural residues can improve both the nutritional profile and productive performance of beef cattle. This feeding strategy elevates crude protein content and enhances fiber digestibility, thereby allowing more effective use of materials traditionally regarded as low-quality feed. Furthermore, rations formulated with fermented rice straw as a major component have been reported to increase average daily gain to 0.4–0.5 kg/head/day, whereas conventional green forage diets achieve only 0.1–0.2 kg/head/day. These results indicate that fermentation not only enhances feed quality but also plays a direct role in boosting beef cattle productivity.

In line with these findings, Ali and Muwakhid (2017) reported that fermenting rice straw markedly improves the quality of basal feed for beef cattle. Their community-oriented program demonstrated that rice straw inoculated with cellulolytic bacteria was more nutritious, more digestible, and more palatable compared to untreated straw. Moreover, applying fermentation techniques to agricultural residues has been shown to enhance production performance by increasing average daily gain (ADG) while at the same time lowering feeding costs. Taken together, these results highlight that the integration of fermentation technology with agricultural by-products delivers not only nutritional improvements but also promotes the sustainability of livestock systems through more efficient use of locally available resources.

Similarly, Nilawati and Suryadi (2018) found that fermenting agricultural residues can significantly enhance the performance of beef cattle. Their study revealed that women’s farmer groups in Lima Puluh Kota Regency who fed fermented rice straw combined with fermented quail manure achieved average daily gains of 700 g/head/day, compared with only 320 g/head/day before treatment. These outcomes demonstrate that fermentation improves the nutritive value of feedstuffs that are otherwise of low quality, making them more digestible and better utilized by cattle. Additionally, rice straw fermentation has been shown to increase crude protein levels from 2–3% to 7–9% while simultaneously reducing crude fiber content, thus making straw a viable replacement for green forages, particularly during the dry season when natural pasture is scarce. Beyond boosting productivity, the use of fermented agricultural residues also yields economic benefits by reducing feed expenditures and ecological gains by lowering pollution associated with organic waste accumulation.

Salam and Safitri (2025) found that locally formulated fermented feeds, such as silage, can substantially improve nutritional value. In their study, crude protein levels rose from about 12% to 18%, while digestibility improved from 60% to 80%. These enhancements occur because the fermentation process enables microbes to break down complex fibrous components into simpler, more digestible forms, while at the same time increasing protein content through microbial biomass accumulation. The silage recipe generally includes 70–75% rice straw or elephant grass as the main fiber source, 5% rice bran for added energy, 3% molasses to provide soluble carbohydrates, sufficient water to maintain 60% moisture for effective fermentation, and 1–2% microbial starter as an inoculant.

In a similar context, residues such as rice bran treated with cellulolytic microbes have also been reported to enhance both the nutritional quality and palatability of basal rations for beef cattle. Fermented agricultural by□products, particularly rice straw can be further combined with simple concentrates (such as rice bran, pollard, or soybean meal) along with Urea Molasses Block Plus (UMBP) supplements. Such formulations have been shown to improve the growth performance of intensively reared beef cattle, yielding higher weight gains compared with rations based solely on unprocessed forages (Ali & Muwakhid, 2017).

Partner beef cattle farms generally provide rations composed of rice and corn straw, complemented by other forages such as field grasses, legume by□products (e.g., bean residues), and pigeon pea leaves gathered from paddy bunds or idle dryland fields. Basal feed is typically supplied ad libitum in troughs, with drinking water made available during both daytime and nighttime. Farmers also often enrich the ration by mixing in bran.

In most cases, forage as the main feed source is provided at around 10% of live body weight, while concentrate supplements range from 1 to 2%. Nevertheless, the recommended requirement for dry matter (DM) intake in beef cattle is 2 to 3% of body weight. Meeting this target is difficult in practice because farmers must estimate the DM content of the forage offered (Yakin, Ngadiyono, & Utomo, 2013).

Incorporating fermented agricultural residues such as rice straw, corn cobs, and legume foliage can enhance the nutritional value of basal feed. Fermentation lowers crude fiber content, improves digestibility, and raises protein levels, thereby making rations more effective in meeting cattle DM requirements. Thus, the use of fermented feeds not only streamlines feed preparation for farmers but also contributes to improved growth performance and overall productivity in beef cattle.

Fermented agricultural residues have been widely recognized as an effective means of providing fibrous feed for beef cattle. A number of studies have confirmed that this approach helps overcome two major constraints in cattle production: the low nutritive value of unprocessed crop by□products and the high expense of feed. Through the action of microorganisms, fermentation decreases crude fiber components (cellulose, hemicellulose, and lignin), raises crude protein levels, enhances digestibility, and improves overall palatability. Consequently, resources such as rice straw, corn cobs, cassava peels, and tofu waste once regarded as nutritionally inadequate—can be efficiently converted into basal feed suitable for beef cattle.

Conclusion

Fermenting agricultural by-products provides an effective and sustainable approach to supplying fibrous feed for beef cattle by improving protein content, digestibility, and palatability while reducing production costs and environmental waste. To maximize its benefits, farmers are encouraged to adopt simple and low-cost fermentation techniques using locally available materials.

Future research should focus on scaling up fermentation technologies, assessing their economic feasibility under different farming conditions, and exploring the most effective microbial strains to optimize nutrient enrichment and feed efficiency for sustainable cattle production.

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