



Evaluation of Agricultural Waste Utilization as Alternative Feed to Improve Beef Cattle Productivity

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Abstract

The increasing demand for beef production requires innovative strategies to maintain productivity while reducing feed costs and environmental impacts. One promising approach involves the utilization of agricultural waste as an alternative feed resource for beef cattle. This study evaluates the effectiveness of agricultural waste utilization in improving beef cattle productivity through a systematic literature-based analysis of empirical studies. Data were collected from peer-reviewed journal articles, conference proceedings, and scientific reports published between 1999 and 2025. The analysis focuses on feed efficiency, animal growth performance, and economic feasibility. The results indicate that various agricultural by-products, including crop residues, agro-industrial waste, and food waste biomass, can enhance feed utilization and growth performance when properly processed and balanced nutritionally. Studies demonstrate that feed formulations containing agricultural waste significantly improve average daily gain, rumen function, and feed conversion ratios in beef cattle. In addition, agricultural waste-based feed contributes to sustainable livestock production by reducing feed costs and minimizing environmental waste. However, nutritional variability and digestibility remain challenges that require proper treatment and supplementation. This study concludes that agricultural waste represents a viable and sustainable alternative feed resource for improving beef cattle productivity, especially in regions with abundant agricultural residues. Further research should focus on optimizing processing technologies and nutrient balancing to maximize livestock performance.

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Introduction

Global demand for beef continues to increase due to population growth, urbanization, and rising income levels in many developing countries. Livestock production systems therefore face strong pressure to improve efficiency while maintaining environmental sustainability. One of the most critical challenges in beef cattle production is the availability and cost of feed. Feed expenses often represent the largest proportion of operational costs in livestock systems, which forces producers to search for alternative feed resources that are both economically viable and environmentally sustainable. In this context, agricultural

waste has gained attention as a potential feed resource that can support livestock productivity while reducing environmental pressure associated with waste disposal (Kamal et al., 2024).

Agricultural activities generate large quantities of residues every year. These residues include crop by-products, agro-industrial processing waste, and food processing discards. In many agricultural regions, these materials remain underutilized and are often disposed of through burning or uncontrolled decomposition. Such practices contribute to environmental pollution and inefficient resource use. The concept of circular agriculture encourages the reuse of these materials within agricultural production systems. Agricultural waste can be converted into livestock feed through various treatments such as fermentation, ensiling, or nutrient supplementation. This approach allows farmers to transform low-value residues into productive inputs within livestock systems (Nepomuceno et al., 2021).

Crop residues represent one of the most widely available forms of agricultural waste that can be used as livestock feed. Materials such as rice straw, wheat straw, corn stover, and other plant residues are produced in large quantities after crop harvesting. These residues contain fiber and structural carbohydrates that can support ruminant digestion. However, untreated crop residues often have low protein content and limited digestibility, which restricts their direct use as animal feed. Recent studies have therefore focused on improving the nutritional value of crop residues through biological or chemical treatments. Such treatments can increase digestibility and enhance feed efficiency in ruminant animals (Ahmed et al., 2025). Research has shown that improved processing techniques allow crop residues to contribute significantly to livestock feeding systems, especially in regions with limited access to conventional feed resources (Kamal et al., 2024).

In addition to crop residues, agro-industrial by-products have also been widely explored as alternative feed ingredients for beef cattle. Agro-industrial processing generates substantial quantities of organic materials such as fruit pulp, oilseed residues, distillers grains, and cereal by-products. These materials often contain valuable nutrients including carbohydrates, fiber, and residual proteins that can support ruminant metabolism. Studies have shown that incorporating agro-industrial by-products into livestock diets can reduce feed costs without compromising animal performance. For example, concentrates formulated with agro-industrial by-products have been reported to maintain growth performance and carcass characteristics in finishing cattle (Moreno Díaz et al., 2020). Similarly, replacing conventional feed ingredients with food industry by-products has been shown to maintain productivity while improving environmental sustainability in beef production systems (Grossi et al., 2022).

Several empirical studies have examined the direct effects of agricultural waste utilization on beef cattle performance. Evidence indicates that properly processed agricultural waste can improve feed intake, digestibility, and animal growth. Research conducted in China demonstrated that banana processing by-products significantly improved feed intake and body weight gain in beef cattle (Xue et al., 2020). These results indicate that agricultural residues can provide valuable nutrients when properly integrated into balanced feeding strategies. Similar findings were reported in Thailand, where feeding pellets containing agro-industrial waste improved rumen microbial populations and enhanced nutrient utilization in beef cattle (Kanakai et al., 2023). These studies suggest that agricultural waste can function as an effective feed ingredient when supported by appropriate nutritional management.

Food waste has also emerged as a potential feed resource within livestock production systems. Food supply chains generate substantial quantities of discarded food materials that still contain usable nutrients. Instead of being disposed of as waste, these materials can be processed and converted into livestock feed. Research has demonstrated that co-ensiling food waste with crop residues can produce stable and nutritionally balanced feed products for cattle (Dou et al., 2022). The integration of food waste into livestock feeding systems not only supports animal productivity but also reduces environmental burdens associated with food waste disposal. A global review of livestock feeding practices further

confirmed that a large proportion of animals fed diets containing food waste achieved optimal or improved productivity outcomes (Wang et al., 2024).

Beyond productivity improvements, agricultural waste utilization also supports environmental sustainability in livestock systems. Livestock production is often criticized for contributing to greenhouse gas emissions and resource inefficiency. Integrating agricultural residues into livestock feed can reduce waste accumulation and improve overall resource efficiency. The use of crop residues and food processing by-products contributes to a circular agricultural system in which waste materials are recycled back into productive use. This approach helps reduce environmental pollution while improving the sustainability of livestock production systems (Nepomuceno et al., 2021).

Although previous studies have reported positive results regarding the use of agricultural waste as livestock feed, several limitations remain. One major challenge relates to the variability of nutrient content in agricultural residues. The nutritional composition of crop residues and agro-industrial waste can vary depending on the type of crop, processing method, and storage conditions. This variability makes it difficult to standardize feed formulations across different production systems. In addition, some agricultural residues contain anti-nutritional compounds or have low digestibility, which may limit their effectiveness as feed ingredients if not properly processed. Therefore, careful evaluation is required to ensure that agricultural waste can be utilized effectively in livestock diets.

Another limitation identified in previous research is the fragmentation of existing evidence. Many studies evaluate specific types of agricultural waste within particular regional contexts. For example, some studies focus on fruit processing waste, while others examine crop residues or agro-industrial by-products separately. Although these studies provide valuable insights, they often lack a comprehensive evaluation of agricultural waste utilization across different feed categories and production systems. As a result, there remains a need for a broader evaluation that synthesizes existing empirical evidence to understand the overall potential of agricultural waste in improving beef cattle productivity.

Furthermore, previous research often emphasizes either productivity outcomes or environmental benefits without integrating both perspectives. Studies that focus on animal performance may not fully address sustainability implications, while research emphasizing environmental aspects may lack detailed evaluation of livestock productivity indicators. A comprehensive evaluation that considers both productivity performance and resource efficiency is therefore necessary to understand the full value of agricultural waste utilization in livestock systems.

Based on these considerations, this study aims to evaluate the utilization of agricultural waste as an alternative feed resource for improving beef cattle productivity. The study synthesizes empirical findings from previous scientific research that examined the use of crop residues, agro-industrial by-products, and food waste biomass in livestock feeding systems. By integrating findings from multiple studies, this research seeks to provide a clearer understanding of how agricultural waste contributes to feed efficiency, animal growth performance, and sustainable livestock production.

The contribution of this study lies in its systematic evaluation of agricultural waste utilization within beef cattle feeding systems. Unlike studies that focus on specific waste materials, this research integrates findings from various categories of agricultural residues to provide a comprehensive perspective on their role in livestock production. The study also highlights the practical implications of agricultural waste utilization for improving feed resource efficiency in regions with limited access to conventional feed ingredients. Through this evaluation, the research provides insights that can support the development of sustainable feeding strategies in beef cattle production systems.

Methods

Research Design

This study applied a systematic literature review design to evaluate the utilization of agricultural waste as an alternative feed resource for improving beef cattle productivity. The review approach allows researchers to synthesize empirical findings from multiple scientific studies in a structured and transparent manner. This method is appropriate for identifying consistent patterns, comparing research findings, and assessing the effectiveness of specific interventions across different contexts. Previous studies examining agricultural waste utilization in livestock feeding systems have used diverse experimental conditions and feed compositions. A systematic evaluation of these studies provides a comprehensive understanding of the productivity outcomes associated with the use of agricultural residues, agro-industrial by-products, and food waste biomass.

The research focuses on empirical studies that evaluate the impact of agricultural waste on key productivity indicators in beef cattle production systems. These indicators include feed intake, digestibility, average daily gain, feed conversion ratio, rumen fermentation, and economic efficiency. By examining these indicators across multiple studies, the review identifies how different forms of agricultural waste influence cattle performance and feed utilization. The approach follows established procedures for systematic literature evaluation in livestock nutrition research.

Data Sources and Literature Selection

The data used in this study were obtained from peer reviewed scientific publications related to agricultural waste utilization in livestock feeding systems. The literature sources include journal articles, conference proceedings, book chapters, and scientific reports published between 1999 and 2025. These publications represent empirical research conducted in various geographic regions including Asia, Europe, and North America.

The literature search focused on studies that specifically evaluated agricultural residues, agro industrial by-products, and food waste biomass used as feed ingredients in beef cattle diets. Key references include studies on crop residue utilization, agro-industrial waste feed formulations, and food waste recycling for livestock feeding systems. Relevant studies were identified from international scientific databases and selected based on their direct relevance to the research objective.

The inclusion criteria for literature selection were defined as follows. First, the study must evaluate the use of agricultural waste or by-products as feed ingredients for ruminant livestock, particularly beef cattle. Second, the research must report empirical results related to animal productivity indicators such as weight gain, feed intake, feed efficiency, rumen function, or economic performance. Third, the publication must provide sufficient methodological information to allow interpretation of the research findings. Studies that focused exclusively on theoretical discussions without empirical evaluation were not included in the analysis.

Based on these criteria, a total of 30 scientific publications were selected for analysis. These studies represent various categories of agricultural waste utilization including crop residues, agro-industrial processing by-products, fruit and vegetable waste, and food supply chain discards. The selected studies form the basis for evaluating the potential contribution of agricultural waste to beef cattle productivity.

Data Extraction Procedure

Data extraction was conducted through a structured review of each selected publication. The process involved identifying key information related to the experimental design, type of agricultural waste used, feed formulation strategy, and reported productivity outcomes. The extracted variables include feed intake, average daily gain, feed conversion ratio, rumen fermentation indicators, and economic performance measures where available.

Each study was also categorized according to the type of agricultural waste utilized. Three main categories were identified. The first category includes crop residues such as rice straw, wheat straw, corn

stover, and similar plant based residues. The second category includes agro-industrial by-products such as fruit processing waste, oilseed residues, and distillers grains. The third category includes food waste biomass derived from food supply chains or household food discards.

This categorization allows the analysis to compare productivity outcomes across different types of agricultural waste resources. The extracted information was compiled and organized into comparative tables to facilitate systematic interpretation of the research findings.

Data Analysis

The analysis applied a qualitative synthesis approach combined with comparative evaluation of empirical findings reported in the selected studies. The objective of the analysis was to identify patterns in productivity improvements associated with agricultural waste utilization in beef cattle feeding systems. The analysis examined whether the inclusion of agricultural residues in cattle diets resulted in improvements in growth performance, feed utilization efficiency, or rumen function.

Studies were first grouped according to the category of agricultural waste used as feed ingredients. Within each category, the productivity outcomes reported in the studies were compared to identify consistent findings and variations across different research contexts. This comparative analysis helps identify which types of agricultural waste provide the most promising results for improving cattle productivity.

The interpretation of the findings was supported by conceptual frameworks related to ruminant nutrition and sustainable livestock production. These frameworks emphasize the importance of fiber digestibility, nutrient balance, and microbial fermentation in determining feed efficiency and animal growth performance. By linking empirical results with these conceptual principles, the analysis provides a structured understanding of how agricultural waste contributes to beef cattle productivity.

Research Validity and Reliability

Several steps were taken to ensure the validity and reliability of the review process. First, only peer reviewed scientific publications were included to ensure the credibility of the research findings. Second, all selected studies were evaluated using consistent inclusion criteria to maintain comparability across studies. Third, the analysis focused on measurable productivity indicators reported in the literature rather than subjective interpretations.

The use of multiple studies from different geographic regions also strengthens the robustness of the analysis. Agricultural waste utilization practices vary across production systems and environmental conditions. By integrating findings from diverse research contexts, the study provides a broader perspective on the effectiveness of agricultural waste as an alternative feed resource for beef cattle production.

Through this systematic evaluation, the study aims to generate reliable insights regarding the potential role of agricultural waste in improving feed efficiency, animal growth performance, and sustainability in beef cattle production systems.

Results and Discussion

The analysis of the selected literature indicates that agricultural waste utilization has a measurable contribution to improving beef cattle productivity when it is processed and formulated appropriately. Various forms of agricultural residues have been used as alternative feed ingredients, including crop residues, agro-industrial by-products, and food waste biomass. These materials contribute nutrients such as fiber, carbohydrates, and residual proteins that support rumen fermentation and animal growth. Several studies report that the integration of agricultural waste into livestock feeding systems improves

feed efficiency, average daily gain, and feed intake while reducing feed costs (Kamal et al., 2024; Ahmed et al., 2025).

Table 1

Empirical Evidence of Agricultural Waste Utilization in Beef Cattle Feeding Systems			
Study	Type of Waste Used	Main Productivity Indicator	Key Findings
Suhartanto et al. (2010)	Agricultural by-product complete feed	Average daily gain	ADG increased to 0.868 kg/day with improved feed conversion ratio
Mulijanti & Teddy (2014)	Rice bran and fermented straw	Weight gain	Improved body weight gain during fattening period
Xue et al. (2020)	Banana processing by-products	Feed intake and growth	Increased feed intake and body weight gain
Kanakai et al. (2023)	Fermented agro-industrial pellets	Rumen microbial activity	Improved digestibility and rumen function
Dou et al. (2022)	Food waste and crop biomass silage	Feed utilization	Maintained digestibility and animal growth
Wang et al. (2024)	Food waste diets	Productivity outcomes	Around 75–77% of animals reached optimal productivity
Grossi et al. (2022)	Bakery waste and distillers grains	Environmental sustainability	Maintained productivity while improving resource efficiency

The results presented in Table 1 indicate that different types of agricultural waste provide consistent positive effects on cattle productivity when properly processed. These results show that agricultural residues can replace part of conventional feed ingredients without negatively affecting animal performance. Similar findings are reported by Moreno Díaz et al. (2020), who observed that diets containing agro-industrial by-products maintained growth performance and carcass characteristics in finishing cattle. These findings demonstrate that agricultural waste utilization can support productive and economically efficient feeding strategies.

One of the most widely studied categories of agricultural waste is crop residues. Crop residues include materials such as rice straw, corn stover, wheat straw, and other plant by-products generated after harvest. These materials contain structural carbohydrates that serve as an important energy source for ruminants. However, untreated crop residues typically have low protein content and limited digestibility. Studies suggest that biological treatments such as fermentation or ensiling can significantly improve their nutritional quality (Ahmed et al., 2025). Improved digestibility allows ruminants to utilize fiber more efficiently, which leads to better feed conversion and animal performance. Kamal et al. (2024) also emphasize that crop residue treatment technologies are essential to increase the effectiveness of these materials as livestock feed.

Another important category of agricultural waste includes agro-industrial by-products derived from food processing industries. These materials often contain higher nutrient concentrations compared with untreated crop residues. Agro-industrial by-products such as fruit pulp, oilseed residues, and distillers grains contain digestible carbohydrates and residual proteins that support rumen microbial activity. Research by Kanakai et al. (2023) shows that fermented agro-industrial pellets significantly improved rumen microbial populations and nutrient digestibility in beef cattle. Similarly, Grossi et al. (2022) demonstrate that replacing conventional feed ingredients with food industry by-products does not reduce

cattle productivity. Instead, the practice improves resource efficiency and supports circular agricultural systems.

Food waste biomass also represents an emerging feed resource for livestock production systems. Food supply chains generate significant quantities of edible materials that are discarded due to quality standards or logistical limitations. These materials often retain nutritional value that can support livestock growth. Research by Dou et al. (2022) demonstrates that co-ensiling food waste with crop residues produces stable feed that maintains digestibility and nutrient balance. In addition, a global review conducted by Wang et al. (2024) shows that livestock fed food waste diets often achieve optimal productivity levels when the diets are nutritionally balanced. These findings highlight the potential role of food waste recycling in livestock production systems.

The conceptual pathway shown in Diagram 1 illustrates how agricultural waste can contribute to improved livestock productivity. Agricultural residues must first undergo processing or treatment to enhance digestibility and nutritional balance. Once integrated into livestock diets, these materials support rumen fermentation processes that enable cattle to convert fibrous feed into energy and protein. Improved rumen function ultimately leads to better feed utilization and growth performance.

Beyond productivity outcomes, the utilization of agricultural waste contributes to broader sustainability objectives in livestock production systems. Agricultural waste recycling reduces environmental pollution associated with residue burning or landfill disposal. It also reduces dependence on conventional feed resources that often require intensive land and water use. Nepomuceno et al. (2021) highlight that integrating agricultural waste into production systems supports circular agricultural models that improve resource efficiency. These sustainability benefits strengthen the long-term viability of livestock production systems.

Despite these advantages, several challenges remain in implementing agricultural waste-based feeding strategies. Nutritional variability is one of the primary constraints. The nutrient composition of agricultural residues varies depending on crop type, harvest conditions, and processing methods. This variability requires careful feed formulation to maintain balanced nutrient supply for cattle. Another limitation is the presence of anti-nutritional compounds in some agricultural residues. Proper treatment methods such as fermentation or chemical treatment are therefore required to improve digestibility and reduce potential negative effects.

Overall, the results demonstrate that agricultural waste has significant potential to function as an alternative feed resource for beef cattle production. When processed appropriately and incorporated into balanced diets, agricultural residues can improve feed efficiency, support rumen fermentation, and maintain growth performance. The integration of agricultural waste into livestock feeding systems therefore represents a practical strategy for improving both productivity and sustainability in beef cattle production.

Conclusion

This study evaluates the potential of agricultural waste utilization as an alternative feed resource to improve beef cattle productivity based on empirical findings from previous scientific research. The analysis indicates that various forms of agricultural waste, including crop residues, agro-industrial by-products, and food waste biomass, can contribute positively to livestock feeding systems when they are processed and nutritionally balanced. Several studies demonstrate that these materials support improved feed intake, better rumen fermentation, and enhanced feed conversion efficiency. As a result, the integration of agricultural waste into cattle diets can maintain or improve growth performance while reducing dependence on conventional feed resources.

The findings also show that appropriate processing methods such as fermentation, ensiling, and nutrient supplementation play an essential role in increasing the nutritional value of agricultural residues. These treatments improve digestibility and allow cattle to utilize fibrous materials more efficiently. Empirical studies further indicate that the use of agro-industrial by-products and food waste can maintain cattle productivity while improving feed resource efficiency. This approach supports sustainable livestock production by reducing feed costs and minimizing environmental waste.

From a practical perspective, agricultural waste utilization provides an opportunity to develop more efficient and sustainable beef cattle production systems. Farmers in agricultural regions with abundant crop residues and food processing by-products can integrate these materials into livestock feeding strategies to optimize resource use. However, successful implementation requires proper feed formulation, quality control, and processing techniques to address variability in nutrient composition.

Future research should focus on improving processing technologies and feed formulation strategies to maximize the nutritional potential of agricultural waste. Additional studies are also needed to evaluate long-term productivity outcomes and economic feasibility in different livestock production systems. Strengthening the integration of agricultural waste into livestock feeding practices will contribute to more resilient and sustainable beef production systems.

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