Global Journal of Engineering and Technology [GJET].
ISSN: **2583-3359** (Online)
Frequency: Monthly
Published By GSAR Publishers
Journal Homepage Link- https://gsarpublishers.com/journal-gjet-home/

Investigation into Value-Addition to Post-Agricultural Produce Waste into Feed for a Sustainable Livestock Development in Nigeria

By

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Article History

Received: 10/09/2026
Accepted: 17/09/2026
Published: 21/09/2026

Vol – 5 Issue – 9

PP: - 01-04

Abstract

Livestock feed deficits are one of the challenges being faced by the livestock industry in Nigeria as a result of heavy reliance on imported feed ingredients. This work, therefore, evaluates the potential of rice husk and corn stover wastes as alternative feed resources through microbial fermentation and enzymatic techniques. There was an increase in the crude protein in corn stover from 5.2 % (control) to 7.6 % and 8.1 %, and a reduction in the fiber content from 36 % to 29.5 % and 27.8 % for the fermented and enzymatic treatments, respectively, from the proximate analysis results obtained. While there was an increase in digestibility from 42 % to 65 % (fermentation treatment) and 68 % (enzymatic treatment), the rice husk protein content was improved from 3.1 % to 4.4 % (fermented) and 4.9 % (enzyme-treated), with digestibility rising from 35 % to 54 % and 57 %. The feeding trials using local goats showed that fermentation and enzyme-treated diets enhanced average daily gain by 62-65 g/day compared with the control at 48 g/day, indicating that feed conversion ratios were enhanced by 8.6-8.7 when compared to the control with 10.5; however, there was no mortality rate was observed in the three treatments.

Keywords: *Agricultural waste, enzymatic treatment, fermentation, sustainable livestock*

INTRODUCTION

Livestock production plays a crucial role in ensuring food security, nutrition, and economic stability in Nigeria. However, the sector continues to face a critical challenge of feed scarcity, which accounts for nearly 70 % of total production costs (Afolayan *et al*., 2024). Nigeria is estimated to face an annual feed deficit of over 20 million metric tons, a gap that has led to heavy reliance on imported feed ingredients such as maize, soybean meal, and fishmeal. This dependence not only inflates production costs but also exposes the livestock industry to market fluctuations and foreign exchange constraints (Afolayan *et al*., 2024).

Nonetheless, large volumes of agricultural waste, such as corn stover, cassava peels, rice husks, groundnut shells, and other crop by-products, are generated annually across farming communities, which are mostly discarded, burnt, or left to decompose, contributing to environmental pollution, greenhouse gas emissions, and waste management difficulties (Ogunbajo. and Belewu, 2021). Whereas, literature (Omotoso and Arilekolasi, 2019; Ogunbajo. and Belewu, 2021; Afolayan *et al*., 2024) have reported the potential of these residues, ranging from being rich in carbohydrates, fiber, and other nutrients, but their direct utilization in animal feed is limited due to poor digestibility, low protein content, and the presence of anti-nutritional factors.

Recent advances in bioprocessing technologies such as microbial fermentation, solid-state cultivation, and enzyme-assisted hydrolysis have demonstrated strong potential for transforming these low-value residues into high-quality, nutrient-dense livestock feed (Obensuyi *et al*., 2022). Fermentation can enrich crude protein levels, degrade fiber, eliminate toxins, and enhance the bioavailability of essential amino acids and minerals. While, enzyme supplementation further improves feed conversion efficiency and reduces waste excretion, thereby promoting both animal health and environmental sustainability (Ogunbajo. and Belewu, 2021; Obensuyi *et al*., 2022).

Thus, the rapidly growing population and increasing demand for animal protein in Nigeria, along with the valorization of agricultural wastes into livestock feed, present the need for

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strategic techniques to achieve food security, reduce feed costs, and minimize environmental burdens. This study, therefore, investigates the potential of corn stover and rice husk residues, processed through microbial and enzyme-assisted methods, to improve nutritional quality and enhance livestock growth performance (Okeniyi *et al*., 2020; Ogunbajo. and Belewu; 2021).

Methods

As adopted from the works of Adebayo *et al*. (2024) and Ogunbosoye *et al*. (2024), samples of corn stover and rice husk waste were collected from post-harvested farmland, which were sorted to remove visible contaminants like plastics and stones and then sun-dried for three days until a moisture content of about 12 % was achieved. The sample was further dried with an electric oven at 60^{O}C for 3 hours to remove any trace of water, before being subjected to milling process using 2 mm size sieve. Then 5 g of the sample was measured for proximate analysis as adopted from the work of Ogunbosoye *et al*. (2024).

Additionally, for the microbial inoculation, a commercial yeast strain (*Saccharomyces cerevisiae*) was propagated at 30^{O}C for 24 hours to assist in culturing *lactobacillus plantarum* at 35^{O}C, which was monitored using optical density and viable counts with concentrated configuration of 4,000 g for 10 min, in which the cells were resuspended in sterile saline to obtain inoculum suspensions near 1×10^{8} CFU·mL^{-1}. For each fermentation run, the yeast and inoculant were mixed 1:1 (v/v) just prior to inoculation so that a final addition rate of 5 mL inoculum per 100 g substrate was used; this delivered approximately 5×10^6 CFU·g^{-1} substrate as starting microbial load, which is sufficient to dominate the fermentation while avoiding excessive heat generation. Solid-state fermentation (SSF) for lactic acid type upgrading of the waste was carried out by first adjusting the moisture content of the milled substrate to approximately 60 % using sterile distilled water; the moisture was checked by weight and mixing was thorough to ensure even distribution. The moistened substrate was placed into food-grade polypropylene fermentation bags fitted with one-way air vents, inoculated with the combined *saccharomyces-lactobacillus* suspension. These were incubated at 30°C for 72 hours for corn stover and rice husk, and up to 96 hours for the more recalcitrant rice husks, with gentle turning or mixing once every 24 hours to maintain aerobic pockets and avoid overheating. During fermentation, pH and temperature were monitored twice daily; a successful lactic fermentation was indicated by a pH drop to approximately 4.5 within 48 hours. The fermented substrate was oven-dried at 50-60 °C to reduce moisture to about 12 % for storage and incorporation into diets.

Enzymatic upgrading was carried out on a milled substrate that had either been fungal-pretreated or left as raw, depending on the experimental arm. For enzyme treatment, commercial cellulase and xylanase were used. The milled substrate was re-hydrated to 60 % moisture and placed in a stirred jacketed vessel for small-scale (5 kg) reactions. The pH was adjusted to 5.0 using 0.1 M citrate buffer because most cellulases/xylanases have optimal activity near pH 4.5–5.5; cellulase was applied at 0.5 % (w/w) of dry substrate and xylanase at 0.2 % (w/w). The mixture was incubated at 50^{O}C with gentle agitation using a magnetic stirrer for 24 hours. After the enzymatic reaction, the slurry was cooled and dried to approximately 12 % moisture at 60^{O}C. Post-treatment processing and diet formulation were performed so treated residues could be compared directly in animal feeding trials. Treated residues (fermented and enzyme-treated) were combined with basal feed ingredients to formulate isoenergetic and isonitrogenous experimental diets containing 30 % residue inclusion on a dry matter basis, to feed the goats.

The animal feeding trial was implemented using three (3) healthy goats, where local goats of approximately similar age and initial body weight; they were randomly allocated into three treatment groups (control group receiving untreated residue diet, fermentation-treated residue group, and enzyme-treated residue group). The animals were housed in individual pens to allow measurement of individual feed intake and to prevent cross-feeding. A 14-day adaptation period was observed during which animals acclimated to housing and basal diets; experimental feeding then continued for 56 days (8 weeks). Diets were offered twice daily (morning and evening), and fresh drinking water was provided at every feeding period. Feed offered and refused were recorded daily to calculate voluntary feed intake; body weights were recorded at day 0 and weekly thereafter in the morning before feeding to compute average daily gain. Feed conversion ratio was calculated as dry matter intake divided by weight gain for each animal.

Results and Discussion

Proximate analysis of the feedstock

Table 1 shows the chemical composition and the level of digestibility of the enhanced corn stover and rice husk as compared to the control feed. As observed from the results, the untreated control corn stover diet contained 5.2 % crude protein, 36 % crude fiber, and 42 % ash, indicating a low nitrogen content, in comparison to an increase in crude protein content to 7.6 % and fiber decreased to 29.5 % following the fermentation process, thereby enhancing the digestibility level from 42 to 65 %. A similar trend was also observed in enzyme treatment, with 8.1 % crude protein content, 27.8 % crude fiber, and 68% digestibility as shown in Table 1.

Table 1: The proximate analysis of the feedstock used

Treatment	Crude Protein (%)	Crude Fiber (%)	Digestibility (%)
Corn stover			
Control	5.2	36.0	42

*Corresponding Author: Bello Abdullahi

Fermentation	7.6	29.5	65
Enzyme-treated	8.1	27.8	68
Rice husk			
Control	3.1	42.5	35
Fermentation	4.4	32.1	54
Enzyme-treated	4.9	30.5	57

This result proved that; the fermentation and enzyme applications substantially enhanced the feeding value of corn stover by enriching protein and breaking down indigestible fiber, with enzyme treatment showing a better potential. Additionally, similar trend was observed for the rice husk treatment as depicted in Table 1, as the control diet contained 3.1 % protein, 42.5 % fiber content and a digestibility level of 35 %, as compared to the fermentation treatment, protein content 4.4 %, 32.1 % fiber, and digestibility level of 54 %, while enzyme treatment further improved these values to 4.9 30.5, and 57 %, protein, fiber and digestibility level respectively. These results demonstrate that biological treatments can upgrade the nutritive value of rice husk, but its improvement is less pronounced than in corn stover, and the treated husk still falls short of meeting the minimum crude protein requirement for optimal rumen function.

Performance growth evaluation analysis

The results of the feed performance evaluation on the growth of the tested goats are presented in Table 2. As shown in Table 2, the initial sampling goat's average weight was 9 kg in each case, in which the control diet biomass treatment gained an average weight of 0.048 kg per day, reaching a final weight of 13.3 kg after the feeding period of 90 days, but recording a mortality rate of 0 at the end of the investigation period.

Table 2: The performance growth evaluation of the goats

Treatment	Initial Weight (kg)	Avg. Daily Gain (g/day)	Final Weight (kg)	Feed Conversion Ratio (FCR)	Mortality (%)
Control (untreated)	9.0	48	13.3	10.5	0
Fermentation-treated	9.0	62	14.6	8.7	0
Enzyme-treated	9.0	65	14.9	8.6	0

However, the goats that fed on the fermentation-treated feed recorded an average daily gain of 0.062 kg/day and attained a final weight of 14.6 kg, starting from an initial weight of 9.0 kg, with an improved feed conversion ratio of 8.7 and also zero mortality, as shown in Table 2. A similar result was observed from the enzyme-treated feed, with the goat gaining 0.065 kg/day and reaching a final weight of 14.9 kg, amounting to the feed conversion ratio of 8.6, and a mortality rate of zero as well, highlighting the strong positive effect of enzyme and fermentation supplementation on nutrient utilization and growth. Similar improvements in weight gain, feed conversion, and survivability of West African Dwarf goats on treated crop residues have been reported by Ogunbajo and Belewu, (2021) and Okeniyi *et al*. (2020). Therefore, these investigations confirm that value-added treatments of crop residues significantly enhance their nutritive potential and translate into measurable improvements in livestock performance.

Conclusions

The present study confirms that agricultural wastes such as corn stover and rice husks can be effectively valorized into nutrient-rich livestock feeds through microbial fermentation and enzyme-assisted bioprocessing. Treatments improved crude protein by up to 56 % in corn stover and 58 % in rice husk, while reducing fiber content and enhancing digestibility by more than 20 percentage points. Feeding trials further validated the nutritional upgrades, with goats on treated diets showing up to 35 % higher weight gains, better feed conversion ratios, and zero mortality compared to untreated controls. Although corn stover showed greater improvement than rice husk, both residues demonstrated clear potential for contributing to sustainable feed production in Nigeria. The adoption of such waste-to-feed strategies could significantly reduce feed costs, mitigate environmental waste challenges, and support food security in the livestock sector.

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