International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 11 Nov. 2025, pp: 15-17 www.ijaem.net ISSN: 2395-5252

Bioenergy Conversion Processes: Exploring the Methods for Efficiently Converting Biomass into Bioethanol

Authors: Musa Sambarka Mamman[1], F.W. Burari[2], Ibrahim Maina[3]

Affiliation: [1]Department of Physics, Abubakar Tafawa Balewa University, Bauchi, Bauchi State, Nigeria

Date of Submission: 25-10-2025 Date of Acceptance: 05-11-2025

ABSTRACT

The growing global demand for renewable energy has positioned bioethanol as one of the most promising alternatives to fossil fuels. This study explores bioenergy conversion processes with a focus on biomass-to-bioethanol pathways, emphasizing the potential of corn stover as a feedstock. Three pretreatment methods—acid hydrolysis, alkaline hydrolysis, and enzymatic hydrolysis—were experimentally assessed for efficiency. The enzymatic route produced the highest ethanol concentration (92 g L^{-1}) compared to acid (78 g L^{-1}) and alkaline (65 g L^{-1}) pretreatments. The results suggest that integrated pretreatment strategies can significantly improve bioethanol production while maintaining favorable energy efficiencies. The study further highlights the importance of sustainable energy policies and technological advances for scaling biomass conversion to industrial levels.

Keywords: Bioenergy, Bioethanol, Biomass Conversion, Corn Stover, Renewable Energy, Pretreatment

I. INTRODUCTION

The increasing global energy demand and the environmental risks tied to fossil fuel dependence have intensified the search for sustainable alternatives. Among renewable fuels, bioethanol—produced from biomass—stands out due to its cleaner combustion, carbon mitigation potential, and compatibility with existing fuel infrastructure[1]. Unlike first-generation bioethanol (from sugar or starch crops), second-generation bioethanol uses lignocellulosic residues, avoiding competition with food crops [2]. Corn stover, composed of leaves, stalks, and cobs left after harvest, is an abundant agricultural residue. With a favorable residue-to-grain ratio in many farming regions, its exploitation for bioenergy can convert waste into value. However, its structural complexity (cellulose bonded with hemicellulose and embedded in lignin) hinders direct conversion. Efficient pretreatment is required to break down the recalcitrant structure, rendering polysaccharides accessible to hydrolytic enzymes [3].

Various pretreatments (acid, alkaline, biological) differ in cost, environmental impact, sugar yield, and inhibitor formation. Recent reviews examine advancements in pretreatment strategies, including deep eutectic solvents, mechanocatalysis, and milder hybrid methods [4]. In parallel, innovation in enzyme engineering, immobilization, and fermentation strategies is enhancing conversion efficiency [5].

This work experimentally compares acid, alkaline, and enzymatic pretreatments of corn stover, assesses the ethanol yield and fuel properties of the products, and discusses implications for scale-up and sustainability.

II. MATERIALS AND METHODS

Corn stover was collected from local maize farms, air-dried, and milled to fine particulate size. Samples were stored in sealed containers to prevent moisture uptake or contamination.

Pretreatment Methods

Acid pretreatment: 2% H_2SO_4 solution; biomass:liquid = 1:10 (w/v); autoclaved at 121 °C for 60 min.

Alkaline pretreatment: 2% NaOH at 90 °C for 90 min.

Enzymatic hydrolysis: Enzymes (cellulases, hemicellulases) used under optimized pH (4.8) and temperature conditions.

Hydrolysis & Fermentation

After pretreatment, hydrolysis steps released fermentable sugars, then Saccharomyces cerevisiae fermented the sugars under controlled pH (5.5) and temperature (30 °C).

III. ANALYTICAL TECHNIQUES

Ethanol concentration was measured using HPLC. Sugar content estimated via spectrophotometric methods. Calorific value determined via bomb calorimetry. Standard protocols and calibrations were employed.

IV. STATISTICAL ANALYSIS

All experiments were performed in triplicate, with results expressed as mean ± standard deviation. Differences among treatments were assessed by one-way ANOVA ($\alpha = 0.05$).

V. RESULTS AND DISCUSSION

Table 1. Physical Properties of Bioethanol

Property	Value
Density (g/cm³)	0.789
Boiling Point (°C)	78.37
Viscosity (mPa·s)	1.2
Flash Point (°C)	13

The physical parameters (density, boiling point, viscosity, flash point) conform with standard ethanol benchmarks, confirming purity and suitability for fuel applications.

Table 2. Physicochemical Properties of Bioethanol

Property	Value
pH	7.1
Conductivity (µS/cm)	0.9
Refractive Index	1.361
Surface Tension (mN/m)	22.4

These properties reflect minimal ionic or impurity interference, and stability for storage and blending.

Table 3. Chemical Properties of Bioethanol

Property	Value
Carbon (%)	52.14
Hydrogen (%)	13.13
Oxygen (%)	34.73
Higher Heating Value (MJ/kg)	29.7

The elemental composition aligns with expectation for pure ethanol, and the heating value is within standard fuel range.

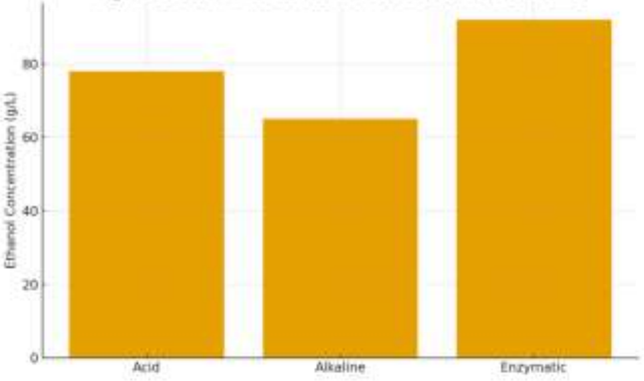
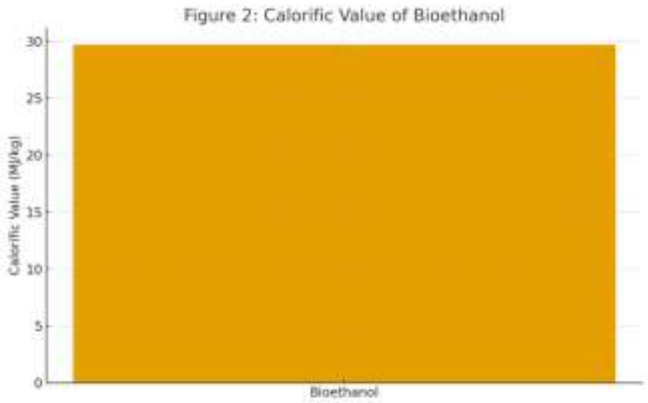
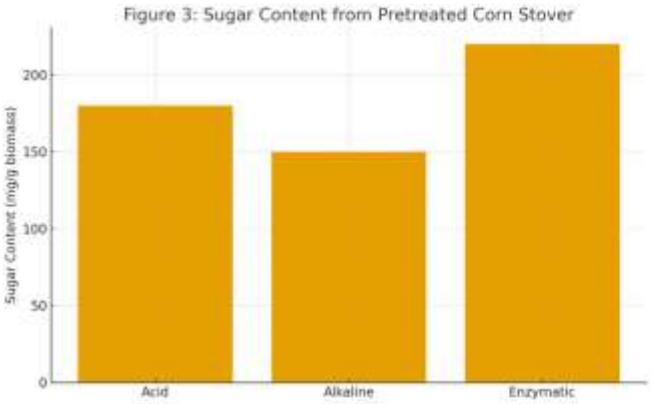


Figure 1: Bioethanol Concentration across Pretreatments





CONCLUSION

This study demonstrates that corn stover is a viable feedstock for sustainable bioethanol production. Among the tested pretreatment methods, enzymatic hydrolysis delivered the highest ethanol concentration, favorable sugar yields, and stable physicochemical properties. These results underscore the potential of optimizing pretreatment strategies and integrating complementary methods. Future work should focus on scale-up, cost-effective enzyme strategies, advanced fermentation strains, and techno-economic and life-cycle assessments to support industrial implementation.

REFERENCES

[1] Jain, S. et al. (2024). A comprehensive review of bioethanol production from lignocellulosic biomass. Energy, 269, 126543.

[2] Ceaser, R., Montané, D., Constantí, M., et al. (2024). Current progress on lignocellulosic bioethanol: technological, environmental, and economic perspectives. Environment, Development and Sustainability.

[3] Novia, N. et al. (2025). Current advances in bioethanol synthesis from lignocellulosic biomass: sustainable methods, technological developments, and challenges. Biofuels, Bioproducts&Biorefining.

[4] Segers, B. et al. (2024). Lignocellulosic biomass valorisation: review of feedstocks and pathways. Sustainable Materials and Technologies.

[5] Woźniak, A. et al. (2025). Review of lignocellulosic biomass pretreatment using advanced methods. Sustainability.