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Research Article

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Utilization of Waste Biomass in Anyigba, Kogi State, Nigeria for the Production of Biofuels and Biochemicals: A Microbiological Perspective

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Abstract

Background: *The increasing demand for sustainable energy solutions underscores the potential of waste biomass for biofuel and biochemical production. This study focuses on agricultural and forestry waste biomass from Anyigba, Kogi State, Nigeria, and aims to optimize microbial processes to convert crop residues and sawdust into valuable biofuels and biochemical.*

Method: *Biomass samples, including rice husks, maize stalks, and sawdust, were collected and analyzed for cellulose, hemicellulose, and lignin content. Various microbial strains such as Bacillus subtilis, Aspergillus Niger, and Trichoderma reesei were isolated and assessed for their enzymatic activities and effectiveness in converting biomass into biofuels and biochemicals. The bioethanol and biogas production from these samples were quantified, and statistical analysis was performed to evaluate the differences in yields.*

Results: *The analysis revealed high cellulose content and varying lignin levels in the biomass samples. Trichoderma reesei exhibited the highest cellulase activity, while Bacillus subtilis was most effective for biogas production. Bioethanol yields ranged from 4.5% to 7.2%, with rice husks providing the highest yield. Biogas production varied from 180 to 250 L/kg of biomass, with sawdust yielding the most. Statistical analysis confirmed significant differences in biofuel yields among the different biomass types.*

Conclusion: *The study demonstrates the feasibility of utilizing waste biomass from Anyigba for sustainable biofuel and biochemical production. The findings highlight the potential of local waste materials for meeting energy needs and environmental goals. Future research should focus on optimizing the processes and scaling up production to further enhance the efficiency and applicability of these technologies.*

Keywords: Waste Biomass, Biofuel Production, Microbial Conversion, Biochemical Production, Sustainable Energy

1. Introduction

The increasing demand for sustainable energy solutions has intensified interest in the utilization of waste biomass for biofuel and biochemical production. As population increased over the years so as the need for food production increased, which has led to the generation of more agricultural waste20. In Anyigba, Kogi State, Nigeria, the disposal of agricultural and organic waste presents both a challenge and an opportunity for advancing renewable energy sources. Waste biomass, such as crop residues and other organic materials, holds significant potential for conversion into valuable biofuels and biochemical through microbial processes.

Recent studies emphasize the role of microorganisms in the efficient conversion of biomass to biofuels, including bioethanol and biogas, as well as high-value biochemicals such as organic acids and enzymes [1,2]. These biotechnological processes not only contribute to waste management but also align with global goals for reducing carbon footprints and promoting sustainable development [3]. In the context of Anyigba, characterized by its substantial agricultural output and corresponding waste generation, harnessing local waste biomass through microbiological methods could address energy needs while mitigating environmental impacts.

This study aims to explore the microbiological potential of waste biomass in Anyigba, focusing on optimizing microbial processes for biofuel and biochemical production. By evaluating the efficacy of local microorganisms in degrading and converting agricultural waste, this research seeks to contribute to the development of sustainable bioconversion technologies tailored to the regional context. The findings could pave the way for more effective waste management strategies and bolster the local economy through the production of renewable energy and valuable biochemical.

2. Materials and Methods

2.1. Biomass Collection

Biomass samples, specifically rice husks, maize stalks, and sawdust, were collected from diverse agricultural and forestry sites in and around Anyigba, Kogi State, Nigeria. The collection sites included local farms and sawmills to ensure a representative sample of available biomass resources. The collected samples were air-dried in a shaded area to prevent degradation and then ground to a uniform particle size using a laboratory grinder, as described by [4].

2.2. Microbial Isolation and Identification

Soil samples were gathered from various locations around Anyigba, including agricultural fields and forested areas, to identify microorganisms with potential biomass-degrading capabilities. Soil was collected from the top 10 cm layer to ensure consistency. Microbial isolation followed standard microbiological procedures, including serial dilution and spread plating on selective media [5]. Isolated colonies were characterized through biochemical assays, such as the API 20E test [6,7].

2.3. Biofuel and Biochemical Production

The ability of selected microbial strains to convert biomass into biofuels and biochemicals was assessed through controlled laboratory experiments. Two primary processes were examined: microbial fermentation for bioethanol production and microbial hydrolysis for biogas production. For bioethanol production, fermentation was conducted in a batch system, and ethanol concentrations were quantified using gas chromatography with a flame ionization detector (FID) as described by [8]. Biogas production was monitored using a gas collection system; with methane, content analyzed using a gas chromatograph equipped with a thermal conductivity detector (TCD) [9].

2.4. Statistical Analysis

Data were subjected to statistical analysis using ANOVA to evaluate significant differences in biofuel and biochemical yields across different biomass types and microbial strains. Post-hoc comparisons were performed using Tukey's HSD test to determine specific group differences [10]. All statistical analyses were conducted using SPSS version 26.0 [11].

3. Results

3.1. Biomass Characteristics

The biomass samples collected included rice husks, maize stalks, and sawdust. Analysis showed that these materials had high cellulose, hemicellulose, and lignin content, making them suitable for microbial degradation.

Biomass Type	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Moisture Content (%)
Rice Husks	35.2	25.4	15.6	10.3
Maize Stalks	32.8	28.1	18.2	12.0
Sawdust	38.5	22.7	20.3	9.8

Table 1: Biomass Characteristics

3.2. Microbial Diversity

A total of 15 microbial strains were isolated, including species of Bacillus, Aspergillus, and Trichoderma. These strains demonstrated significant cellulolytic and ligninolytic activities.

Microbial Strain	Enzyme Activity (Units/g)	Type of Enzyme
Bacillus subtilis	52.5	Cellulase
Aspergillus niger	48.0	Cellulase
Trichoderma reesei	60.2	Cellulase, Ligninase
Saccharomyces cerevisiae	35.3	Fermentation Enzymes

Table 2: Microbial Diversity and Enzymatic Activities

3.3. Biofuel Production

Fermentation of biomass using selected microbial strains yielded bioethanol concentrations ranging from 4.5% to 7.2%. The highest ethanol yield was achieved with Saccharomyces cerevisiae in combination with Aspergillus Niger.

Biomass Type	Microbial Strain (%)	Ethanol Yield
Rice Husks	*Saccharomyces cerevisiae + Aspergillus niger*	7.2
Maize Stalks	*Saccharomyces cerevisiae + Aspergillus niger*	6.8
Sawdust	*Saccharomyces cerevisiae + Aspergillus niger*	4.5

Table 3: Bioethanol Production

3.4. Biochemical Production

Biogas production from biomass hydrolysis ranged from 180 to 250 liters per kilogram of biomass. The highest biogas yield was observed with *Bacillus subtilis*, which was effective in breaking down lignocellulosic materials.

Biomass Type	Microbial Strain	Biogas Yield (L/kg)
Rice Husks	*Bacillus subtilis*	200
Maize Stalks	*Bacillus subtilis*	180
Sawdust	*Bacillus subtilis*	250

Table 4: Biogas Production

Biomass Type	Process Type	Mean Yield	Standard Deviation	p-value
Rice Husks	Bioethanol	7.2	0.5	0.03
Maize Stalks	Bioethanol	6.8	0.6	0.03
Sawdust	Bioethanol	4.5	0.7	0.02
Rice Husks	Biogas	200	10	0.05
Maize Stalks	Biogas	180	12	0.05
Sawdust	Biogas	250	15	0.04

Table 5: Statistical Analysis of Bioethanol and Biogas Yields

4. Discussion

4.1 Biomass Characteristics

Table 1 presents the compositional analysis of different types of biomass, including rice husks, maize stalks, and sawdust. The data show varying levels of cellulose, hemicellulose, and lignin, which are critical for assessing the suitability of these materials for biofuel and biochemical production. Rice husks and maize stalks have similar cellulose and hemicellulose content, but sawdust has a higher cellulose content and lignin level. The moisture content is relatively low across the samples, which is advantageous for efficient microbial processing [12].

Higher cellulose content, as seen in sawdust, generally suggests greater potential for bioethanol production due to the higher availability of fermentable sugars [13]. Lignin content, which is also elevated in sawdust, can inhibit microbial degradation processes, indicating that pre-treatment might be necessary to enhance digestibility [14].

4.2 Microbial Diversity and Enzymatic Activities

Table 2 shows the enzyme activities of different microbial strains isolated from soil samples. Trichoderma reesei demonstrates the highest cellulase activity, which aligns with its known efficiency in degrading cellulose [15]. Bacillus subtilis and Aspergillus Niger also show significant cellulase activity, but lower than T. reesei. These enzyme profiles are crucial for determining the effectiveness of these microbes in biomass conversion processes.

The enzyme activities support previous findings that cellulase and ligninase activities are essential for effective biomass conversion [16]. The combination of these microorganisms can optimize the breakdown of complex biomass into simpler fermentable sugars.

4.3 Bioethanol Production

Table 3 reports the bioethanol yields from different biomass types using a combination of Saccharomyces cerevisiae and Aspergillus Niger. Rice husks achieve the highest ethanol yield (7.2%), followed by maize stalks (6.8%) and sawdust (4.5%). This outcome is consistent with expectations given the higher cellulose content in rice husks, which facilitates more efficient fermentation.

The results demonstrate that both S. cerevisiae and A. Niger are effective in converting the cellulose into ethanol, but pre-treatment to increase biomass digestibility might further enhance yields.

4.4 Biogas Production

Table 4 presents the biogas yields from biomass types using Bacillus subtilis. Sawdust yields the highest biogas (250 L/kg), followed by rice husks (200 L/kg) and maize stalks (180 L/kg). This higher yield from sawdust can be attributed to its cellulose and hemicellulose content, which are more readily converted into biogas compared to maize stalks.

The biogas yield aligns with the expected results based on the chemical composition of the biomass, with cellulose-rich materials generally producing more biogas [17].

4.5 Statistical Analysis

Table 5 provides statistical validation of the bioethanol and biogas yields. The p-values indicate significant differences in yields among different biomass types for both bioethanol and biogas production. The lower p-values for sawdust compared to other biomass types underscore its potential for higher yield but also highlight the need for optimizing pre-treatment processes to overcome its high lignin content [18].

5. Conclusion

This study demonstrates the potential of using local waste biomass from Anyigba for sustainable biofuel and biochemical production. Rice husks and sawdust, with their varying cellulose and lignin contents, present viable options for bioethanol and biogas production, respectively. The microbial strains identified, particularly those with high cellulase and ligninase activities, are effective in biomass conversion processes. Future research should focus on optimizing pre-treatment methods and scaling up production to enhance efficiency and economic viability.

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