Published by :
https://www.ijert.org/
An International Peer-Reviewed Journal

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

Bioethanol Production from Municipal Solid Waste (MSW): A Comparative Study on Economic Viability and Physicochemical Characterization of Paper and Plastic bottle Waste in Ikot Abasi L.G.A

[1]Afia, Ephraim R., [2]John, John A., [3]Akam, Felix N., [4]Bassey, Nsikakabasi I., [5]Umah, Mathew K., [6]Kporna, Michael N., [7]Joseph Benedict B., [8]Philip, Philip E.

[1,4] Department of Mechanical Engineering, Federal University of Technology, Ikot Abasi (FUTIA), Akwa Ibom State, Nigeria.
[2,7,8] Department of Mechanical Engineering, Akwa Ibom State University, Ikot Akpaden, Akwa Ibom State, Nigeria.
[3] Department of Marine Engineering, Akwa Ibom State University, Ikot Akpaden, Akwa Ibom State, Nigeria.
[5] Department of Chemical Engineering, Rivers State University, Rivers State, Nigeria.
[6] Department of Mechanical Engineering, University of Warwick, England, United Kingdom.

***Abstract* - This study presents a comparative analysis of the physiochemical characterization and economic viability of bioethanol produced from paper and (PET) plastic bottles feedstock. By adopting a parallel experimental design, paper waste underwent dilute-acid pre-treatment, followed by fermentation with saccharomyces cerevisiae, while PET bottles were processed through acid-catalyzed glycolysis into ethylene glycol, which was fermented using an engineered strain of Escherichia coli. Triplicate experiments (n=3) were conducted for each pathway, with outputs analyzed using ANOVA and bench marked against ASTM D4806 fuel standards. Results from the experiments revealed that the paper to ethanol pathway demonstrated significant technical superiority, yielding 0.39 ± 0.02L of the ethanol per kg of dry feedstock with a process efficiency of 76.5%. The resulting bioethanol met all key ASTM D4806 specifications including high purity (99.1% V/V), low water content, and an excellent research octane number of 108.5. In contrast, the PET to ethanol pathway was less efficient, yielding 0.12 ± 0.01L/kg with a 20.3% process efficiency and produced a non-compliant ethanol stream (64.5% V/V). A preliminary techno-economic analysis based on experimental data indicated that paper derived bioethanol could be produced at an estimated cost of ₦333 per litre, which is competitive with estimated local market prices of premium motor spirit (PMS), whereas PET-derived ethanol cost ₦2,323 per litre making it economically non-viable. The study concludes that waste paper is a technically robust and economically promising feedstock for sustainable bioethanol production in Nigeria, while PET bottles are not a viable feedstock for bioethanol via the examined pathway under current technological and economic conditions, underscoring the need for continued investment in mechanical recycling for plastics. These findings provide crucial evidence for policymakers and waste management strategist to prioritize paper waste valorization for waste reduction and renewable energy generation in similar developing urban contexts while advocating for more innovative and efficient ways for the (PET) plastic waste.**

***Keywords: Bioethanol, Municipal Solid Waste (MSW), Waste Paper, PET Plastic, Sustainable Energy, Techno-Economic Analysis*.**

1.0 INTRODUCTION

MSW generation has become a pressing issue worldwide, driven by population growth, economic development, and urbanization. [1- 2]. The establishment of institutions such as the Federal university of Technology, Ikot Abasi (FUTIA) has exacerbated this problem, resulting in increased waste generation in the surrounding areas. Effective MSW management and disposal have become significant challenges, posing environmental and health risks. According to [3], MSW generation is projected to exceed 2 billion tons per year globally, threatening the ecosystem. Conventional management methods, including landfilling, incineration, and composting, have limitations and environmental drawbacks [2,4]. These challenges compromise land use, water quality, air quality, and human health [5]. In response to these concerns, the global community is shifting focus towards environmental sustainability, energy security, and waste

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

management, hence bioethanol production from MSW offers a promising solution to mitigate the negative impacts of fossil fuel use. In its simplest form, bioethanol production relies on three consecutive stages: Pretreatment, hydrolysis and fermentation [6,1].

Several research has explored bioethanol production from various MSW components, including kitchen waste [2], waste paper [7-8], pineapple waste [9], biodegradable waste [10], wood waste [11], garbage waste [12], fruit waste [13], landfill organic waste [14,5] and a review on bioethanol production [15,1]. Despite extensive research on the production of bioethanol from different waste streams, the economic viability and physicochemical characterization of bioethanol produced from paper and plastic bottle waste remain understudied especially in the Nigeria context. This knowledge gap necessitates a comparative analysis of the economic viability and physicochemical characterization of bioethanol produced from paper and plastic bottle waste.

By focusing on waste generated within the heart of Ikot Abasi town where FUTIA is located, this study aims to provide valuable insights into the production of bioethanol from paper and plastic bottle waste streams. The findings will help identify the most viable waste stream for bioethanol production in similar urban settings, supports sustainable waste management strategy and contributes to Nigeria's renewable energy targets, thus aligning with United Nations Sustainable Development Goals (SDG 7 and 11). In addition, the use of paper and plastic bottle waste for bioethanol production offers numerous benefits, including reduced environmental issues related to waste management and disposal, decreased dependence on fossil fuels, contribution to environmental sustainability and energy security and Potential economic benefits through waste valorization.

2.0 Materials and Methods

The materials and equipment used for this study are presented in Tables 1 - 4.

2.1 *Feedstock and Consumables.*

Table 1: Primary Feedstock, Chemicals and Reagents

Item	Specification	Used for
Primary Feedstock Mixed waste paper	Office paper, exercise books, newspaper	Paper pathway
Plastic Bottle	Carbonated drinks and water bottles	Plastic (PET) pathway
Chemicals and Reagents		
Sulfuric Acid (H_2SO_4)	98% for hydrolysis and depolymerization	Both Pathway
Sodium Hydroxide (NaOH)	Pellets/flakes, for neutralization of acid	Both Pathway
Brewer's Yeast	Saccharomyces Cerevisiae	Paper Pathway
Engineered E. Coli Strain	For EG fermentation	Plastic Pathway
Calcium Hydroxide ($Ca(OH)_2$)	For sulfate ion removal	Plastic Pathway
Detergent Solution	2% (V/V), for cleaning PET bottles	Plastic Pathway
Yeast Extract, Peptone, Dextrose	For yeast pre-culture	Paper Pathway
Luria-Bertani (LB) medium	For E. Coli pre-culture	Plastic Pathway
Distilled Water	Produced in laboratory	Both pathway

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

Figure 2.1: Shredded Paper Samı

Figure 2.2: Shredded plastic Bottle

Table 2: Equipment and Apparatus for Safety, Drying, Testing, shredding, Weighing

Item	Specification/model	Used for
Laboratory Consumables		
Sample bags/containers	For collection and storage	Both Pathway
Gloves	For safety	Both Pathway
Safety Goggles	Eye Protection	Both Pathway
Masks/Respirators	Dust and Fume Protection	Both Pathway
Filter Paper	Whatman No.1	Both Pathway
PH Strips	For monitoring	Both Pathway
Equipment and Apparatus		
Digital Weighing Scale	Model: ZPX10557	Both Pathway
Scissors	Manual size reduction	Paper Pathway
Jaw Crusher	Model: FZSP6503GT	Both Pathway
Drying Oven	For drying feedstock	Both Pathway
Desiccator	For storing dry, shredded feedstock	Both Pathway
Magnetic stirrer and hotplate With heating mantle	(model: SYB9937D)	Plastic Pathway

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

Figure2.3: Jaw Crusher

Figure 2.4: Multi Parameter Tester

Table 3: Equipment and Apparatus for Fermentation, Hydrolysis, Distillation

Item	Specification	Used for
Pretreatment and Reaction		
Bioreactor/reaction vessel	10L capacity (for hydrolysis)	Paper Pathway
Large container/reactor	10L capacity (for PET glycolysis)	Plastic Pathway
Autoclave	For sterilization and high temperature hydrolysis	Paper Pathway
Water Bath	For temperature-controlled steps	Both Pathway
Condenser	For reflux during PET glycolysis	Plastic Pathway
Separation and Purification		
Centrifuge	Capable of 10,000 x g	Both Pathway
Simple Distillation Apparatus/fractionating Column	Heating Mantle (SYB9937D), Liebig Condenser, Stand	Both Pathway

Figure 2.5: Flash Point Apparatus

Figure 2.6: Cloud Point App

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

Figure 2.7: Alcohol Tester App

Figure 2.8: Viscometer

Table 4: Equipment and Apparatus for Physicochemical Characterization

Item	Specification	Used for
Analytical and Characterization		
PH Meter	Digital	Both Pathway
Alcohol Refractometer	ATC51130	Both Pathway
Hydrometer	Ethanol estimation	Both Pathway
Multimeter tester	For ASTM D4052	Both Pathway
Flash Point Test	SGR 00425	Both Pathway
Viscometer	TYP 0032GR	Both Pathway
Karl Fischer Titrator	For water content (ASTM E203)	Both Pathway
Pour/cloud point apparatus	HTZ8876SP	Both Pathway
Sulfur Analyzer		Both Pathway
Moisture Analyzer	For feedstock moisture content	Both Pathway
Software		Both Pathway
SPSS Software	Version 26.0, for ANOVA	Both Pathway

Methods

2.2 Study Area and Feedstock Collection

2.2.1 Study Area Description

This study was conducted in Ikot Abasi Local Government Area, Akwa Ibom State, Nigeria. The selection of Ikot Abasis was based on its status as a fast

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

growing commercial and administrative centre, further amplified by the establishment of FUTIA. This urbanization and increase in population have led to increased MSW generation, presenting a crucial management challenge and an opportunity for resource and energy recovery (1,15,17). Figure 2.9 depicts the google map of Ikot Abasi.

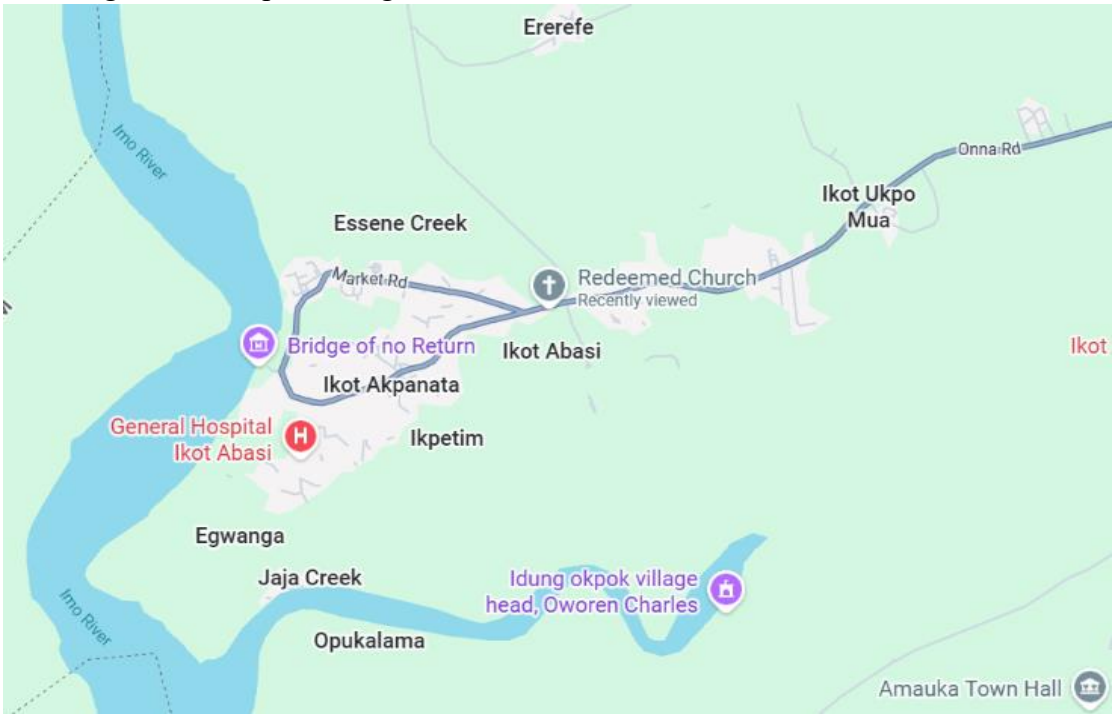

Figure 2.9: Study Area (Google Map 2025) 2025

2.2.2 Sourcing of Feedstock and Sampling Strategy

A multipoint stratified random sampling technique was adopted for sourcing MSW for this study. This was conducted over a three-month period between September 2025 to November 2025. This approach was adopted in other to capture the heterogeneity of the waste stream. The feedstock was sourced from seven (7) different location within Ikot Abasi town. These locations are; Central Market, three (3) Residential Zones (Household Waste Dumps), Motor Parks, Institutional waste collection points (including FUTIA), Government office complexes, Restaurants and eateries and Health Centre premises. At each site as seen in Figures 2.10 and 2.11, a minimum of 10kg of mixed MSW was collected. This was adopted in other to have a statistically robust sample size for further sorting and analysis.

Figure 2.10: Waste Bottle dump

Figure 2.11: Waste Paper dumpsite

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

2.2.3 Feedstock Sorting and Preparation

The collected MSW was manually sorted according to manual sorting guidelines described by [7]. The paper feedstock was composed of office paper, discarded exercise book pages and newspaper. Contaminants such as metal staples, adhesives, coatings, dirt were removed manually. Similarly, plastic feedstock composed of carbonated drink and purified water bottles (PET). Contaminants such as caps, labels were removed manually while residual liquid was removed by rinsing with clean tap water. The sorted feedstocks were stored in thick polyethene bags and plastic containers and transported to the laboratory for processing. The total mass collected for each feedstock type exceeded 20kg. This was adopted to allow for uniform representation of each feedstock.

2.3 Experimental Design

A parallel comparative experimental design was employed to process the paper and plastic bottle feedstock independently under optimized but different pathway because of their difference in biochemical compositions. All experiments (pretreatment, fermentation, distillation) were conducted in triplicate (n=3) to ensure statistical reliability. The variables taken into cognizance were bioethanol yield (%, V.V) and key physicochemical properties such as density, viscosity, pour point, flash point, water content, octane number using the equipment/apparatus in Figures 2.4 to 2.8. Data were subjected to one way analysis of variance (ANOVA) using SPSS Software (version 26.0) with a statistical significance set at $P<0.05$.[2]

All laboratory work was conducted at the Department of Chemical Engineering Laboratory, Rivers State University, Nigeria.

2.4 Paper to Bioethanol Conversion Pathway

2.4.1 Feedstock Pretreatment

The paper feedstock was air-dried to remove ambient moisture. It was then reduced to a size of between 2-5mm as seen in Figure 2.1 using a scissors and jaw crusher in Figure 2.3. (model: FZSP 6503GT). This size was reduced in other to increase surface area for hydrolysis [7,8]. A 2.5kg sample of the shredded feedstock was used for conversion.

2.4.2 Acid Hydrolysis

The shredded paper was subjected to dilute-acid hydrolysis. This is a widely used method for lignocellulosic biomass [7]. The feedstock was mixed with 5L of distilled water in a 10L bioreactor. Concentrated sulfuric acid (H_2SO_4, 98%, Sigma-Aldrich) was added to achieve a final concentration of 2% (V/V).

The mixture was heated to 121^{O}C in an autoclave for 60minutes to hydrolyze hemicellulose and disrupt the lignin-cellulose matrix. After cooling, the hydrolysate was neutralized to a PH of 6.5 using 5M sodium hydroxide (NaOH). This was done to neutralize the acid and create a suitable environment for fermentation. The neutralized mixture was filtered using a Whatman NO.1 filter paper to remove solid residue from the sugar-rich liquid hydrolysate.

2.4.3 Fermentation

The cellulosic hydrolysate was transferred to a fermentation vessel. Brewer's yeast saccharomyces cerevisiae was used as the fermenting micro-organism [7]. A pre-culture was prepared in yeast extract-peptone-Dextrose (YPD) medium and added to the hydrolysate to achieve an initial cell density of 5g/L. Batch fermentation was carried out at 30 ± 2^{O}C under static conditions for 72hours. The extent of fermentation was monitored by reducing sugar concentration (DNS method) and ethanol content (hydrometer) at 12-hour intervals.

2.4.4 Distillation and Purification

At the end of the fermentation process, the broth was centrifuged at 7000 x g for 25minutes to remove yeast cells and solids. The supernatant was then subjected to simple batch distillation as seen in Figure 2.12 using a standard laboratory set up (heating mantle, round bottom flask, Liebig condenser). Ethanol was collected at its boiling point of 78.3^{O}C. To increase purity, the distillate further underwent a second round of fractional distillation.

Figure 2.12: Simple Distillation Setup

2.5 Plastic Bottle (PET) to Bioethanol Conversion Pathway

2.5.1 Feedstock Cleaning and Preparation

PET bottles collected from different sampling sites were cleaned manually. Labels and caps were removed, and the bottles were rinsed with water to remove dirt and other residual liquids. The bottles were then washed in a 2% (V/V) detergent solution for 1 hour with agitation, rinsed thoroughly with distilled water, and air dried. The clean bottles were crunched into 5-10mm sizes using the same jaw crusher (model: FZSP 6503GT). A 2.5kg sample of PET flakes was

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

used in other to match the mass of paper feedstock for yield comparison.

2.5.2. Chemical Depolymerization

PET depolymerization through acid-catalyzed glycolysis was performed to convert the polymer into its monomers. The PET flakes were reacted with a 20:1 (W/W) mixture of ethylene glycol (EG; Sigma-Aldrich) and concentrated H_2SO_4 (acting as a catalyst) in a 10L reactor equipped with a magnetic stirrer and condenser. The reaction was carried out at 190^{O}C for 8 hours under atmospheric pressure. The products which are primarily bis (2-hydroxy ethyl) terephthalate (BHET) and oligomers, was then hydrolyzed in an aqueous solution at 90^{O}C for 4 hours to yield terephthalic acid (TPA) and ethylene glycol (EG). TPA was precipitated, filtered, and dried. The remaining aqueous EG-rich filtrate was neutralized to a PH of 7.0 with 10% (W/V) NaOH.

2.5.3 Microbial Conversion of EG to Ethanol

The neutralized EG stream served as the carbon source for fermentation. An engineered strain of Escherichia (E. Coli Strain K-11 which expresses genes for EG assimilation and ethanol production) was used. A glycerol stock of the strain was revived in Luria Bertani (LB) medium, then adapted in a minimal medium with EG. Fermentation was conducted in a 2L bioreactor with a working volume of 5L, containing the neutralized EG solution. Conversion conditions were maintained at 30^{O}C at a PH 6.8 and 200rpm agitation for 96hours. Anaerobic conditions were induced after an initial aerobic growth phase to promote ethanol production.

2.5.4 Ethanol Recovery

The fermentation broth was centrifuged at 9000 x g for 40minutes to separate cells and particles. The supernatant containing ethanol was distilled at 78.3^{O}C using the same apparatus for paper derived ethanol.

2.6 Analytical Methods and Characterization

2.6.1 Ethanol Yield and Concentration

The ethanol concentration in the final distillate was determined using an alcohol refractometer (ATC 51130) calibrated with ethanol/water standards. The volume of ethanol produced was measured, and the percentage yield was calculated relative to the dry weight of the initial feedstock.

2.6.2 Physicochemical Characterization

The purified bioethanol from both feedstocks was characterized according to the following ASTM standard methods

- Density: ASTM D4052 using a digital densitometer
- Flash Point: ASTM D93
- Viscosity: ASTM D445 using calibrated viscometer
- Acidity: ASTM D1613
- Water Content: ASTM E203
- Octane Number: ASTM D2699
- Sulfur Content: ASTM D5453
- PH: Measured with a calibrated PH meter

2.5.3 Economic Viability Assessment

A preliminary techno-economic analysis (TEA) framework was adopted to assess the economic viability of producing bioethanol from paper and plastic feedstock respectively. The analysis considered:

- Operational Expenditure (OPEX): These includes, Feedstock collection, sorting, transportation, storage, chemicals (acids, bases, catalyst, nutrients, yeast), utilities (water, energy for heating) and labour cost.
- Revenue: This was determined based on ethanol yield and assumed (PMS) market price in Nigeria.

A simplified ethanol production cost (₦/L) was calculated for each pathway

based on the total cost of production of ethanol from each feedstock for comparative purposes. S

3.0 Results and Discussion

This section presents the comparative yield, physicochemical properties and preliminary economic output of bioethanol produced from paper and plastic bottle (PET) feedstocks. All values are reported as mean ± standard deviation of triplicate experiments (n=3). Statistical significance was determined by one-way Analysis of variance (ANOVA) using IBM SPSS statistics (V 26.0), where a P-Value of < 0.05 was considered statistically significant.

3.1 Feedstock Characterization and Process Performance

The two feedstocks showed fundamentally different conversion efficiencies in the primary yield metrics as shown in Table 5.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

Table 5: Comparative Bioethanol Production Yield from Paper and Plastic Bottle (PET) Feedstock

Parameter	Formula/Description	Paper Feedstock	Plastic Feedstock	Statistical Significance (P-Value)
Total dry feedstock mass		2.50 ± 0.04L	0.31 ± 0.02L	<0.001
Final Ethanol Volume	Total volume of distillate collected	0.98 ± 0.04L	0.31 ± 0.02L	<0.001
Volumetric yield	(L ethanol/kg of dry feedstock)	0.39 ± 0.02L/kg	0.12 ± 0.01L/kg	<0.001
Theoretical ethanol yield	Based on cellulose $(C_6H_{10}O_5)_n$ for paper and EG ($C_2H_6O_2$) for PET	0.51L/kg	0.59L/kg	-
Process Efficiency	Volumetric yield/theoretical yield x 100%	76.5 ± 3.9%	20.3 ± 1.7%	<0.001
Total Process Time	From pre-treatment to distillation	4.5 ± 0.5 days	10.5 ± 0.5 days	<0.001

From the results presented in Table 5, the paper to ethanol pathway demonstrated a higher volumetric yield (0.39L/kg) with a statistical significance ($P<0.001$) compared to plastic bottle pathway. This indicates a 3.25% greater ethanol production per kilogram of paper waste feedstock compared to that of the plastic feedstock.

In terms of process efficiency, the dilute acid hydrolysis and fermentation of paper feedstock achieved a robust process efficiency of 76.5%, indicating effective sugar release and conversion by S. Cerevisiae. In contrast, the multi-step PET depolymerization and microbial fermentation of EG achieved a low efficiency of 20.3%. This significant difference ($P < 0.001$) highlights major technical challenges in the plastic conversion pathway, likely related to incompletely depolymerization, substrate inhibition, or sub-optimal fermentation of EG by the engineered E. Coli.

In terms of process duration, results presented in table 5 indicate that the plastic bottle pathway required more than twice the total processing time (10.5 days) compared to the paper pathway (4.5 days), a statistically significant difference ($P < 0.001$), impacting its potential through put and operational cost.

3.2 Physicochemical Characterization

The fuel properties of bioethanol produced from paper and plastic bottle feedstocks were analyzed and bench marked against ASTM D4806 as shown in Table 6.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

Table 6: Physicochemical Properties of Produced Bioethanol Versus ASTM D4806 Standard

Property	ASTM D4806 Specification	Paper Derived Bioethanol (Mean ± SD, n=3)	Plastic Derived Bioethanol (Mean ± SD, n=3)
Ethanol Content (% V/V)	≤ 92.1% (min)	99.1 ± 0.3	64.5 ± 0.8
Water Content (% V/V)	≤ 1.0% (max)	0.18 ± 0.03	2.5 ± 0.04
Density at 20°C (kg/m^3)	789.2 ± 0.3	789.2 ± 0.3	799.4 ± 0.4
Research Octane Number (RON)	≥ 99	108.5 ± 0.4	107.5 ± 0.5
Flash Point (°C)	12.8 – 14.0	13.5 ± 0.5	11.8 ± 0.5
Sulfur Content (mg/kg)	≤ 5 (max)	1.2 ± 0.5	9.5 ± 0.5
Pour point	< - 40	-29.8 ±2	-41±1
Total Acid Number (TAN) mg KOH/g	≤ 0.007 (max)	0.003 ± 0.001	0.005 ± 0.001
Kinematic Viscosity at 40°C (mm^2/5)		1.19 ± 0.02	1.21 ± 0.03
PH	> 6.5	6.6 ± 0.2	6.9 ± 0.2
Refractive index	1.360 – 1.362	1.3612±0.0003	1.3654±0.0004

From the results presented in Table 6, Bioethanol from paper feedstock met all critical specification of ASTM D4806, confirming its potential as a good feedstock for gasoline. In contrast, bioethanol from plastic bottle feedstock failed the primary specification due to its low ethanol content (64.5% V/V), rendering it non-compliance as a fuel without extensive and costly downstream dehydration. The ethanol purity from paper feedstock (99.1%) was significantly higher ($P<0.001$) than that of plastic bottle feedstock (64.5%). The high purity from paper is attributed to the effectiveness of the simple distillation following a clean fermentation broth. The low purity from plastic bottle feedstock indicates significant co-distillation of water and possibly other volatile organics from the complex fermentation medium, from the results in Table 6, both bioethanol exhibited exceptionally high RON values (>107), with no significant difference between them ($P=0.12$). This confirms their excellent anti-knock property. For sulfur content, plastic bottle derived ethanol had a statistically higher sulfur content than that of the paper feedstock. This outcome is traceable to residual sulfate ions from the acid-catalyzed depolymerization step. The same higher content was observed in Acidity and water content properties as presented in the results in Table 6.

3.3 Economic Viability

Based on the experimental material inputs and yields, a preliminary cost structure per litre of produced Bioethanol was calculated as presented in Table 7. This analysis focuses on operational expenditure (OPEX) from the experimental batch scale.

Table 7: Preliminary Production Cost Analysis Per Litre of Bioethanol (Experimental Scale)

Cost Component	Paper-Derived Ethanol (₦)	PET-Derived Ethanol (₦)	Assumptions
Feedstock Cost (₦/L)	128	1613	Based on processing, collection/ sorting/transportation/storage cost Paper = ₦50,000

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

			PET = ₦150,000. Allocates per litre
Chemical and Catalyst Cost (₦/L)	85	420	Includes H_2SO_4, NaOH, Yeast, nutrients and EG (for PET)
Estimated Energy Cost (₦/L)	120	290	Based on measured power consumption for crunching heating, distillation
Total Production Cost (₦/L)	333	2,323	Sum of column of paper and PET derived Bioethanol per litre
Benchmark: Market Ethanol wholesale price (₦/L)	₦ 900 – ₦ 1000		Approximate price range for PMS in Nigeria, Q3, 2025

From the results presented in Table 7, the paper derived bioethanol showed a preliminary product cost of (₦333/L) which in below the lower bound of the estimated market price (₦900/L) suggesting potential economic viability if scaled with integrated waste management. The PET derived bioethanol had a cost of (₦2,323/L) which is more than double the lower bound of the estimated market price. This output is driven by extremely high feedstock cost per litre due to low yield and expensive chemical inputs for depolymerization. This renders it economically non-viable with the current conversion technology and efficiency. The PET derived low volumetric yield (0.12L/kg as presented in the results of Table 5 further amplifies all upstream costs (collection, sorting, cleaning, storage, transportation, processing) when allocated per litre of product. The preliminary cost analysis therefore indicates a fundamental economic viability for the paper to ethanol pathway, while the PET pathway is economically non-viable for the conversion technology and bioethanol yield for this study.

4.1 Conclusion

This study demonstrate that waste paper is technically feasible and economically promising feedstock for bioethanol production in Nigeria, yielding high-purity, ASTM compliant fuel at a competitive cost. In contrast PET plastics bottles are currently unsuitable for bioethanol production via the glycolysis-fermentation pathway due to low yield, high cost and noncompliant fuel properties. These findings emphasize the importance of feedstock specific valorization strategies within integrated MSW management framework.

4.2 Limitations and Recommendations for future research

- Experiments were conducted at bench scale in this study hence pilot scale trials are recommended to validate yield, cost, and energy balance under real world conditions.
- The paper stream was mixed. Future work should characterize and optimize processes for specific paper grade.
- Environmental impacts of both pathways were not considered in this study, hence further study should consider this

Credit Authorship Contribution Statement

Afia, Ephraim R., - Writing original draft, Conceptualization/supervising, John, John A., – Review and Editing, Umah, Mathew K., and Akam, Felix N., – Laboratory work/Methodology, Bassey, Nsikakabasi I., and Kporna, Michael N., - Analysis of results/Writing, Joseph Benedict B., and Philip, Philip E. - Final Review/Editing.

Funding

The study was funded by 2024 Institution Based Research (IBR) for Tertiary institutions in Nigeria with grant number TETF/DR&D/CE/UNI/IKOTABAS/IBR/2024/V0L1

Declaration of Competing Interest

The authors declare that they have no known financial competing interest or personal relationship that could have appeared to influence the output of this study.

Acknowledgement

Authors Acknowledges the Tertiary Education Trust Fund (TETFUND) of Nigeria for funding this research.

REFERENCES

[1] Osadebe, B., Imhontu, M., Akenzua, O., Okoru, C., Onabe, J., Atsegha, B., Angalapu, J. D., Kubeyuye, B., Orerome, R., Akuyba, W & Iyeke, I. D. (2021). Bioethanol Production from Municipal Solid Waste: Technical Overview, Progress and Challenges. *International Journal of Energy and Environmental Research.* 9 (3), 1-9. ISSN 2055-0197.

[2] Oya, N.U (2009). Optimization of Bioethanol Production from Kitchen Waste. Thesis, Graduate School of National and Applied science, Middle East Technical University

[3] Karak, T., Bhagat, R. M., & Bhattacharyya, P. (2012) Municipal Solid Waste Generation, Composition and Management: The world Scenario. *Critical Reviews in Environmental Science and Technology, 4215(2), 1509-1630.*

[4] Matsakas, L., Jansson, S., Rova, U., Gao, Q., & Christakopoulos, P. (2017) Green Conversion of Municipal solid Wastes into Fuels and Chemicals, *Electronic Journal of Biotechnology,* 26(4).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

[5] Verhe, R., Varghese, S., Thevelein, J. M., Redant, E., & Declercq G. (2022) Production of Bioethanol from the Organic Waste Fraction of Municipal Solid waste and Refuse-denied Fuel. 2, 224-236.

[6] Li, A & Khraisheh, M. (2008) Rubbish or Resources; An investigation of converting Municipal Solid Waste to Bio ethanol Production. WIT Transaction Biology and Environment 109, ISSN 1743- 3541

[7] Yadeta, N. C., Yessuf, A. M., & Eranna, B. C. (2019). Synthesis and Production of Bioethanol from Waste Paper. *International Journal of Engineering Trends and Technology* 67 (10), 2231- 5381.

[8] Byadgi S. A. & Kalburgi P.B. (2015) Production of Bioethanol from Waste Newspaper. *International Conference on Solid Waste Management,* 35 (2016) 555-562

[9] Efunwoye O. O & Oluwole, O. R. (2019) Bioethanol Production from Pineapple Waste by Solid State Fermentation Method. *Nigerian Journal of Microbiology*, 33 (2) 4811-48201

[10] Hayder, N. H., Flayeh, H. M., & Ahmad, A. W. (2018). Optimization of Bioethanol Production from Biodegradable Municipal Solid Waste Using Response Surface Methodology (RSM). *Journal of Engineering and Sustainable Development.* 22(1), ISSN 2520-0917.

[11] Senila, L., Varaticeanu, C., Roman, M., Miclean, M., & Roman C. (2014) Bioethanol Production from Wood Waste. *Research Institute for Analytical Instrumentation.* 1 (2), 149-154

[12] Feyzolahi, E., Asadabadi, Z. A., & Sharif, R. (2022). Potential Measurement of Bioenergy Production from Urban Waste in Isfahan City. *Journal of Urban Management and Energy Sustainability*. 3 (4), 96-107.

[13] Mgeni, S.T., Mero H.R., Mtashobya, L.A., & Emmanuel J.K. (2024) The Prospect of fruit Waste in Bioethanol Production: A review. *Elsevier LTD.* 2405 – 8440

[14] Manyuchi, M. M., Mbohwa, C., & Muzenda, E. (2018). Bioethanol production from the Landfall Organic Waste Fraction. *Proceedings of the International Conference on Industrial Engineering and Operation Management,* Paris, France, July 26-27.

[15] Lee, S. Y., Sankaran, R. Chew, K. W., Tan, C. H., Krishnamoorthy, D. C. and Show, P. L (2019) Waste to Bioenergy; A Review on the Recent Conversion Technologies. *BMC Energy* 1C4).

[16] Osadebe B., Kubeyinje, B., Maureen, I., Olawale, A., Rita., O. Amrasa, S., Akenzua, O., James, O. Christopher, O., Jonah, A., & Iyeke I.D. (2023) Assessment of bioenergy potential from MSN in urban municipalities of Nigeria. *Advanced Journal of Environment Science and Technology.* 8 (I) 304-309, ISSN 2136- 3468

[17] Bassey, J. B., Odesola, I. F., Osunsade, A. T. (2020).Challenges and Opportunities of Plastic Waste: A Case Study of Akure Metropolis.*International Journal of Scientific & Engineering Research*. ISSN 2229-5518, 11(5),1546-1552.