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Evaluating the Performance of Siam Weed (*Chromolaena odorata*) and Girdlepod (*Mitracarpus Hirtus*) For Bioethanol Production

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Abstract

This study comparatively evaluates the bioethanol production potential of two invasive plant species, *Chromolaena odorata* (Siam weed) and *Mitracarpus hirtus* (Girdlepod), as lignocellulosic feedstocks for renewable energy generation. Biomass samples were pretreated using dilute acid hydrolysis and fermented with *Saccharomyces cerevisiae.* Lignocellulose, FT–IR analyses were employed to determine chemical composition and fuel characteristics. Siam weed exhibited higher cellulose (35%) and lower lignin (15%) than Girdlepod (32% and 16%, respectively), yielding higher reducing sugars (42 mg/g) and ethanol (0.0193g/g). The physicochemical properties, including pH (6.8 ± 0.1), density (0.78 g/cm³), and octane number (108 ± 1.0), met ASTM standards, confirming suitability as biofuel. FT–IR revealed O–H, C–H, and C=O functional groups characteristic of lignocellulosic ethanol. Findings confirm that Siam weed offers superior bioethanol yield and energy potential compared to Girdlepod, demonstrating the feasibility of invasive weeds as sustainable second-generation biofuel feedstocks. The study demonstrates that invasive weeds like *Chromolaena odorata* and *Mitracarpus hirtus* can be transformed from environmental problems into valuable renewable energy resources, offering benefits for energy policy, environmental management, and biofuel industry development.

Keywords: *Chromolaena odorata, Mitracarpus hirtus,* Bioethanol, Invasive species, Lignocellulosic biomass, Renewable energy

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1. Introduction

The global transition toward renewable energy alternatives has accelerated in response to climate change and depleting fossil fuel reserves (IRENA, 2021). Bioethanol has gained attention as a promising biofuel, capable of reducing greenhouse gas emissions and providing a sustainable energy source (Raj, 2024). Lignocellulosic biomass, derived from agricultural residues and invasive plant species, offers an abundant and non-food-based feedstock for bioethanol production and other applications (Prasanthan *et al.,* 2025). In other words, this biomass, derived from agricultural residues (olive pomace, wheat straw and argan shells), is processed by biorefineries into sustainable energy, biochemicals, and eco-friendly materials, thereby effectively reducing the environmental impact and promoting a circular bioeconomy (Ad *et al.,* 2016; Awasthi *et al.,* 2020; Haoufazane *et al.,* 2025; aadil *et al.,* 2026).

Among potential candidates, *Chromolaena odorata* (Siam weed) and *Mitracarpus hirtus* (Girdlepod) are widely distributed invasive weeds in tropical regions. *C. odorata* is recognized for its aggressive growth and ecological disruption but also for its high biomass productivity (Pragati *et al.,* 2025). Studies have demonstrated its suitability for bioethanol conversion through hydrolysis and fermentation (Alwis *et al.,* 2024). *M. hirtus,* although less studied, possesses adaptable growth characteristics on marginal soils, offering potential as an alternative feedstock (Wei *et al.,* 2025).

Converting invasive biomass into biofuels serves dual ecological and energy functions, mitigating environmental damage while generating renewable energy (Pragati *et al* 2025). The present study evaluates and compares the conversion efficiency and fuel characteristics of bioethanol produced from *C. odorata* and *M. hirtus.* These plants are widely distributed across farmlands, roadsides, and disturbed areas in Kebbi State. Their abundance and rapid growth make them suitable biomass resources for bioethanol production. The selection of this geographical area therefore provides an opportunity to explore the potential use of locally available invasive plant species as feedstock for renewable energy production.

2. Materials and Methods

2.1. Sample Collection and Preparation

Fresh *C. odorata* and *M. hirtus* specimens were collected from Gesse Campus, Birnin Kebbi, Kebbi State, Nigeria, authenticated at Abdullahi Fodio University Herbarium (voucher nos. AFUSTA/PSB/H/1134 and AFUSTA/PSB/H/1135). Samples were cleaned, air-dried, and milled to 0.5mm particle sizes for both samples.

2.2. Chemical composition (lignocellulose)

Lignocellulose fractions were quantified using NaOH extraction (hemicellulose), H_2SO_4 hydrolysis (lignin), and residue mass for cellulose (Sluiter, 2025).

2.3. Pretreatment and Hydrolysis

Biomass (10 g) was pretreated with 1% H_2SO_4 at 120 °C for 2 h on hot plate, the filtered washed to neutral pH, and hydrolyzed with 1% H_2SO_4 at 121 °C for 60 min in an autoclave (Raj, 2024). The hydrolysate was neutralized with $Ca(OH)_2$ and analyzed for reducing sugars using the DNSA method (Moron *et al.,* 2025).

2.4. Fermentation

The fermentation process was carried out using the *Saccharomyces cerevisiae*, a widely utilized microorganism in bioethanol production due to its high fermentative capacity, rapid growth rate, and tolerance to relatively high ethanol concentrations. The yeast was activated in a nutrient medium to ensure optimal metabolic activity and viability, 10% of the activated yeast culture of *S. cerevisiae* were inoculated into the hydrolysate derived from *Chromolaena odorata* and *Mitracarpus hirtus* in YPD broth and incubated at 30 °C for 72 h under anaerobic conditions. Ethanol yield was quantified by using the equation below:

$$Bioethanol\ yeild = \left(\frac{mass\ of\ distillate}{sample\ weight}\right) \times 100$$

2.5. Physicochemical and Fuel Property Analysis

Density, viscosity, pH, pour and flash points, and octane rating were measured following ASTM standards (D97, D93). Molecular confirmation was performed using FT–IR spectroscopy.

3. Results

3.1. Chemical Composition

Siam weed contained 35% cellulose, 25% hemicellulose, and 15% lignin; Girdlepod contained 32%, 28%, and 16%, respectively. Siam weed exhibited slightly higher cellulose content and lower lignin, favoring enzymatic hydrolysis.

3.2. Sugar and Ethanol Yields

The result in (**Table 1**) show, Siam weed recorded higher reducing sugar yield (42.0 ± 0.3 mg/g) and ethanol yield (1.93 ± 0.3%) than Girdlepod (36.5 ± 0.3 mg/g; 1.68 ± 0.03%, at $p < 0.05$). Data obtained from the experiments were analyzed using descriptive statistics such as mean and standard deviation. Inferential statistical analysis was performed using Student's t-test to determine significant differences between bioethanol yields from *Chromolaena odorata* and *Mitracarpus hirtus* at a significance level of $p < 0.05$.

Table 1: presents reducing sugar yield and ethanol yield from Siam weed and Girdlepod (Mean ± SD, n = 3)

Sample	Sugar Yield (mg/g)	Ethanol Yield (g/g)
C. odorata (Siam weed)	42.0 ± 0.3	0.0193 ± 0.0003
M. hirtus (Girdlepod)	36.5 ± 0.3	0.0168 ± 0.0003

Values are presented as mean ± standard deviation (n = 3).

3.3. Physico-chemical Fuel Properties

Experimental data were analyzed using descriptive statistics, including the mean and standard deviation. Inferential statistical analysis was conducted using Student's t-test to assess significant differences in bioethanol yields between Chromolaena odorata and Mitracarpus hirtus at a significance level of $p < 0.05$. The results in (**Table 2**) indicates that the ethanol produced from Siam weed and Girdlepod was a colorless liquid with an acceptable pH (6.5–6.8). Density (0.78 g/cm³, Siam weed; 0.765 g/cm³, Girdlepod) and viscosity (5.6–5.4 mm²/s) met ASTM standards. Both Siam weed and Girdlepod ethanol displayed an octane rating of 108 RON, which is within the acceptable ASTM standard range of 108–109 RON. Siam weed showed a lower pour point (−121 °C) than Girdlepod (−116 °C), indicating better combustion and cold-flow performance. The higher pour point of bioethanol from Girdlepod is mainly due to differences in biomass composition, residual compounds after fermentation and distillation, and possible variations in ethanol purity compared with Siam.

Table 2: presents the results of the physico-chemical and fuel properties analysis of bioethanol produced from Siam weed and Girdlepod.

(Mean ± SD, n = 3)

Parameters	Siam weed (Mean ±SD)	Girdlepod (Mean ±SD)	ASTM standard
Color	-	-	-
P^{H}	6.8 ± 0.1	6.5 ± 0.1	6.5–9.0
Density (g/cm³)	0.780 ± 0.002	0.765 ± 0.001	0.750-850
Specific Gravity	0.88 ± 0.01	0.90 ± 0.01	0.87
Viscosity (mm²/s)	5.6 ± 0.1	5.4 ± 0.1	5.0
Flash Point (°C)	18.95 ± 0.05	19.81 ± 0.01	18.6
Pour point(^{0}C)	-121 ± 1.0	-116 ± 1.0	5.2
Octane rating	108 ± 1.0	108 ± 1.0	108-109

Values are presented as mean ± standard deviation (n = 3).

3.4. FT–IR Characterization

Fig 1 shows the FT–IR spectra indicating the presence of O–H (3331 cm^{-1}), C–H (2980 cm^{-1}), and C=O (1631 cm^{-1}) stretching vibrations consistent with lignocellulose ethanol for both Siam weed and Girdlepod.

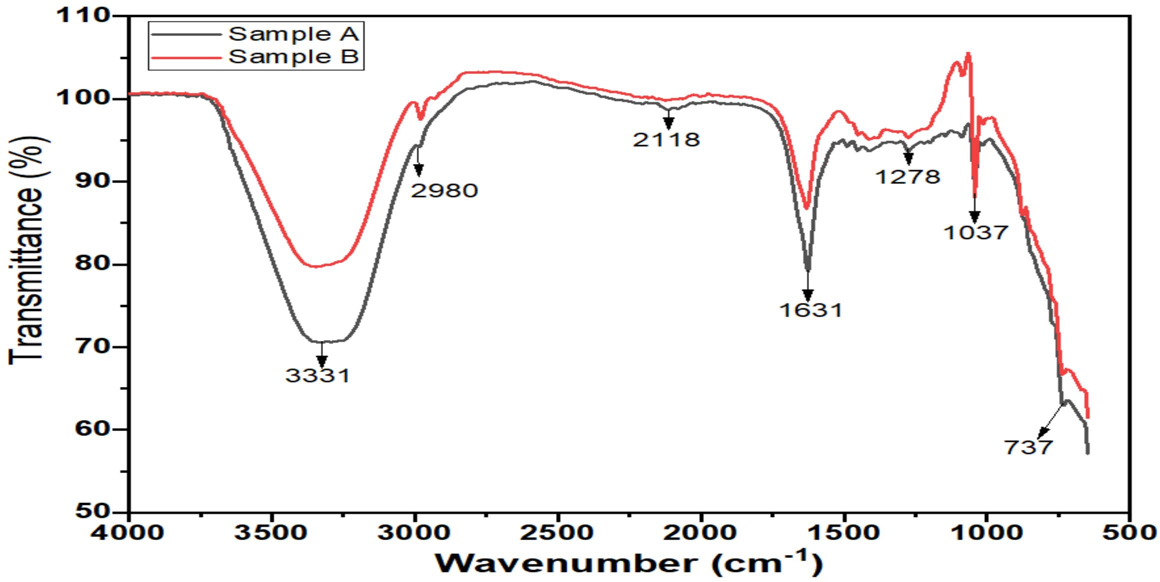

Fig 1. Shows the functional group presents from the Siam weed and Girdlepod.

4. Discussion

Siam weed's higher cellulose and lower lignin content facilitated greater hydrolysis and fermentation efficiency compared to Girdlepod. This aligns with previous findings that cellulose-rich invasive weeds yield significant fermentable sugars (Li *et al.,* 2024). The ethanol yields (1.7–1.9%) were comparable to those obtained from *Eichhornia crassipes* and *Lantana camara* in similar studies.

Fuel properties such as density, octane, and viscosity indicate that the produced ethanol complies with ASTM standards, ensuring compatibility with gasoline engines (Hoekman *et al.,* 2012). FT–IR data further confirmed the transformation of polysaccharides into bioethanol. These results collectively demonstrate that *C. odorata* not only serves as an efficient energy crop substitute but also contributes to ecological management. Siam weed performed better due to higher cellulose content, improved sugar release during hydrolysis, reduced lignin interference, and improved fermentation efficiency, which together enhance its bioethanol production potential compared to Girdlepod.

First-generation bioethanol is primarily produced from food crops rich in starch or sugar, particularly corn and sugarcane. These crops generally yield more ethanol because their carbohydrates are more readily fermentable than lignocellulosic biomass.

Sugarcane is considered one of the most efficient bioethanol feedstocks, producing approximately 6000–7000 liters of ethanol per hectare, while corn produces about 3500–4000 liters per hectare under optimal conditions (Niu *et al*., 2024; Yang *et al.,* 2024). In contrast, invasive plants such as *Chromolaena odorata* and *Mitracarpus hirtus* belong to second-generation bioethanol feedstocks. These plants contain lignocellulose biomass composed of cellulose, hemicellulose, and lignin. Although lignocellulose materials require additional pretreatment and hydrolysis steps before fermentation, they offer significant advantages because they do not compete with food production and are often abundant as waste or invasive species. Despite generally lower ethanol yields compared with first-generation crops, Siam weed demonstrated relatively higher conversion efficiency than Girdlepod due to its higher cellulose content and improved fermentable sugar release during hydrolysis. The utilization of such invasive weeds for bioethanol production provides an environmentally sustainable alternative by transforming unwanted vegetation into renewable energy resources.

Furthermore, the use of non-food biomass such as *Chromolaena odorata* and *Mitracarpus hirtus* aligns with global efforts to develop second-generation biofuels, which aim to reduce reliance on food-based feedstocks while promoting sustainable energy systems (Prasanthan *et al.,* 2025). Invasive weeds provide a promising low-cost biomass source for second-generation bioethanol, their commercial deployment faces challenges related to pretreatment cost, enzyme expenses, supply chain logistics, and technological scalability. Addressing these issues through technological innovation and supportive policies will be essential for their successful industrial implementation.

Conclusion

This study demonstrates that both *Chromolaena odorata* and *Mitracarpus hirtus* can serve as viable lignocellulose feedstocks for second-generation bioethanol production. Siam weed exhibited superior yields of fermentable sugar, ethanol output, and fuel quality, making it a more promising candidate. Utilizing invasive biomass for biofuel production aligns with circular economy principles, achieving both renewable energy generation and invasive species control. Future research should explore process optimization and advanced pretreatment technologies to improve the conversion efficiency of lignocellulose biomass from *Chromolaena odorata* and *Mitracarpus hirtus*. Investigating the use of improved microbial strains, genetic engineering of fermentation organisms, and integrated biorefinery approaches could enhance ethanol yield and reduce production costs. In addition, life-cycle assessment (LCA) and techno-economic analysis should be conducted to evaluate the environmental sustainability and commercial viability of large-scale bioethanol production from these invasive plant species.

Recommendations

- Scale-up experiments to pilot and industrial levels are needed to validate these findings.
- Optimize pretreatment and fermentation parameters to enhance ethanol yield and purity.

- Integrate invasive weed exploitation into national bioenergy and weed management policies.
- Employ advanced analytical methods (HPLC, NMR) for purity verification and process optimization.
- Conduct engine performance testing of ethanol-gasoline blends for practical application studies.

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