International Journal on Emerging Technologies 17(1): 27-31(2026)

ISSN No. (Print): 0975-8364
ISSN No. (Online): 2249-3255

Production of Bio-Ethenol from Banana Peels

R.N. Singh, Shilpi Yadav, Bobby Singare and K.P. Tiwari*
School of Energy and Environment Studies,
Devi Ahilya Vishwavidyalaya, Takshashila Campus, Khandwa Road, Indore (Madhya Pradesh), India.

(Corresponding author: K.P. Tiwari)*
(Received 03 November, 2025; Accepted 10 January, 2026, Published: 07 February, 2026)
(Published by Research Trend, Website: www.researchtrend.net)

DOI: https://doi.org/10.65041/IJET.2026.17.1.3

ABSTRACT: With increasing concerns over fossil fuel depletion & environmental sustainability, the exploration of agriculture residues for bio fuel production has gain significant attention. The growing demand for sustainable & renewable energy source has led to the exploration of biomass waste for bio-ethanol production. This study focuses on banana peel biomass waste which is abundant & underutilized biomass as a sustainable feed stock. For bio-ethanol production specifically from banana peels has very good potential to produce bio-ethanol via anaerobic fermentation which is rich in lignocellulosic content. Ethanol production ratio was prepared in 5:3:2 with banana peels slurry, fermentation media & yeast suspension respectively. The fermentation was conducted under anaerobic condition at room temperature (25°C). Latter fermentation distillation process was carried out at 78°C to collect pure ethanol. From 14.7kg banana peels mixture (banana peels + fermentation Media + yeast suspension) about 1 L bio-ethanol could be produced. This research focused on the potential of banana peels waste as an efficient low-cost feed stock for bio fuel generation, offering a promising route for waste utilization & renewable energy production. Utilization such agro waste not only reduce environment burden but also contributes to renewal energy goal by converting waste into valuable fuel.

Keywords: Banana peels, Anaerobic Fermentation, Agro-Waste Utilization, Renewable Energy, Bio-Ethanol.

INTRODUCTION

The rising global demand for energy, coupled with concerns over depleting fossil fuel reserves and environmental degradation, has accelerated the search for renewable and sustainable fuel sources. Among various biofuels, bioethanol has gained significant attention due to its ability to serve as a clean-burning, renewable alternative to conventional fuels in transportation and industry (Ackom *et al*., 2013; FAO 2021; Osman *et al.*, 2024). Traditional bioethanol production relies heavily on food crops like sugarcane and corn; however, there is growing interest in utilizing non-food agricultural residues and waste materials to avoid the food- versus-fuel conflict (Paminto *et al.*, 2024; Pattnaik *et al*., 2024).

In many tropical countries like India have major banana peel fruit waste, which represents a significant substrate for renewable energy like bioethanol production. The banana peel waste are rich in sugar, cellulose and starch making an efficient source for ethanol production by fermentation (Gaur *et al.*, 2025; Oyeleke and Jiblin 2009).

In the whole world India is the greatest banana producing country, generating lot of waste from banana peels which is dumped in landfill or turned into less value compost. Annually, approximately 36.6 million tons of banana are produced in India, yielding banana peels around 13.4 million tons (Devi *et al*., 2025). On the other hand creating environmental consequences like emissions of greenhouse gases, climate change and waste disposal etc. To overcome these problem many researchers converting this banana peel waste into renewable bioethanol energy which is help to achieve SDG 13 by 2030 (Singh and Tiwari 2024). In this work bioethanol production was done by banana peel as a raw material by using microbial fermentation. This practice draws attention to produce cheap, sustainable and valuable biofuel from waste providing various advantages and applications (Rai *et al.*, 2022; Singare and Singh 2025a).

A. Literature Review

As per the literature reviewed production of bioethanol from agriculture lignocellulosic biomass like rice straw, corn stover and sugarcane bagasse are efficient raw materials. Studies emphasized that these raw material having high content of cellulose and hemicellulose (Singh and Yadav 2020). For the maximum yielding of bioethanol it is essential to carried out pretreatment step of lignocellulosic materials for improving enzyme accessibility to cellulose (Singare and Singh 2025b). In tropical nations having higher widespread availability of banana peel waste as a source of renewable biomass. In the fruit of banana pseudo stem contains a significant amount of cellulose and fermentable sugars.

Halimi *et al.* (2025) illustrated that under favorable conditions banana stem juice could be effectively fermented by using yeast to yield bioethanol.

According to Rai *et al.* (2019) Ethanol production by Saccharomyces cervisiae for the saccharification and fermentation of banana peel residues around 7.2 % (v/v) yield of ethanol after 5 days fermentation. This result confirmed the viability of using banana peel waste to produce ethanol. Although this process is dependent on such key factors like pretreatment technique, relevant type of microorganism, fermentation condition and procedures of detoxification.

Although, various challenges occurs like banana stems having high moisture content, pretreatment process and optimization of parameters limits the large scale application (Huang, 2024). More research is required to enhance conversion efficiency and lower production costs, with recent studies emphasizing sustainable pathways for large-scale deployment (Balat and Balat 2009; Bharadwaj, 2013).

MATERIALS AND METHODS

A. Collection and Preparation of Raw Material

Approximately 1.5 kg, waste banana fruits were collected from the local market of Indore, Madhya Pradesh. The selection focused on overripeor discarded bananas to ensurethe use of agro-waste for sustainable bio-resource utilization. From the collected bananas, banana peels were separated carefully. About 330 grams of fresh banana peels were used as the primary raw material for further processing. The peels were thoroughly washed with clean water to remove any dirt, soil, or surface contaminants. To improve process efficiency, the hard root portion attached to the peel was removed using a gentle steam treatment. This step ensured that only the soft and fermentable portion of the peel was retained for further experimentation. Care was taken not to mix the root part with the rest of the material to maintain consistency and accuracy in the results. The weight of the final processed material was measured using an electronic weighing balance (Capacity 310 grams and least count 1 mg) to ensure precision in all further experimental steps.

B. Estimation of Physical Characteristic of Banana Peel

These are some of the physical characteristics of banana peel, which is what produces bio-ethanol. For cellulose and semi-cellulose, it was calculated using the techniques recommended by IEA (2024); Nigam and Singh (2011).

C. Preparation of Fermentation Media for Bio-Ethanol Production from Banana Peels

Appropriate fermentation is necessary to turn waste banana peels into bio-ethanol. The biological process of fermentation occurs when microorganisms, usually yeasts, break down organic materials in anaerobic environments (FAO, 2021).

For efficient fermentation required a desirable fermentation medium which may help to promote growth of yeast and metabolic activity. To create a balanced environment, two kind of media are helpful one is yeast media and another one is growth media (Bhardwaj, 2013). By using the combination of both media in equally 50: 50 ratio that enhances both yeast growth and bioethanol production efficiency (Halimi *et al.,* 2025).

(i) **Growth Media.** The growth media provides the essential nutrients required for the general development and multiplication of microorganisms. The components of the growth medium include 2 g of glucose (serves as a primary carbon and energy source), 2 g of peptone (supplies nitrogen, vitamins, and other growth factors) and 1 g of yeast extract (adds essential nutrients and improves the growth rate of the yeast culture) (Gaur *et al.*, 2025).

(ii) **Yeast Media.** Yeast media specifically supports the development and metabolic functions of yeast strains that are used in the fermentation process. The composition of the yeast medium is as follows 0.5 g of urea (serves as an additional nitrogen source), 0.1 g Magnesium Sulfate ($MgSO_4$) (provides magnesium ions that are essential for enzyme activity), 2 g glucose (acts as a fermentable sugar) and 0.2 g Potassium dihydrogen phosphate (KH_2PO_4) (acts as a buffering agent and supplies phosphate ions) (Oyeleke and Jiblin 2009).

(iii) **Preparation Steps.** All the components of both media were accurately weighed using an electronic weighing balance. Components were mixed thoroughly with an appropriate volume of distilled water to dissolve them completely (Van *et al.,* 1991; Paminto *et al.,* 2024). Later prepared media was transfer into a conical flask. Mouth of the flask was covered with aluminum foil to prevent contamination from airborne bacteria and viruses.

D. Preparation of Banana Peels Slurry

To begin the preparation of banana peels slurry, approximately 330 grams of banana peels were taken. These peels were carefully weighed to ensure accuracy in the process. After weighing, the banana peels were thoroughly ground to convert into a fine paste using a grinder (Fig. 1). In order to facilitate effective fermentation, this step increases the surface area. For the effective fermentation slurry was stand to settled and kept to dry for 2-3 hr that process helped to eliminate excess moisture content. After this put slurry into a sterile conical flask for proper mixing of slurry and fermentation process. The slurry containing flask was kept in a room temperature. However, the suitable temperature for the fermentation required 25-30^{o}C.

Lastly, a yeast suspension was made. It is essential for starting the fermentation process. For the preparation of yeast suspension following reagents are required *i.e.* 5gm glucose, 2gm peptone and 1gm dry yeast, which are a source of sugar, supply nitrogen and acts as a fermenting agent respectively.

Fig. 1. Grinded banana peels (fermentation process).

(i) Fermentation Test. A small amount of lukewarm distilled water is used to thoroughly mix all of these ingredients. To guarantee that every component dissolves fully and forms an even suspension, the mixture is thoroughly stirred. The slurry, fermentation medium, and freshly made yeast suspension are then combined in the conical flask. It is essential that the yeast works efficiently throughout the slurry with all ingradients (Fig. 2). During fermentation process after making slurry, the slurry containing conical flask was securely covered with aluminum foil to prevent from contamination. The flask is then kept undisturbed at room temperature for a period of 48 hours, allowing complete fermentation to take place. At the end of the process sample convert sugar into ethanol and other by product.

Fig. 2. Mixture of freshly prepared yeast suspension.

For the confirmation of successfully completed of fermentation process, a few observation were made. Initially absent of air bubbles specially bubbles of CO_2 in the slurry represents the yeast activity has showed down or stopped, suggesting the end of the active fermentation. The production of gases has ceased when no bubbles are rising to surface. In addition, changed nature of slurry was also noted. Which is another major sign of fermentation has taken place. This change in acidity, verified by pH meter, which typically drops to around pH 6 (Devi *et al.*, 2025; Halimi *et al.*, 2025). A mild but distinct fermented smell may also be present, which is characteristic of microbial activity and the breakdown of organic matter. Once these signs are observed, the fermented slurry is considered ready for further processing (Fig. 2). The slurry is then sieved using filters or mesh of different sizes usually 2 to 3 times—to separate the liquid portion from the solid waste materials. This helps in refining the fermented product and removing any coarse particles or undigested residues (Fig. 3). The leftover solid waste, often referred to as residual biomass, is not discarded. Instead, it is collected and utilized for composting. This organic waste, rich in nutrients, is added to compost pits or composting systems where it decomposes further. Over time, it transforms into a valuable organic fertilizer or compost, which can be used to enrich soil in agricultural fields or home gardens.

RESULTS AND DISCUSSION

The present study explores the feasibility of producing bio-ethanol from ripe banana peels through a simple, lab-scale fermentation and distillation process. About 600 grams banana peel biomass slurry was prepared and used as the feedstock.

Fig. 3. By product.

A. Physical and Thermal Characteristics

The physical and thermal characteristics of banana peel are presented in Table 1. These properties provide essential information about its composition and suitability for further processing and applications.

Table 1: Physical and Thermal Characteristic of Banana Peel.

Sr. No.	Properties, %	Values
1.	Moisture	92.04%
2.	Total Solid	7.95%
3.	Ash Content	14.15%
4.	Volatile Solid	85.85%
5.	Cellulose	15.32%
6.	Hemi – Cellulose	14.36%

B. Observations during Fermentation

The biomass slurry was subjected to natural fermentation for 48 hours at room temperature without the addition of any external microorganisms. The fermentation relied on naturally occurring microbial flora present in the banana peel. Over the course of fermentation, a distinct acidic smell developed, and pH dropped, indicating microbial activity and the formation of organic acids and ethanol.

C. Bio-Ethanol Yield

Post fermentation, Fig. 4 the slurry was subjected to distillation at 78°C, which is the boiling point of ethanol. This process resulted in the collection of approximately 45mL of crude bio- ethanol from 660 grams of biomass slurry. The final product had a characteristic alcoholic odor and clear appearance.

This process's ethanol yield efficiency can be computed as follows: Yield = 45 mL/660 g = 0.068, mL/g.

According to Fig. 5, this indicates a yield of roughly 68 mL of ethanol per kilogram of biomass from banana peels. As compared to commercial methods this yield showed banana peel played crucial role as a fermentable substrate for producing bioethanol in low cost and small scale.

Fig. 4. Distillation Process.

The result indicated that banana peel having high sugar and starch content that property playing using substrate for the production of bioethanol. Hence there was microbial free procedure happened which made simple, affordable and low cost procedure to produce ethanol. According to literature review, when pH decreases naturally during fermentation it means sugars are broken down by microorganisms into ethanol and organic acids (Balat and Balaty 2009; Osman *et al.*, 2024). For maximum yield, before fermentation optimized each essential factors such as pH, inoculation with yeast strain like enzymatic hydrolysis. Through the distillation procedure at 78°C bioethanol was produced by the successful fermentation of sugars into bioethanol. Finally study revealed that ripe banana peel is useful and accessible substrate of bioethanol.

Natural fermentation and distillation were used to produce 45 mL of ethanol from 660 g of banana biomass slurry.

Fig. 5. Final Bio-ethanol.

In other words, 1 kg ripe banana peels can yield about 68.18 mL Bio-ethanol. The process was conducted at room temperature without any special microorganisms, highlighting its cost-effectiveness and simplicity. Although the ethanol yield is lower than that achieved in industrial settings, however this study lays the foundation for low-cost, small-scale biofuel production, especially in rural or resource-limited environments. Improvements in pretreatment methods, use of yeast strains, and optimization of fermentation parameters may further enhance yield and efficiency.

Physical and thermal properties of banana peels bio-ethanol was compared with standard ethanol available in the markets. Details are summarized in Table 2.

Table 2: Physical and thermal properties of banana peels and its Bio-ethanol.

Sr. No.	Parameters	Banana Peels Bio-ethanol	Standard Ethanol*
1.	Purity	90.40%	100%
2.	Moisture Content	35.60	-
3.	Density	0.76g/ml (at 25°C)	9.789g/ml (at 25°C)
4.	p^{H}	6.90	6.8
5.	Boiling Point	78.5	78°C
6.	CalorificValue	27.68 MJ/kg	29.60 MJ/kg

Source*: Singh and Yadav (2020)

CONCLUSIONS

Following conclusion could be drawn from the study.

1. Banana peel could be used asa raw material for Bio-ethanol Industry.
2. About 68 mL bio-ethanol yield could be obtained from per kg of ripped Banana peel.
3. India harvests 36.5 million tones ripped banana, from which about 13.4 million tones Banana peels are available every year and it have the capability to yield about 231, 200 m^3 of Bio-ethanol.

REFERENCES

Ackom, E., Mabee, W. & Saddler, J. (2013). Progress in the development of biofuels in industrialised countries and the need for developing country involvement. *Energy Policy, 52*, 85–97.

Balat, M. & Balat, H. (2009). Recent trends in global production and utilization of bio-ethanol fuel. *Applied Energy, 86*(11), 2273–2282.

Bharadwaj, A. K. (2013). Waste to energy: An overview on technologies and policy in India. *Energy Policy, 39*(10), 6196–6206.

Devi, R. P., Vijayakumary, P., Murugananthi, D., Sangeetha, S. M., Karthikeyan, S. & Ramesh, D. (2025). A review on renewable energy sources for production of bioethanol. *Plant Science Today, 12*(sp1).

Food and Agriculture Organization of the United Nations (2021). *FAOSTAT statistical database*. http://www.fao.org/faostat/

Gaur, R. K., Goyal, R., Srivastava, A., AlGhamias, N. A., Alablani, B. A. & Alam, M. M. (2025). Optimization of biodiesel production from mixed waste cooking and pongamia oils using the entropy-VIKOR method. *Discover Applied Sciences, 7*, 727.

Halimi, N. A. N., Odunsi, A., Sebastiani, A. & Kamel, D. (2025). Waste to biofuel: Process design and optimisation for sustainable aviation fuel production from corn stover. *Energies, 18*(13), 3418. https://doi.org/10.3390/en18133418

Huang, W. Z. (2024). Agricultural sources of biofuels: Selection and optimization of energy crops. *Journal of Energy Bioscience, 15*(2), 108–117.

International Energy Agency (2024). *IEA renewables 2023: Biofuel and biogas forecasts*. https://www.ieabioenergy.com/blog/publications/iea-renewables-2023-biofuel-and-biogas-forecasts

Nigam, P. S. & Singh, A. (2011). Production of liquid biofuels from renewable resources. *Progress in Energy and Combustion Science, 37*(1), 52–68. https://doi.org/10.1016/j.pecs.2010.01.003

Osman, A. I., Nasr, M., Farghali, M., Rashwan, A. K., Abdelkader, A., Al-Muhtaseb, A. A. H. & Rooney, D. W. (2024). Optimizing biodiesel production from waste with computational chemistry, machine learning and policy insights: a review. *Environmental Chemistry Letters, 22*(3), 1005-1071.

Oyeleke, S. B. & Jiblin, N. M. (2009). Production of bioethanol from guinea corn husk and millet husk. *African Journal of Microbiology Research, 3*(4), 147–152.

Paminto, A. K., Karuniasa, M. & Frimawaty, E. (2024). Optimization of palm oil biodiesel production: Environmental impact analysis and POME waste utilization. *Applied Environmental Science, 2*(1), 15–30.

Pattnaik, F., Patra, B. R., Nanda, S., Mohanty, M. K., Dalai, A. K. & Rawat, J. (2024). Drivers and barriers in the production and utilization of second-generation bioethanol in India. *Recycling, 9*(1), 19.

Rai, A. K., Al Makishah, N. H., Wen, Z., Gupta, G., Pandit, S. & Prasad, R. (2022). Recent developments in lignocellulosic biofuels, a renewable source of bioenergy. *Fermentation, 8*(4), 161. https://doi.org/10.3390/fermentation8040161

Rai, R. K., Tiwari, A. & Singh, R. N. (2019). Optimization of media components for bioethanol production using agro-waste substrates. *Bioresource Technology Reports, 6*, 243–249.

Singare, B. & Singh, R. N. (2025a). Key determinants of algal biomass growth for bioenergy: A comprehensive review. *Current World Environment, 20*(1), 53–64. https://doi.org/10.12944/CWE.20.1.5

Singare, B., & Singh, R. N. (2025b). Optimal growth strategies for sustainable cultivation of *Chlorella vulgaris* microalgae for the application of bioenergy: A review. *The Nucleus, 62*(2), 76–82. https://doi.org/10.71330/thenucleus.2025.1485

Singh, R. N. & Tiwari, K. P. (2024). Evaluation of straight karanja oil (*Pongamia pinnata*) as a compatible fuel for compression ignition engines. *The Nucleus, 61*(2), 108–116. https://doi.org/10.71330/thenucleus.61.1394

Singh, R. N. & Yadav, S. (2020). Optimization of operational parameters for production of bio-ethanol from soybean straw. *International Journal of Scientific Research in Multidisciplinary Studies, 6*(2), 66–70.

Van Soest, P. J., Robertson, J. B. & Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science, 74*(10), 3583–3597.

How to cite this article: R.N. Singh, Shilpi Yadav, Bobby Singare and K.P. Tiwari (2026). Production of Bio-Ethenol from Banana Peels. *International Journal on Emerging Technologies, 17*(1): 27–31.