International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 12 Issue: 12 | Dec 2025 www.irjet.net p-ISSN: 2395-0072

"Techno-Economic Study on Jatropha Oil as Binder and Energy Booster in Biomass Pellets"

Mr. Sandeep Supalkar , [1]Santosh k.pandit,[2]Jay V. Gechand, [3]Pranit R.Manchekar,[4]Aditya D.Gaikwad

Diploma students Department of Mechanical Engineering, Thakur Polytechnic Kandivali (East), Maharashtra, India.

Abstract-*The growing demand for sustainable and renewable energy has increased the importance of biomass- based fuels. Biomass pellets are an efficient form of biofuel made from agricultural and organic residues, providing an eco-friendly alternative to conventional fossil fuels. However, the calorific value (CV) and durability of raw biomass pellets are often limited due to their high moisture content and weak binding strength.*

This study focuses on a techno-economic analysis of using Jat ropha oil as a binder and energy booster in biomass pellets. Jatropha oil, being rich in carbon and having good flammable properties, enhances the calorific value and mechanical strength of the pellets. Experimental trials were conducted by blending controlled quantities of Jatropha oil with biomass feedstock, followed by densification under optimal pressure and temperature.

The results indicated a significant improvement in pellet density, durability, and calorific value compared to untreated biomass pellets. The study concludes that Jatropha oil is a promising additive for improving both the energy and economic efficiency of biomass pellets, making them more suitable for clean and sustainable energy generation.

Keywords: Biomass Pellets, Jatropha Oil, Calorific Value, Biofuel, Techno-Economic Study, Renewable Energy.

I. INTRODUCTION

In recent years, the demand for renewable and sustainable sources of energy has significantly increased due to the depletion of fossil fuels and rising environmental concerns. Biomass has emerged as one of the most promising renewable energy resources because it is abundantly available, carbon-neutral, and capable of being replenished within a relatively short period compared to conventional fossil fuels. The utilization of biomass for energy generation not only helps reduce dependency on non-renewable fuels but also contributes to lowering greenhouse gas emission Biomass pellets are a compact, dandified form of biofuel produced from agricultural residues, forestry waste, and organic materials. These pellets offer several advantages such as ease of handling, transportation, uniform size, and higher energy density. However, the natural limitations of raw biomass—such as high moisture content, low calorific value, and poor binding strength—restrict its widespread application for efficient energy generation.

To overcome these challenges, various methods have been explored to enhance the calorific value (CV) and mechanical properties of biomass pellets. In this study, Jatropha oil has been selected as a binder and energy booster due to its high carbon content, good flammability, and natural adhesive properties. The integration of Jatropha oil into biomass pellets improves the binding strength, reduces moisture absorption, and increases the calorific value, making the pellets more efficient for thermal applications.

II. Literature Review

The use of biomass as a renewable source of energy has gained significant attention over the past two decades due to its potential to replace fossil fuels and reduce carbon emissions. Several researchers have explored different methods to improve the calorific value, density, and durability of biomass pellets and briquettes.

1. Biomass as an Energy Source:

According to various studies, biomass such as rice husk, sawdust, sugarcane bagasse, and cow dung can be effectively used for pillarization. However, the calorific value and mechanical strength of these pellets depend on the type of binder used and the moisture content during production.

2. Role of Binders:

Researchers like Sharma et al. (2018) and Kumar et al. (2020) have reported that adding natural binders such as starch, molasses, and vegetable oils significantly improves the compactness and combustion properties of briquettes. The binder not only holds the particles together but also enhances ignition and burning characteristics.

3. Jatropha Oil as a Binder:

Jatropha oil, a non-edible vegetable oil, has been studied for its excellent adhesive and high-energy properties. Studies by Patel and Singh (2021) revealed that blending a small percentage of Jatropha oil (around 5–10%) in biomass briquettes improved the calorific value by 15–20% and reduced the breakage during handling. Its high carbon and hydrogen content make it a potential energy booster and eco-friendly binder alternative to synthetic resins.

4. Economic and Environmental Studies: Research by Ravindra etal.(2019) emphasized the techno-economic feasibility of using agricultural residues with natural binders, showing lower production costs and higher sustainability. Using Jatropha oil also promotes the use of locally available, renewable materials, supporting rural industries and reducing dependence on fossil fuels.

5. Research Gaps:

Although many studies focus on biomass briquetting, limited work has been done on combining Jatropha oil as both a binder and energy enhancer. Therefore, the present study aims to bridge this gap by analyzing its techno-economic potential in biomass pellet production.

III. Material Selection

Selecting appropriate materials is one of the most important steps in biomass pellet production.
The materials are chosen based on factors such as availability, cost-effectiveness, environmental compatibility, and fuel efficiency. In this project, two major categories of materials are selected —

(1) Biomass raw material and (2) Binder and energy booster.

1. Biomass Raw Material

The primary biomass materials used in this project are rice husk, sawdust, and sugarcane bagasse.
These materials are easily available in rural and industrial areas and are relatively low-cost.

Characteristics of selected biomass materials:

1. They are renewable and environmentally friendly sources of energy.
2. They produce lower emissions compared to fossil fuels.
3. Their calorific value generally ranges between 3000–4000 kcal/kg.
4. Due to their low density, pelletization (densification) is required to enhance handling and combustion efficiency

2 Binder and Energy Booster

In this study, Jatropha oil is used as both a binder and an energy booster.
Jatropha oil is a non-edible vegetable oil obtained from the seeds of the Jatropha curcas plant.
It has been selected due to its high flammability and strong adhesive properties, which improve both the strength and energy content of the pellets

Key properties of Jatropha oil:

1. Contains a high percentage of carbon and hydrogen, making it an excellent energy source.
2. Acts as a natural adhesive, improving the mechanical strength and durability of the pellets.

3. When mixed in the proportion of 5–10% by weight, it increases the calorific value of the biomass pellets significantly.
4. It is a renewable, biodegradable, and eco-friendly alternative to chemical binders.

IV.METHODOLOGY

This section describes the systematic procedure adopted for preparing and testing biomass pellets using Jatropha oil as a binder and energy enhancer. The aim was to evaluate the performance improvement in terms of calorific value, mechanical strength, and combustion efficiency

1. Raw Material Preparation

Biomass residues such as rice husk, sawdust, and sugarcane bagasse were collected from local industries. These materials were sun-dried for 24–48 hours to reduce the moisture content below 10%. The dried biomass was then ground into fine powder (less than 2 mm size) to ensure uniform mixing and better pillarization.

2. Blending with Jatropha Oil

Different samples were prepared by mixing Jatropha oil in varying proportions (0%, 5%, 10%, and 15% by weight) with the powdered biomass. The mixture was manually stirred until the oil was evenly distributed. Jatropha oil acted as both a binder—increasing the compactness of pellets—and an energy booster, enhancing the overall calorific value.

3. Pelletization Process

The prepared mixture was fed into a pelletizing machine, where it was compressed under high pressure (200–300 bar) without using any external heating source. The produced cylindrical pellets had an average diameter of 6–8 mm and a length of 20–30 mm. After pelletization, pellets were cooled and air-dried to ensure dimensional stability.

4. Testing and Characterization

The prepared pellets were tested for various physical and thermal properties:

1. **Calorific Value (CV):** Measured using a bomb calorimeter to determine heat content.
2. **Density:** Evaluated to check the compactness and strength of pellets.

5 Performance Evaluation

The performance of each pellet sample was compared based on its calorific value and strength. Results indicated that the 10% Jatropha oil blend produced the most efficient pellets with higher energy output and improved durability compared to other samples.

6 Combustion Performance Study

Combustion characteristics of the produced pellets were analyzed under controlled burning conditions. The Jatropha oil–mixed pellets exhibited smooth ignition, stable flame, and uniform heat release throughout the combustion process. The ignition time was shorter, and smoke generation was significantly reduced compared to untreated biomass pellets. These findings confirm that the inclusion of Jatropha oil not only enhances the calorific value but also improves combustion stability and environmental performance, making the pellets suitable for sustainable energy generation.

7. Summary

The methodology demonstrates that the controlled addition of Jatropha oil effectively enhances both the physical and thermal characteristics of biomass pellets. This approach offers a low-cost, eco- friendly and scalable solution for clean energy production.

Fig. 1 Prepared Biomass Pellets with Jatropha Oil Binder

Fig. 1 shows the biomass pellets prepared by mixing raw biomass with a controlled percentage of Jatropha oil, followed by pelletization under high pressure.

3. **Moisture Content:** Determined by oven-drying method to ensure dryness.
4. **Ash Content:** Measured after combustion to assess combustion cleanliness.
5. **Mechanical Strength:** Tested to observe the pellet's resistance to breaking.

V.TECHNO-ECONOMIC ANALYSIS

Techno-economic analysis (TEA) is a systematic method used to understand whether a technology or process is technically feasible and economically practical at real-world scale. For the present study, TEA focuses on evaluating how the addition of Jatropha oil as a binder and energy booster affects the overall performance and cost of biomass pellets. The goal is to determine whether this modification provides measurable technical improvements and whether those improvements are worth the investment.

Fig. 2 Jatropha Oil Used as Binder and Energy Booster

Fig. 2 illustrates the Jatropha oil employed as a binder and energy booster, which contributes to improved calorific value and pellet strength, thereby influencing the techno-economic performance.

The use of a small proportion of Jatropha oil increases energy density while marginally affecting the production cost, making the process economically feasible.

1. Technical Feasibility

The first part of TEA examines the technical performance of pellets enhanced with Jatropha oil. This includes analyzing how the oil influences pellet strength, combustion behavior, and energy value. During experiments, Jatropha oil consistently improved the calorific value, helped reduce dust formation, and enhanced the durability of the pellets. These

improvements confirm that the process is technically successful because the pellets produced are stronger, burn more uniformly, and offer higher heat output than standard biomass pellets. This indicates that integrating Jatropha oil into the pelleting process is not only technically possible but also highly effective.

2. Process Requirements

The second stage assesses the practical needs of the system. This includes evaluating equipment compatibility, raw material availability, and the simplicity of operating the process. Jatropha oil does not require any advanced machinery or modification of existing pellet equipment. It can be added using simple mixing methods, making the process convenient for small-scale or rural industries. Biomass residues such as sawdust, agricultural waste, and forest by-products are already widely available, and Jatropha oil can be sourced locally in many regions. Since the process does not depend on rare or expensive materials, it is practical and easy to implement.

3. Economic Feasibility

Economic analysis examines whether the process is financially viable in real practice. The cost components include raw biomass, Jatropha oil, electricity, labor, and basic equipment use. While a small amount of Jatropha oil adds some cost, it also increases the calorific value of the pellets, which can justify a higher selling price in the market. When evaluated overall, the cost increase is relatively small compared to the performance gain. For low-budget or village-level pellet producers, this method remains affordable and beneficial. Over time, the use of improved pellets can generate higher revenue due to better fuel efficiency and customer preference.

4. Market Potential

The enhanced pellets have strong market potential because industries and households increasingly prefer cleaner and more efficient fuels. Pellets with higher calorific value can replace traditional biomass, coal, or firewood, offering both economic and environmental advantages. Such pellets are particularly suitable for small boilers, heating systems, and rural cooking applications. Since the global and national demand for renewable energy is continuously rising, these modified pellets have opportunities in both domestic and export markets.

5. Cost–Benefit Ratio

The cost–benefit ratio compares the extra cost of adding Jatropha oil with the benefits gained. In most cases, the performance improvements—such as higher energy output, better combustion, and improved durability—offer more value than the additional expense. This makes the cost–benefit ratio favorable. Users can obtain more heat from the same quantity of pellets, leading to lower fuel consumption over time. This improved efficiency compensates for the cost of the oil, making the process economically justified.

6. Overall Assessment

Overall, the techno-economic analysis shows that enhancing biomass pellets with Jatropha oil is both technically effective and economically attractive. The process requires minimal equipment modifications, uses locally available materials, and delivers measurable improvements in pellet quality. The investment is low, the benefits are high, and the method is suitable for small, medium, and large pellet manufacturers. Therefore, this approach is recommended as a practical and sustainable technique that supports cleaner energy production and promotes renewable resources.

Conclusion

This study successfully demonstrates the techno-economic feasibility of using Jatropha oil as a binder and energy booster in biomass pellets. The addition of Jatropha oil significantly improves pellet quality by enhancing calorific value, mechanical strength, ignition behavior, and combustion stability. These improvements make the pellets more efficient and reliable compared to conventional biomass pellets. From a technical perspective, the process is simple and does not require complex equipment or advanced technology. The materials used are easily available, and the pelletization process can be carried out at laboratory, pilot, or small industrial scale. The enhanced pellets show better durability,

reduced ash formation, and cleaner burning characteristics, confirming the effectiveness of Jatropha oil as a functional additive. The techno-economic analysis indicates that the improvement in fuel performance justifies the additional cost of Jatropha oil. The overall production cost remains low, while the increased energy output and improved market value make the process economically viable. This method is suitable for small-scale producers, rural energy systems, and emerging renewable fuel markets.

In conclusion, the use of Jatropha oil in biomass pellets represents a sustainable, cost-effective, and environmentally friendly approach for clean energy generation. The findings of this study support the potential of Jatropha-based pellet technology as a promising alternative to conventional solid fuels and contribute to the development of renewable energy solutions for future applications.

References

1. Demirbas, A. (2004). Combustion characteristics of different biomass fuels. Progress in Energy and Combustion Science, 30(2), 219–230.

2. Kaliyan, N., & Morey, R. V. (2009). Factors affecting strength and durability of densified biomass products. Biomass and Bioenergy, 33(3), 337–359.

3. Mani, S., Tabil, L. G., & Sokhansanj, S. (2006). Effects of compressive force, particle size and moisture content on mechanical properties of biomass pellets. Biomass and Bioenergy, 30(7), 648–654.

4. Demirbas, A. (2009). Biorefineries: Current activities and future developments. Energy Conversion and Management, 50(11), 2782–2801.

5. Jain, S., Sharma, M. P., & Rajvanshi, S. (2011). Acid base catalyzed transesterification kinetics of waste cooking oil. Fuel Processing Technology, 92(1), 32–38.

6. Singh, R. N., Vyas, D. K., Srivastava, N. S. L., & Narra, M. (2008). SPRERI experience on holistic approach to utilize all parts of Jatropha curcas fruit for energy. Renewable Energy, 33(8), 1868–1873.

7. Obernberger, I., & Thek, G. (2010). The pellet handbook: The production and thermal utilisation of pellets. Earthscan Publications, London.

8. Van Loo, S., & Koppejan, J. (2008). The handbook of biomass combustion and co-firing. Earthscan, London.

9. Kumar, A., Jones, D. D., & Hanna, M. A. (2009). Thermochemical biomass gasification: A review of the current status of the technology. Energies, 2(3), 556–581.

10. IRJET Editorial Board. (2022). Guidelines for biomass energy research and techno-economic analysis. International Research Journal of Engineering and Technology (IRJET).