iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** V **Month of publication:** May 2025

DOI: https://doi.org/10.22214/ijraset.2025.70605

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue V May 2025- Available at www.ijraset.com

Design and Development of a Cost-Effective Semi-Automatic Biomass Briquetting Machine for Small-Scale Applications

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Abstract: This study shows that the comparison between Hand operated briquetting machine and Briquetting Machine in Bio coal Industry. Briquetting presents a practical solution for turning agricultural waste into clean, efficient energy for rural and suburban communities. To address this need, we developed an accessible, user-friendly briquetting machine that can be locally manufactured. This machine is low-cost, has a small capacity, and operates under low pressure, making it ideal for meeting the domestic energy needs in rural households. The machine we created underwent testing with different combinations of agricultural residues. We explored various mixes and proportions of raw material briquettes, evaluating the thermal and physical properties of the resulting briquettes. We designed the machine to be low-cost and easy to operate.
Keywords* Briquetting Machines, Bio-briquettes, clean energy, Domestic energy needs, Efficient energy.

I. INTRODUCTION

The process of converting biomass into briquettes is a fairly recent development in many African nations. In contrast, various commercial briquetting technologies have already been established across Asia, America, and Europe. The growth of biomass as a viable alternative energy source for heating largely hinges on three key elements: the availability of raw materials for briquetting, the presence of suitable technologies, and a market for the finished briquettes. (3). In the densification phase, it's crucial to focus on several key factors, including the compaction pressure applied by the bio-briquetting machine, its overall capacity, and the specific type of press utilized. Various bio-briquetting machines have been designed, each featuring different pressing mechanisms such as piston, screw, roller, pelletizing, manual, and low-pressure briquetting systems. The selection of these different press types during the densification process results in bio-briquettes that come in a range of shapes and qualities. (6). Bio-coal briquettes are a form of solid fuel created by compressing a mixture of crushed coal, organic matter, binding agents, and a substance to fix sulphur. The intense pressure applied during production causes the coal and biomass particles to fuse tightly, preventing them from breaking apart during transport, storage, and burning. (2). Briquetting typically involves the use of charcoal as a primary material; however, incorporating charcoal into briquettes presents several challenges. One significant issue is the release of greenhouse gases such as carbon dioxide (CO2), sulfur oxides (SOX), nitrogen oxides (NOX), and methane (CH4). To address these concerns, biomass briquetting emerges as a more favorable alternative. This method primarily incorporates materials such as rice husks, wheat straw, cotton stalks, bagasse, and jute sticks. (1) Biomass briquetting involves compressing loose agricultural waste, with or without the use of a binding agent, to create solid, compact forms of various dimensions through the application of pressure. A briquette is generated by transforming dry, loose, and fine particles—sometimes with the addition of an additive—into a uniform solid shape. These briquettes are primarily utilized for heating purposes and for generating energy by gasifying biomass briquettes, as well as for home use. (5Currently, the rising energy requirements of our planet, coupled with a steadily expanding population, are leading to significant waste and amplified energy demands. The use of various agricultural products often results in the stems, leaves, and peels being discarded or wasted. However, creating bio-briquettes can effectively contribute to meeting the escalating energy needs. (4). The conventional briquetting press facilitates the large-scale creation of cost-effective briquettes, catering to culinary requirements in both countryside and city settings. This project provides a sustainable income stream for local farmers and rural populations, generating job options for young individuals and enhancing the quality of life for those with limited financial resources. With minimal initial investment and the use of materials sourced from the local environment, this initiative holds significant promise. The durable briquettes produced serve as excellent cooking fuel in households and hotels alike. (7).

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A. Argo Waste Three Phase Fully Automatic Biomass Briquetting Machine

A state-of-the-art device that effectively converts agricultural waste into high-density biomass briquettes via an automated method is a fully automatic three-phase biomass briquetting machine. Large-scale biomass production facilities and a variety of industries make extensive use of these machines. At ₹22 lakh, the briquetting machine has a remarkable 1000 kg/hr production capacity, which means to 1000 briquettes per hour. Each 90mm briquettes costs ₹6 per kilogram. This machine presents a viable option for large-scale briquette production due to its affordable price and high production rate.

Argo Waste Three Phase Fully Automatic Biomass Briquetting Machine

Argo Waste Three-Phase Completely Automated Biomass Briquetting Device. The briquetting machine produces a lot of high-quality briquettes every hour at remarkable high rates of production. Increased productivity, shorter production times, and suitability for large-scale and industrial manufacturing are some of its advantages. It does, however, have certain disadvantages, such as the need for a lot of space, labour and energy, and expensive upkeep. In addition, the machine itself requires a substantial financial outlay. Notwithstanding these difficulties, its benefits make it a useful tool for producing briquettes on a large scale.

Considering the current situation, we decided to create a semi-automatic briquetting machine for small-scale briquette production. This will make it easier to produce briquettes commercially, by small scale users, as well as by villagers. To accomplish this goal, our screw-type semi-automatic briquetting machine will be priced reasonably so that it is affordable for middle-class families and people who routinely require production.

B. Semi- Automatic Briquetting Machine

The briquetting machine is an economical choice, with a price tag around ₹8,500. It can produce at a rate of 5 Kg per hour, making it appropriate for small to medium-sized production needs. This device creates briquettes that are 100mm in size, which are sold at ₹4 per kilogram. Its budget-friendly and compact design makes it perfect for individuals or small enterprises interested in starting briquette production. Furthermore, this briquetting machine comes with multiple benefits, such as its affordable price and the convenience of being operated by just one person.

Semi- Automatic Briquetting Machine

This device enables users to create briquettes in specific amounts as required, taking up very little space. Nevertheless, it comes with certain drawbacks. The output capacity is fairly limited, and the briquettes are formed under relatively low pressure. Furthermore, the production process can be rather slow, which makes it impractical for large-scale operations because of its modest yield. In general, this machine is most appropriate for small-scale or personal use.

C. Specification of Semi-Automatic Briquetting Machine

The components table offers an in-depth view of the crucial elements of a briquetting machine, emphasizing their sizes, roles, and importance in creating briquettes. Each part is meticulously crafted to promote effective compression, moulding, and handling of raw materials, such as biomass, transforming them into solid fuel briquettes. Table 1 illustrates the various parts of the semi-automatic briquetting machine.

Table no. 1 Name of Components

Components	Dimensions
Closing Plate	5mm
Cylinder	10mm
Plunger	10mm
Hydraulic Jack	2 Ton
Tension Spring	20 mm
Circular Disc	115mm Diameter
One Valve	8mm Diameter 105 mm 90 mm
DC Motor	24V and 250-watt DC motor
Battery	12 V and 28 Amp
Battery Stand	195mm X 85mm (2)
Switch Stand	45mm Diameter Disc
wheels	50mm

II. COMPONENTS

A. Closing Plate

In a briquetting apparatus, the horizontal closure plate is essential to the compression mechanism. This plate, measuring 5mm in thickness, is located at the upper section of the machine, allowing for vertical movement that guarantees a uniform pressure on raw materials such as biomass and other flammable materials. Consequently, it generates tightly packed and consistently dense briquettes. By maintaining an even distribution of pressure, the closing plate improves the compaction process, resulting in efficient and dependable briquette manufacturing.

Closing Plate

B. Cylinder

A cylinder with a thickness of 10mm plays an essential role in a briquetting machine, which is designed to compress materials into cylindrical briquettes. It is securely fastened to the machine's frame beneath the closing plate, promoting consistency and effectiveness in the processes of handling, storage, and combustion.

Cylinder

C. Plunger

A plunger with a diameter of 10 mm is utilized in a briquetting machine to compact raw materials into solid briquettes by applying pressure. This action forms a cavity within the briquette while it is housed in the chamber. Usually operated by hydraulic or mechanical systems, which often include a hydraulic jack, these machines are available in a wide range of sizes and configurations, tailored to suit different briquetting methods and types of materials.

Plunger

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D. Hydraulic Jack

A hydraulic jack with a capacity of 2 tons is utilized in a briquetting machine to effectively compress biomass materials into solid briquettes. By engaging the system manually, hydraulic fluid is directed into the cylinder of the jack. This motion drives the piston, exerting force to compact the biomass into briquettes. This method guarantees accurate control and uniform output of premium-quality briquettes, enhancing the transformation of biomass waste.

Hydraulic Jack

E. Tension Spring

The spring ensures smooth operation by returning the piston to its original position after each compression cycle, enabling efficient and continuous briquetting.

Tension Spring

F. Circular Disc

The circular disc with a diameter of 115 mm is connected to the motor. Additionally, a rod linked to the same motor is attached to a hydraulic jack, assisting in lifting the jack efficiently.

Circular Disc

G. One Valve

The release valve, measuring 105mm x 90mm, regulates pressure in the hydraulic jack system by allowing fluid to exit the cylinder, facilitating safe and controlled operation

One Valve

H. DC Motor

The 24V 250-Watt DC motor is designed to deliver high torque and low RPM, effectively powering the machine's critical components, including the crankshaft and piston. This powerful motor efficiently compresses biomass materials, optimizing the performance and reliability of your equipment.

DC Motor

I. Battery

A 28 Amp battery powers our DC motor, ensuring smooth and reliable operation of the machine whenever needed.

Battery

J. Caster Wheels

We equipped the machine frame with 2-inch caster wheels, enhancing mobility and allowing for convenient relocation.

Caster Wheels

III. MATERIALS

Briquettes can be produced using a wide variety of materials, including leftover agricultural products like crop leftovers, sugarcane pulp, and cotton stems. Moreover, leftover wood products such as sawdust, wood shavings, and tree bark are also excellent for making briquettes. Urban and industrial waste, as well as biomass sources like bamboo, various grasses, and water hyacinth, can be repurposed as well. These resources are abundant, renewable, and often viewed as waste, making them an attractive option for alternative energy. Creating briquettes from these materials not only aids in reducing waste disposal costs but also opens up new income possibilities, lowers greenhouse gas emissions, and supports sustainable development.

Soyabean shell

Soybean husks serve as a perfect resource for making briquettes, thanks to their abundant supply and distinctive characteristics. These husks, which are a byproduct of extracting soybean oil, retain a small amount of oil that functions as a natural adhesive, aiding in the compaction process. By varying the amount of soybean husks used, we can produce briquettes that boast enhanced strength and better burning efficiency. The natural binding qualities of soybean husks negate the requirement for additional binders, positioning them as a superb option for eco-friendly briquette manufacturing. The various mixes of soybean husk, oil, and water ratios employed in briquette creation are displayed in Table 2.

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Table no. 2. Materials proportions

Materials	Size	Proportions
(Soyabean shell: oil: water) Sample A	1.18mm	(80:10:10)
Soyabean shell Sample B	15mm – 30mm	(100:00)

The measurements are expressed as a ratio reflecting the weight of each separate ingredient. These mixtures are designed to investigate how varying proportions of soybean shell, soybean oil, and water affect the physical traits and burning qualities of the briquettes created.

IV. PRODUCTION OF BRIQUETTES

The briquetting procedure starts with categorizing soybean shells according to their size and quality to guarantee uniformity. Following this, the shells are crushed and cut into tiny fragments to aid in smooth processing. Subsequently, the biomass is combined with water and oil binders.

Sample A

Sample B

V. TEST CONDUCTED

A. *Calorific Value Test*

The calorific value of soybean shell briquettes is determined through a simple and practical method involving the burning of briquettes and boiling of water. This method is based on the principle of heat transfer, where the heat energy released from the burning briquettes is used to boil water.

The Calorific value is calculated by using the following formula- (1).

$$Q_v = C(Q_1 - Q_2)/W_b$$

here: Q_v = Heating/ Calorific value (kJ/kg),

C = Calibration of constant for biomass acid (0.6188),

Q_1 = Galvanometer deflection without sample,

Q_2 = Galvanometer deflection due to test sample,

W_b = Weight of sample

B. *Moisture Content*

To determine the moisture content, the first step involves weighing all the briquettes created by the manually operated briquetting machine, recording the starting weight as W1. After this, the briquettes are set out in the sun for 24 hours to facilitate drying. Once this drying phase is complete, the briquettes are weighed again, and the weight at this stage is recorded as W2.

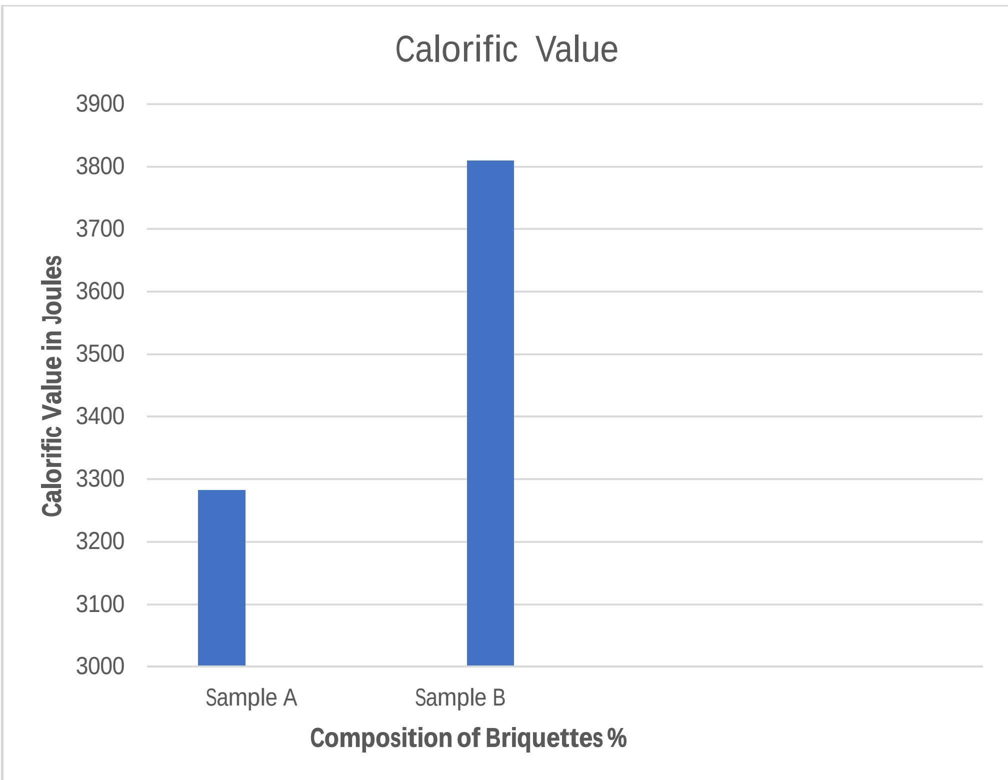
The moisture content (MC) is then calculated using the recorded weights with the formula: (2).
MC (%) = [(W1 - W2) / W1] × 100.
W1= Initial weight,
W2= Weight after drying

Ash Content
The ash levels in the briquettes were assessed using a simple method. First, the briquettes were ignited, and the ash produced was meticulously gathered and measured.
The ash content was then calculated using the formula: (3).
AC (%) = (W2/W1) × 100.
W1 = Original weight of dry sample,
W2 = Weight of ash after cooling.

VI. RESULT

A. Calorific Value Test

The energy content of the briquettes is detailed below: For the mixture consisting of soybean husk, oil, and water in a proportion of 80:10:10, the briquettes created using the current machine provide an energy value of 3281.824 joules. On the other hand, the sample made solely from soybean husk (100:00) produced in the factory machine achieves a higher energy content of 3809.26 joules.



Calorific Values

The energy content of briquettes created by two different techniques is displayed in (Figure a). The blue bar represents Sample A (Soybean Shell: Oil: Water), which has a calorific value of 3,281.824 Joules. Conversely, the orange bar indicates that Sample B (Soybean Shell) has a higher calorific value of 3,809.26 Joules.

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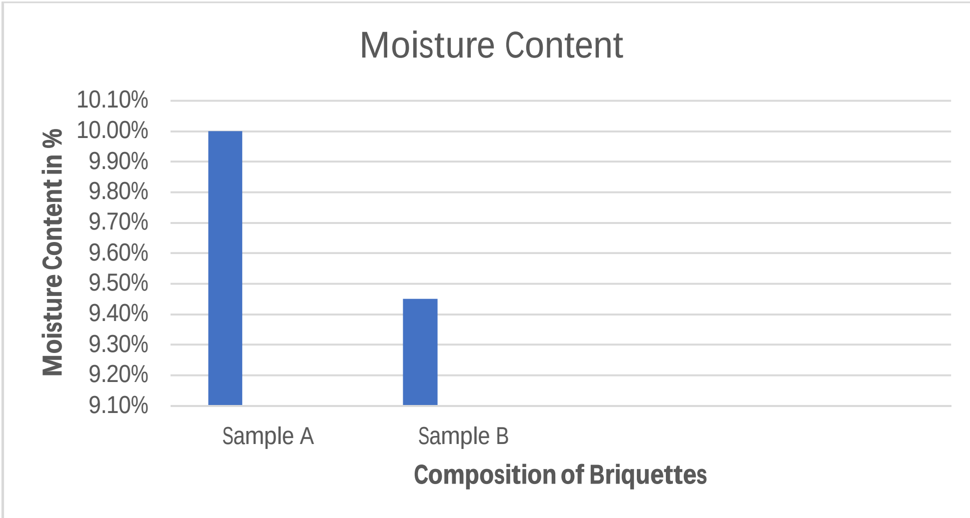
B. Moisture Content

The following information outlines the moisture levels of the briquettes. A mixture of soybean husk, oil, and water in an 80:10:10 ratio, created using the current machine, shows a moisture level of 10%. On the other hand, a sample that purely composed of soybean husk (100:00), produced by the factory's machinery, reveals a moisture content of 9.45%.

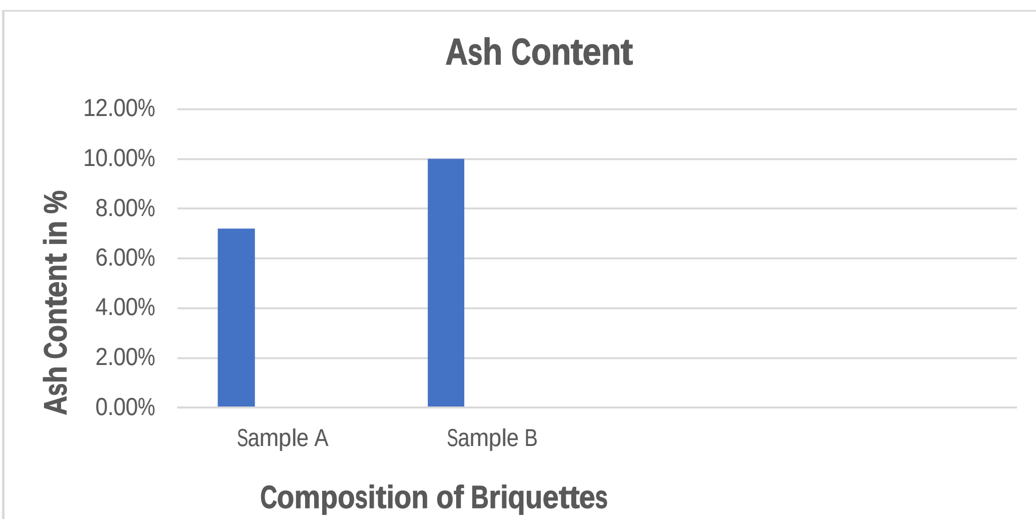


Moisture Content

The moisture content comparison is illustrated in the preceding figure (Fig. b). The graph indicates a significant disparity in moisture levels between the two samples, which will have a direct impact on the composition of the briquettes.

C. Ash Content

The ash composition of the briquettes is outlined here. A mixture of soybean husk, oil, and water in the proportions of 80:10:10 resulted in briquettes that contained 7.2% ash when processed with the current equipment. On the other hand, when briquettes were produced exclusively from soybean husk at a ratio of 100:00, they exhibited an ash content of 10.13% when manufactured using the factory machinery..



Ash Content

The comparison of ash content is shown in the earlier figure (Fig. c). Sample B, which comes from the Factory Machine, shows an ash content that is 2.93% higher than Sample A, produced by the Existing Machine. To be precise, Sample A has an ash content of 7.2%, whereas Sample B has a higher value of 10.13%. This suggests that the Existing Machine might be producing briquettes with a lower ash content, which could be beneficial for certain uses.

VII. CONCLUSION

This research offers a comparative analysis of two different kinds of briquetting machines: a manually operated semi-automatic model and a fully automated industrial version, both used for creating bio-coal. The aim of this investigation was to evaluate the heat value, moisture levels, ash content, and financial feasibility of the briquettes produced by each machine. The findings highlight the advantages and disadvantages of both methods, delivering important information on their suitability for diverse uses.

This research analyzes both manually operated and fully automated industrial briquetting machines, focusing on their effectiveness, expense, and ecological viability. The manual version, priced at ₹8,500, is designed for small-scale production with a capacity of 5 kg per hour; however, it necessitates physical labor and results in briquettes of lower density. On the other hand, the industrial unit, costing ₹22 lakh, boasts a substantial output of 1000 kg per hour and produces denser briquettes, yet it requires a significant financial commitment and ongoing maintenance. Both types of machines contribute to sustainable energy by transforming agricultural waste into fuel. The manual machine is more appropriate for smaller users, while the industrial model caters to larger production needs. Looking ahead, future advancements should focus on improving efficiency, reducing costs, and enhancing their environmental benefits.

Briquettes crafted solely from pure soybean shells (in a 100:00 ratio) using industrial machinery exhibited a superior calorific value of 3809.26 J. In contrast, those produced with a blend of soybean shells, oil, and water (in an 80:10:10 ratio) via a manual machine showed a lower calorific value of 3281.824 J. This clearly demonstrates that briquettes made from pure soybean shells are more energy-efficient and yield greater heat during burning, establishing them as a more potent fuel option.

The moisture content of pure soybean shell briquettes (100:00 ratio) was 9.45%, slightly lower than the 10% found in mixed briquettes (80:10:10 ratio). A lower moisture content enhances burning efficiency, allowing the briquettes to ignite more easily and burn more consistently while producing less smoke. This makes pure soybean shell briquettes more effective as a fuel source, as they provide better combustion performance and reduce energy loss due to moisture evaporation.

Briquettes made from 100% soybean husk show a higher ash level of 10.13%, compared to just 7.2% in the blended briquettes. This difference suggests that the pure soybean variety leaves behind more ash after burning. A higher ash content can contribute to increased air pollution and requires more frequent cleaning and maintenance. While the mixed briquettes provide slightly less energy, they are a cleaner option because they produce less ash, making them better suited for environments where reducing emissions and easing upkeep are priorities.

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