

Design and Development of a Press Machine for Biobriquettes Made from Patchouli Distillation Waste and Rice Husk

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Abstract: The increasing availability of biomass residues such as patchouli distillation waste and rice husk presents an opportunity for renewable energy production; however, their utilization remains limited due to the lack of efficient and safe small-scale processing equipment. Developing practical briquette production systems is therefore essential to support sustainable energy use at household and MSME levels. **Objective:** This study aims to develop and evaluate a hydraulic briquette press capable of producing biomass briquettes from patchouli distillation waste and rice husk while enhancing operational safety, maintenance efficiency, and usability for small-scale production. **Method:** The research employed an engineering research-and-development approach involving machine design, prototype fabrication, and functional testing. Data were collected through technical observation and performance monitoring of pressing cycles, followed by descriptive analysis to evaluate operational functionality, safety response, and cleaning effectiveness. **Findings:** The developed press integrates a pressure-sensor-based safety system and an automatic pneumatic cleaning mechanism. The machine is capable of forming six briquettes per cycle at an operating pressure of approximately 50 kg/cm². The integrated systems functioned as intended, supporting stable operation, reducing manual cleaning needs, and improving operational safety. **Implications:** The proposed design demonstrates potential for improving briquette production efficiency and reliability in small-scale applications. By reducing downtime and enhancing safety, the system can support wider adoption of biomass briquette technology and contribute to community-level renewable energy utilization. **Originality/Value:** This study offers a novel integration of hydraulic pressing, automatic pneumatic cleaning, and pressure-based safety monitoring within a single multi-cavity briquette press, providing a practical and user-oriented solution for transforming agricultural waste into renewable energy products.

Keywords: Hydraulic Briquette Press; Patchouli Waste; Rice Husk; Pneumatic Cleaning; Safety System

INTRODUCTION

Agricultural and agro-industrial biomass waste continues to increase in many developing countries, including Indonesia, yet its utilization as a sustainable energy resource remains limited. Residues such as rice husks and essential-oil distillation waste are frequently disposed of through open burning or uncontrolled dumping, contributing to air pollution while simultaneously wasting a potentially valuable renewable feedstock.

Lignocellulosic biomass has been widely recognized as a promising renewable energy resource due to its availability and its potential to substitute conventional solid fuels when properly processed and densified. A key barrier is that most raw biomass has low bulk density and heterogeneous physical properties, which increase handling costs and reduce combustion stability; densification technologies (briquetting/pelletizing) are therefore widely adopted to improve fuel logistics, storage, and combustion behavior (Kpalo et al., 2020; Nunes et al., 2020; Sarker et al., 2021).

Briquetting has gained attention because it can improve bulk density, reduce volume, and produce a more uniform solid fuel suitable for decentralized energy use in households and small industries (Lisowski et al., 2019; Tumuluru, 2020). However, briquette quality is strongly governed by feedstock preparation and compaction conditions. Prior studies consistently show that moisture content is among the most influential parameters affecting briquette density, durability, and mechanical integrity; excessive moisture can weaken inter-particle bonding, while overly dry material may reduce cohesiveness depending on binder and fiber composition (Abdel Aal, 2023; Wang et al., 2022). In addition, particle size distribution, compaction pressure, and dwell time significantly affect relaxed density and mechanical durability, reinforcing the importance of controlled process settings and robust equipment design (Lisowski et al., 2019; Sarker et al., 2021).

Rice husk is one of the most abundant agricultural residues in Indonesia and many rice-producing regions. While it is commonly available at low cost, its high silica/ash characteristics and lightweight structure can create challenges for stable densification and consistent combustion unless process parameters and binders are optimized. Reviews of briquetting technology emphasize that binder type and dosage, along with die/mold geometry and compression ratio, can substantially influence density, compressive strength, and durability of densified biomass fuels (Jekayinfa et al., 2024; Kpalo et al., 2020). Peer-reviewed studies on briquettes/charcoal briquettes also demonstrate that binder selection (e.g., molasses/starch-based binders) can measurably affect briquette strength and handling durability, particularly for small-scale production systems (Carnaje et al., 2018).

In parallel, essential-oil distillation industries generate large quantities of solid residue after extraction. Patchouli (*Pogostemon cablin*) is an important essential-oil commodity in Indonesia, and the distillation process leaves a large fraction of solid biomass residue. Experimental characterization of patchouli essential-oil industry residue has reported its heating value and proximate/thermal behavior, supporting its feasibility as a renewable

bioenergy feedstock ([Ginting, 2022](#)). More broadly, valorization studies on patchouli residue (e.g., via thermal conversion routes) further highlight the magnitude and environmental relevance of this waste stream, motivating integrated waste-to-energy pathways ([Ginting, 2025](#)). Blending patchouli distillation residue with rice husk therefore represents a practical approach to co-utilize two abundant residues into a densified solid fuel, provided that the densification process and equipment can ensure consistent compaction and manageable operation during repetitive cycles.

Recent research in biomass densification can be grouped into three streams relevant to this work. First, the feedstock–quality stream focuses on how composition, particle size, moisture content, binder formulation, and compaction pressure affect briquette density, durability, and combustion-related behavior ([Abdel Aal, 2023](#); [Nunes et al., 2020](#); [Sarker et al., 2021](#); [Wang et al., 2022](#)). Second, the machine-design stream addresses press architectures and control strategies particularly hydraulic presses because hydraulic systems can deliver controllable and repeatable compaction forces, supporting consistent briquette geometry and structural integrity ([Rahman et al., 2020](#); [Subekti, 2023](#)). Third, the operational-reliability stream emphasizes monitoring and safety in high-pressure equipment, noting that sensor-based monitoring and safety logic can reduce operational risk and improve reliability ([Kim & Park, 2022](#)).

Despite progress, many small-scale briquette press designs still concentrate on force generation and basic automation, while practical operational constraints remain under-addressed. Two recurring problems are (i) residual material accumulation on the mold surface that causes sticking, inconsistent briquette release, increased cleaning time, and cycle disruption; and (ii) safety management that relies mainly on operator judgment without integrated pressure sensing and standardized warning/response logic. Meanwhile, standardized evaluation of densified fuels increasingly emphasizes measurable durability/handling resistance using recognized methods (e.g., ISO 17831-2 for briquette mechanical durability), which implies that stable and repeatable production cycles are essential for achieving consistent quality. Therefore, an engineering gap remains in developing a compact briquette press that simultaneously targets cleanliness, throughput efficiency, and operator safety within one integrated operational sequence.

To address this gap, the present study proposes the design and development of a hydraulic biobriquette press machine utilizing a mixture of patchouli distillation waste and rice husk. The system integrates three key features: (i) a hydraulic pressing mechanism

enabling multi-cavity molding for higher throughput, (ii) a mechanically synchronized automatic pneumatic cleaning subsystem actuated during the return stroke to reduce residue accumulation and minimize manual maintenance, and (iii) a pressure-sensor-based warning mechanism that alerts the operator when hydraulic pressure reaches or exceeds a predefined threshold. The novelty lies in combining these functionalities within a single machine platform aimed at practical small-scale operation. Based on this premise, the study evaluates the developed prototype through functional testing and performance analysis during repeated briquette production cycles, guided by three working hypotheses: (H1) automatic pneumatic cleaning reduces residue accumulation and maintenance time compared to manual cleaning; (H2) pressure-sensor-based warnings improve operational safety awareness by enabling early detection of excessive pressure; and (H3) the combination of multi-cavity molding and automated cleaning improves production efficiency by reducing cycle interruptions and stabilizing the molding process.

RESEARCH METHOD

The unit of analysis of this study is a prototype hydraulic biobriquette press machine developed to mold briquettes produced from a mixture of patchouli distillation solid waste and rice husk. The analysis focuses on the machine as an engineering artifact, including (i) the mechanical structure (main frame and multi-cavity mold), (ii) the hydraulic pressing subsystem (cylinder, valve, and pressure regulation), (iii) the automatic pneumatic cleaning subsystem (3/2 roller valve, nozzles, air supply, and activation mechanism), and (iv) the pressure-sensor-based safety subsystem (sensor, indicator, and alarm). In addition, the operational cycle (pressing–return stroke–automatic cleaning–safety response) is examined as part of the machine’s functional behavior during repetitive production.

This study adopts a research and development (R&D) engineering design with a functional prototyping orientation. This design is appropriate because the objective is to create and validate a working machine, not to test human perceptions or survey responses. The R&D approach enables iterative stages of requirement definition, detailed design, fabrication, system integration, refinement, and functional verification to ensure the prototype meets operational needs for small-scale users (Irzandy et al., 2024). Similar development logic has been used in briquette press engineering and control studies, where systematic design and testing cycles are essential to achieve stable machine performance

and reliable operation (Subekti et al., 2023). The overall research procedure is presented in Figure 1.

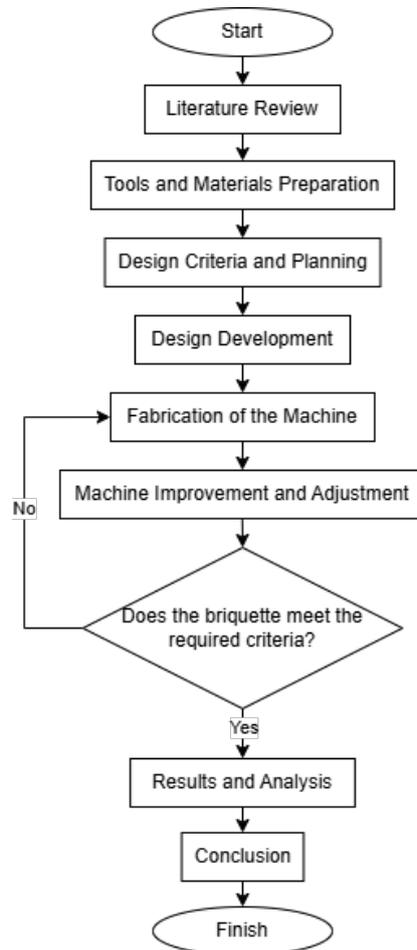


Figure 1. Research Flowchart

This research uses three categories of data sources. First, literature and technical references are used to define design requirements for briquette pressing mechanisms, pneumatic cleaning concepts, and safety monitoring in hydraulic circuits. Second, engineering design documents generated during development serve as primary information sources, including CAD drawings, mechanical specifications, hydraulic and pneumatic circuit schematics, and safety wiring/indicator diagrams. Third, prototype trial data are obtained from functional runs of the machine, including observations and measurements of pressing performance, pneumatic cleaning activation, and safety warning responses under controlled operating conditions.

Data are collected through engineering observation, measurement, and functional testing of the prototype. The machine is operated using a prepared briquette mixture of

patchouli residue and rice husk with a fixed binder formulation, and the press is run for repeated cycles to observe operational stability. During each cycle, the following are recorded: (i) hydraulic pressure (from the pressure gauge and/or sensor output) during the pressing stage, (ii) the activation timing and consistency of the pneumatic cleaning system triggered by the 3/2 roller valve during the return stroke, and (iii) the safety indicator and alarm response when pressure approaches or exceeds the preset threshold. The briquette outputs are then documented and measured for basic operational indicators such as dimensional consistency and visible integrity (e.g., cracks, incomplete compaction, sticking to the mold). A structured testing checklist is used to standardize observations across trials, covering leakage, alignment, valve functionality, cleaning effectiveness, and alarm activation.

Data are analyzed using descriptive engineering analysis and criterion-based performance evaluation. Measured and observed variables are summarized across repeated cycles to assess whether the prototype meets predefined operational criteria, including consistency of pressing pressure, stability of cycle operation, reliability of pneumatic cleaning activation, and responsiveness of the safety warning system. Cleaning effectiveness is evaluated by comparing the level of residue accumulation and the need for manual cleaning before and after the pneumatic cleaning cycle, supported by documentation notes and visual records. Safety performance is confirmed by verifying that the pressure sensor reliably triggers the warning indicator and alarm at the defined threshold. The final interpretation integrates these findings to conclude the feasibility and operational advantages of the developed press machine for small-scale briquette production.

RESULT

Prototype configuration and main components

The briquette press developed in this study comprises a main structural frame, a vertical hydraulic cylinder as the primary pressing actuator, and a six-cavity mold unit integrated into a single working assembly. The multi-cavity configuration enables simultaneous molding of six briquettes in one cycle. The system also includes a hydraulic pressure control lever for regulating the pressing force during operation. The complete prototype assembly is presented in Figure 2. The press is configured for a stated pressing pressure of 50 kg/cm².

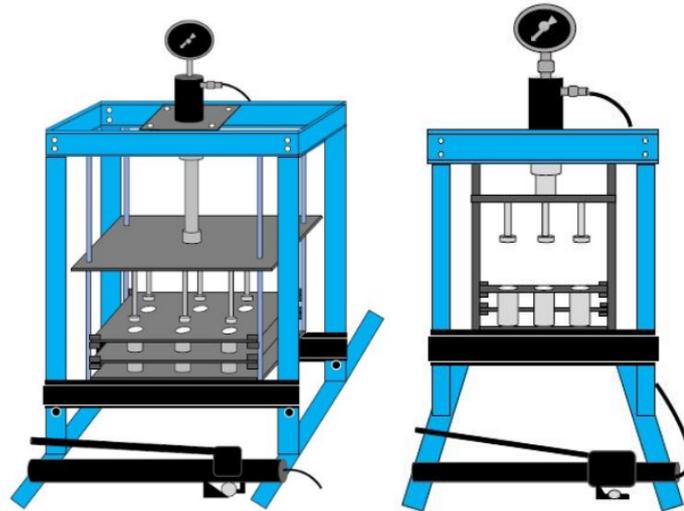


Figure 2. The Complete Hydraulic Briquette Press Assembly

Automatic pneumatic cleaning subsystem

An automatic pneumatic cleaning subsystem is integrated into the machine to remove residual briquette mixture from the mold area after each pressing cycle. The subsystem consists of an air compressor (or compressed air source), a 3/2 roller-type pneumatic valve, pressurized air hoses, and spray/air-blowing nozzles directed toward the mold chamber. As illustrated in Figure 3, the cleaning function is activated mechanically: when the hydraulic cylinder returns upward after compression, the actuator motion contacts the roller lever on the 3/2 valve, shifting the valve position and allowing pressurized air to flow toward the nozzles for cleaning.

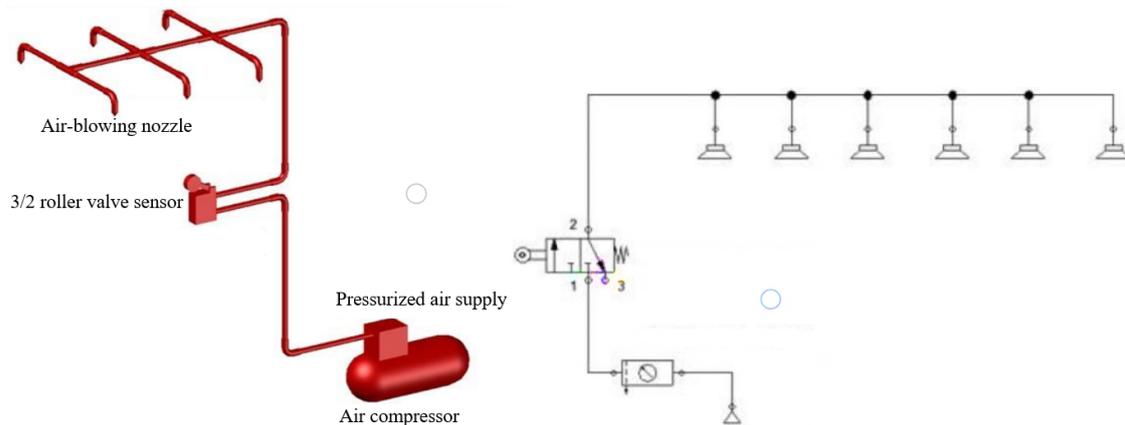


Figure 3. Automatic Pneumatic Cleaning System Schematic

Pressure-sensor-based safety subsystem

The machine is equipped with a pressure-based safety subsystem consisting of a hydraulic pressure sensor installed in the hydraulic circuit and an indicator module featuring warning lights and an audible alarm. The safety function is designed to activate when hydraulic pressure reaches or exceeds a predetermined limit. Upon detection, the sensor transmits an electrical signal to the indicator module, which triggers light illumination accompanied by an alarm sound as an operator warning. The safety schematic is shown in Figure 4.

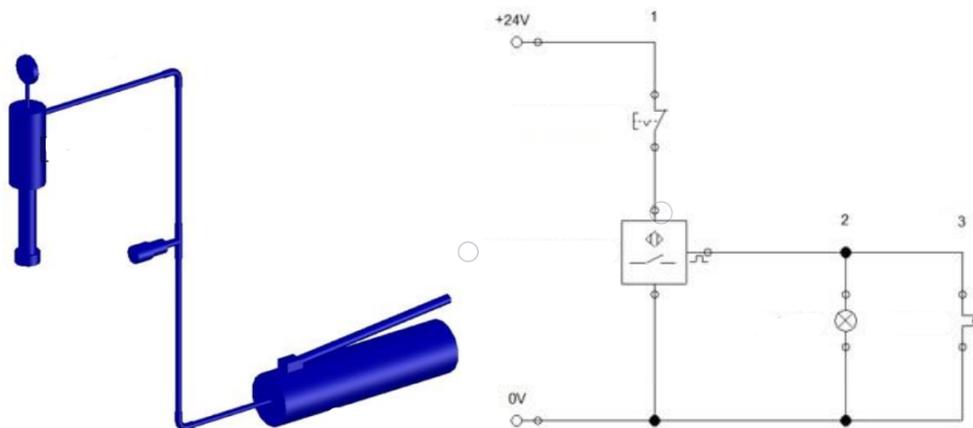


Figure 4. Pressure-Sensor-Based Safety System Schematic

Operational sequence of the integrated system

The operational cycle begins with the pressing stage, where the hydraulic cylinder applies compression through the pressing plate into the six-cavity mold chamber. After compression is completed, the hydraulic cylinder moves upward to return to its initial position. During this return stroke, the actuator lever engages the 3/2 roller valve, initiating airflow toward the nozzles. Pressurized air is then delivered into the mold chamber to remove remaining briquette mixture, reducing residue on the mold surface and concluding the cycle before the next pressing operation.

DISCUSSION

This study demonstrates the successful development of a functional hydraulic biobriquette press prototype intended for blended feedstock from patchouli distillation residue and rice husk. The main outcome is an integrated machine concept that combines a six-cavity mold for simultaneous molding, an automatic pneumatic cleaning subsystem that is mechanically triggered during the return stroke via a 3/2 roller valve, and a pressure-sensor-based safety warning subsystem that activates a visual indicator and an audible alarm when hydraulic pressure reaches a predetermined limit. Functionally, the prototype confirms that the pressing–return–cleaning sequence can be executed as a coherent cycle, and the system was configured to operate at a stated pressure of 50 kgf/cm² (\approx 4.9 MPa) based on gauge indication. These results emphasize that the contribution of the work is not limited to force generation for briquette formation, but also to operational continuity through automated cleaning and improved operator awareness through pressure monitoring.

The observed design logic can be explained by the way each subsystem is embedded into the machine's kinematics and operating constraints. Residual mixture accumulation in briquette molds commonly increases downtime, causes sticking, and disrupts cycle consistency, particularly in small-scale operations where cleaning is often manual and highly dependent on operator discipline. By coupling the pneumatic cleaning actuation to the cylinder's return motion, the cleaning event occurs consistently at the end of each pressing cycle, when loose residue is most likely to remain on the mold surfaces.

This mechanical synchronization reduces the likelihood that cleaning is skipped or delayed, and it simplifies implementation compared with electronically timed systems that require additional control hardware. In parallel, the pressure warning system is technically relevant because the resistance of biomass mixtures during densification can vary with moisture content, binder proportion, and particle packing, potentially elevating hydraulic pressure during the pressing stage. A sensor-based warning provides immediate feedback beyond analog gauge reading and can prompt corrective action when abnormal conditions occur, thereby strengthening the safety posture of the equipment at the operational level. The six-cavity mold configuration is also consistent with the production realities of household and SME environments, where increasing output per cycle can be more practical than increasing cycle frequency, provided that mold filling and alignment are controlled to avoid non-uniform compaction among cavities.

When compared with previous studies, the findings align with the broader biomass densification literature that stresses the importance of controlled processing conditions and stable compaction parameters for producing consistent densified fuels (Nunes et al., 2020; Sarker et al., 2021; Wang et al., 2022). Hydraulic briquetting designs are widely recognized for their ability to deliver controllable and repeatable compaction forces that support briquette integrity (Rahman et al., 2020) and automation approaches using controllers and systematic control logic have been explored to improve repeatability (Subekti, 2023). In industrial press contexts, monitoring and sensor-based safety strategies are also emphasized to enhance reliability and reduce operational risks (Kim & Park, 2022). The novelty of the present work lies in integrating these themes into a single small-scale platform by explicitly addressing a practical operational gap that is often underemphasized in press designs, namely mold cleanliness and routine maintenance burden. Rather than focusing solely on force delivery or basic automation, this prototype embeds an automatic cleaning event into the physical motion of the press cycle while adding a real-time pressure warning layer, thereby targeting cleanliness, efficiency, and operator safety simultaneously.

The meaning of these results extends beyond the mechanical configuration of a single prototype. In regions where patchouli distillation residue and rice husks are abundant, equipment that improves the practicality and safety of briquette production can support a waste-to-energy pathway that reduces unmanaged disposal and creates additional economic value through alternative solid fuel production. Technically, the work contributes to the understanding that appropriateness of small-scale densification technology is determined not only by capacity, but also by maintainability and risk-informed operation. By integrating cleaning and warning functions, the prototype concept is positioned to reduce cycle interruptions and improve operational discipline, which are often decisive factors for field adoption and sustained use.

At the same time, a reflective reading of the results highlights trade-offs and limitations that should be acknowledged. The pneumatic cleaning outcome will depend on nozzle placement, air pressure stability, and the stickiness of the mixture; if airflow is not well tuned, cleaning may be insufficient or may disperse fine particles that require additional housekeeping. The safety subsystem currently functions as a warning mechanism, so risk mitigation still depends on operator response; without an automatic protective action, the safety benefit is constrained by human factors. Multi-cavity molding increases throughput

potential, but it may also introduce cavity-to-cavity variability if filling uniformity, tolerances, or pressing plate alignment are not maintained. These considerations reinforce that, while functional integration is achieved, stronger evidence of operational advantage requires quantitative validation.

Accordingly, the practical implication of this work is that the prototype should be advanced through a focused action pathway that prioritizes measurable performance verification and safety strengthening. Future testing should report cycle time repeatability, cleaning activation consistency, residue or sticking indicators over repeated cycles, and pressure stability during pressing to directly evaluate the intended benefits. In addition, basic briquette quality characterization such as density, durability or compressive strength, moisture content, and calorific value would connect the machine's operational claims with fuel performance expectations established in prior densification studies ([Sarker et al., 2021](#); [Wang et al., 2022](#)) a design and operational standpoint, establishing a simple SOP for feedstock conditioning, uniform cavity filling, and response procedures when the alarm is triggered would improve reliability in small-scale deployment, while upgrading the warning-only safety feature toward a protective interlock or an automatic pressure-relief response would strengthen engineering safety consistent with press monitoring principles ([Kim & Park, 2022](#)). Through these steps, the prototype can move from demonstrating integrated functionality to providing validated, field-ready performance for sustainable briquette production using patchouli distillation waste and rice husk.

CONCLUSION

This research resulted in the successful design and development of a hydraulic briquette press equipped with an automatic pneumatic cleaning system and a pressure-based safety mechanism to support the production of biomass briquettes derived from patchouli distillation waste and rice husks. The machine features a six-cavity mold, an automatic cleaning cycle that removes residual briquette mixture after pressing, and a real-time pressure warning system to enhance operator safety. The design improves efficiency, reduces maintenance effort, enhances cleanliness, and is suitable for small-scale production environments, offering environmental benefits through waste reduction and economic value through alternative fuel utilization.

To further improve the system, adjustments to pneumatic nozzle positioning, routine component maintenance, and operator training are recommended to ensure reliable

operation and extended equipment lifespan. Future research may focus on performance testing, evaluation of briquette fuel characteristics, optimization of mold geometry and pressing parameters, and the integration of automation technologies such as digital monitoring and microcontroller-based controls. Scaling the system for wider production and assessing economic feasibility are also suggested to explore commercialization opportunities and broader adoption in renewable energy applications.

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