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Experimental study on the use of wood pellet briquettes in rocket stoves for household energy needs

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Abstract: This experimental study investigates the effect of air supply configurations on the combustion performance and thermal efficiency of wood pellet briquettes in rocket stoves for household energy use. With increasing global demand for energy and the depletion of fossil fuels, the shift to renewable biomass fuels, such as wood pellets, is essential to reduce carbon emissions and enhance energy efficiency. The study evaluates four airflow configurations: right fan only (F3), lower-left + right fans (F2+F3), two left fans (F1+F2), and all fans (F1+F2+F3). The results show that the F3 configuration achieved the fastest boiling time, highest boiling temperature, and lowest heat-loss temperature, indicating superior thermal performance. In contrast, configurations with higher airflow (F1+F2 and all fans) led to greater heat losses and slower boiling times, suggesting that excessive airflow can negatively affect efficiency. Additionally, the analysis of residual mass revealed that F3 and F2+F3 configurations produced the lowest residuals, indicating more complete combustion. This study provides important insights into optimising airflow configurations to improve the efficiency of biomass stoves. The findings offer practical implications for the design and operation of sustainable cooking technologies, promoting energy efficiency and reducing reliance on fossil fuels in households, particularly in rural areas.

Keywords: forced-draft air supply; thermal efficiency; combustion performance; biomass energy

1. Introduction

Global energy demand continues to rise with population growth and economic activities (Jie et al., 2023; Rehman et al., 2022, 2023). Household energy needs are also increasing, while fossil energy availability becomes more limited, leading to fuel shortages and escalating energy costs, particularly in households still reliant on LPG and kerosene (Haselip et al., 2022; Qudrat-Ullah, 2024). The reliance on fossil fuels such as LPG and kerosene imposes an increasing economic burden, particularly in rural areas. Currently, fossil fuels dominate the global energy supply, with the household sector being a significant contributor to carbon emissions through cooking activities (Du et al., 2023; Fan et al., 2024; Jia et al., 2022; Qin et al., 2024). This makes the transition to renewable energy an urgent agenda for many countries. The depletion of fossil fuel reserves underscores the need for more sustainable alternative energy sources, among them biomass in the form of wood pellets, a renewable fuel with considerable potential (Kalak, 2023; Rimantho et al., 2023; Saleem, 2022). Indonesia, with its abundant biomass resources, offers an alternative energy source, and biomass is recognised as a carbon-neutral energy source (Erdiwansyah et al., 2022; Simanjuntak et al., 2022).

Wood pellets have a higher energy density than raw biomass, and their use can support economic growth through energy diversification (Mawusi et al., 2023; Rodriguez Franco, 2022; Saosee et al., 2022). The stable and efficient combustion characteristics of wood pellets make them a preferred biomass fuel. These pellets, produced through densification from wood industry waste such as sawdust and agricultural residues, offer numerous advantages, including lower moisture content and ease of storage and transport (Ahmed et al., 2022; W. Li et al., 2022; Rupasinghe et al., 2024). Despite the proven potential of wood pellets, their combustion technology faces challenges, particularly in terms of thermal efficiency and emissions reduction. The rocket stove, a biomass stove utilising an insulated combustion chamber, presents a promising solution for optimising heat (Katerla & Sornek, 2025; Pandit et al., 2025). Previous studies indicate that pellet-fueled gasifier stoves with forced-draft air supply can achieve performance comparable to that of gas stoves in household settings (Gutiérrez et al., 2022, 2025). Rocket stove technology can enhance thermal efficiency by optimising air supply, heat insulation, and the speed of the hot gas flow, thereby improving combustion (Gao et al., 2023; Mekonnen, 2022). However, the influence of air supply variations, especially in forced-draft systems, still requires further investigation better to understand their impact on wood pellet combustion performance. Computational Fluid Dynamics (CFD) studies by (Gao et al., 2023) suggest that optimal air inlet positioning and airflow rates are critical for maximising thermal efficiency.

While the rocket stove has been widely adopted, research gaps remain in understanding the effects of forced-draft air supply on combustion performance. Studies such as those by (Jiang et al., 2023; Machi et al., 2024) emphasise the importance of secondary air inlet positioning and airflow rates on thermal efficiency. However, comprehensive studies examining optimal air-supply configurations and their effects on stove performance, particularly in wood-pellet combustion, remain scarce. Additionally, although previous research has focused on thermal performance, the effects of air supply variations on residual ash formation and overall combustion quality remain underexplored (Sari & Prasetyo, 2021; Widodo et al., 2020). This research aims to address the following questions:

RQ1. What is the effect of airflow speed variations on thermal efficiency and ash residue formation in wood pellet-fueled rocket stoves?
RQ2. How significant is this variation in improving combustion performance and reducing emissions?

This study contributes to the field of biomass energy by analysing the role of air supply variations in optimising rocket stove performance when using wood pellets. It proposes an optimal configuration for air inlet positioning and airflow rate to maximise thermal efficiency and minimise heat loss. Furthermore, it explores the relationship between air supply balance and ash residue formation, providing insights into improving combustion quality. The findings are expected to enhance the design and operation of biomass stoves, offering more efficient and sustainable energy solutions for households.

2. Material and methods

This study adopts an experimental approach to analyse the combustion performance of wood pellet briquettes in rocket stoves for household energy use (Roy & Corscadden, 2012). The testing equipment includes a rocket stove, a digital scale for measuring the mass of pellets and ash residue, thermocouples for measuring the stove and exhaust-gas temperatures, an anemometer for measuring the airflow velocity induced by the fan, and a stopwatch to record the boiling time of water and the combustion duration. During the tests, several parameters are measured, including water boiling temperature, boiling time, pellet burn resistance, residual water mass, ash mass, stove temperature, and exhaust gas temperature.

2.1 Design and selection of rocket stove materials

The rocket stove used in this study is designed using hollow iron with dimensions of 100mm x 100mm and a thickness of 5mm, ensuring high mechanical and structural resistance to the combustion temperatures inside the stove's combustion chamber. The biomass combustion process, particularly with wood pellet briquettes, generates high temperatures exceeding 100°C. The selected iron material with adequate thickness can maintain the stove's shape, reduce the risk of deformation, and increase the stove's lifespan during testing and repeated use (Zhang et al., 2025). Table 1 provides the stove's dimensions.

Table 1. Dimension specifications

Dimension	Size (mm)
Length	758
Width	541
Height	955

For the design phase, the stove was modelled in 3D using SolidWorks to visualise its structure and components in detail. The 3D model of the stove, shown in Figures 1(a) and 1 (b), highlights the main structure and configuration and serves as a reference for its construction.

2.2 Rocket stove design

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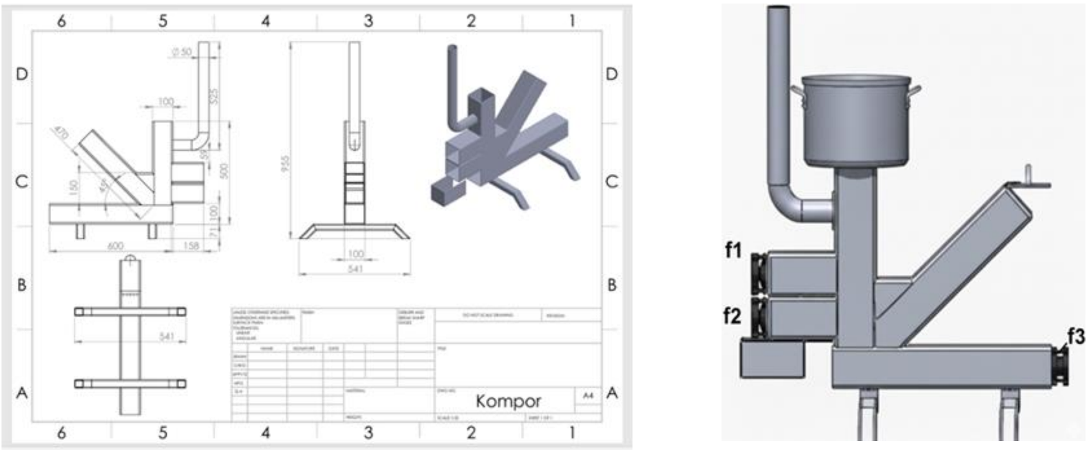

(a)

(b)

Figure 1. (a) 2D and (b) 3D views of the rocket stove

2.3 Determining the calorific value of combustion

The calorific value of combustion is determined by the heat absorbed by the water during heating (Gan et al., 2022; Wang et al., 2022). The calculation is performed using Equation (1).

$$Q = m \times c \times \Delta T \tag{1}$$

Where:

- Q is the thermal energy (kJ),
- m is the mass of water (kg),
- c is the specific heat capacity of water (4.186 kJ/kg°C)
- ΔT is the temperature difference (°C).

The value Q indicates the amount of heat generated from the combustion of the fuel and serves as a thermal performance indicator for the system.

2.4 Thermal efficiency of the biomass stove

The thermal efficiency of the combustion system (η_{th}) is defined as the ratio of the thermal energy absorbed by the water to the total energy available from the fuel, as shown in Equation (2).

$$\eta_{th} = \frac{(m_{air} \times C_p \times (T_2 - T_1))}{m_{fuel} \times HHV} \tag{2}$$

Where:

- m_{air} is the mass of water (kg),
- C_p is the specific heat capacity of water (kJ/kg°C),
- $T_2 - T_1$ is the temperature rise of the water (°C),
- m_{fuel} is the mass of the fuel (kg),
- HHV is the higher heating value of the fuel (kJ/kg),

The value (η_{th}) indicates how efficiently the energy from the fuel is utilised to heat the water; the higher the value, the better the combustion performance.

2.5 Thermal power of the biomass stove

The following equation calculates the thermal power (p_{th}) produced during the heating process (Shibata et al., 2018). Thermal power represents the rate at which thermal energy is transferred over time, as expressed in Equation (3).

$$p_{th} = \frac{(m_{air} \times C_p \times (T_2 - T_1) + m_{evap} \times h_{fg})}{t} \tag{3}$$

Where:
- m_{air} is the mass of heated water (kg),
- C_p is the specific heat capacity of water (kJ/kg°C),
- $T_2 - T_1$ is the temperature rise of the water (°C),
- m_{fuel} is the mass of water evaporated during the heating process (kg),
- h_{fg} is the latent heat of vaporisation (kJ/kg),
- t is the heating time (s),

This equation accounts for energy transfer during both sensible heat (temperature increase) and latent heat (evaporation), providing an assessment of the stove's ability to generate heat over time.

2.6 Fuel Burning Rate (FBR)

The fuel burning rate (FBR) is used to determine the fuel consumption rate and is calculated using Equation (4) (Osei Bonsu et al., 2020).

$$FBR = \frac{(m_{fuel\ consumend})}{t} \tag{4}$$

- $m_{fuel\ consumend}$ is the mass of the fuel consumed during testing (kg),
- t is the burning time (s).

The value FBR indicates the rate at which fuel is consumed, directly related to the combustion intensity and energy release rate in the stove.

3. Results and discussion

3.1 Experimental overview

This study evaluates how forced-draft air supply (fan configuration) affects the combustion behaviour and heating performance of a pellet-fired rocket stove operated under controlled initial conditions: pellet mass = 700 g, initial water temperature = 32°C, initial water volume = 1000 mL, and fan air velocity = 14 m/s and 21 m/s (as reported). Four airflow configurations were tested: (i) right fan only (F3), (ii) lower-left + right fans (F2+F3), (iii) two left fans (F1+F2), and (iv) all fans (F1+F2+F3), as illustrated in Table 2. Overall, the dataset confirms that air supply distribution strongly influences combustion intensity, heat transfer to the pot, and thermal losses, consistent with the air–fuel ratio concept in combustion theory: combustion temperature and efficiency increase toward an optimum oxygen supply. In contrast, insufficient air promotes incomplete combustion and excess air (over-aeration) can cool the flame and increase sensible heat loss in the exhaust stream (Huang et al., 2021).

Table 2. Test results

Fan Variation	Boiling temperature (°C)	Remaining Water Mass (ml)	Boiling Time (s)	Pellet Burn Resistance (s)	Ash Mass (g)	Stove Temperature (°C)	Heat Loss Temperature (°C)
Right fan only (F3)	114	500	556	1711	130.87	110	62
Lower-left + right (F2+F3)	108	477	1090	1981	129.59	124.3	93
Two left fans (F1+F2)	67.1	800	2870	2870	370.73	102	87.5
All fans (F1+F2+F3)	88.03	637	1612	1612	165.66	125.9	116

3.2 Boiling temperature (thermal response)

Figure 2 illustrates that the boiling-temperature indicator shows a clear dependence on airflow configuration. F3 (right fan only) produced the highest reported boiling temperature (114°C) and the shortest boil time, suggesting that the air-jet direction and mixing pattern under this configuration promote stable, flammable combustion and effective heat transfer to the pot. The F2+F3 configuration also performed relatively well (108°C), indicating that introducing a second air stream can maintain strong combustion, although not as effectively as F3 in this dataset.

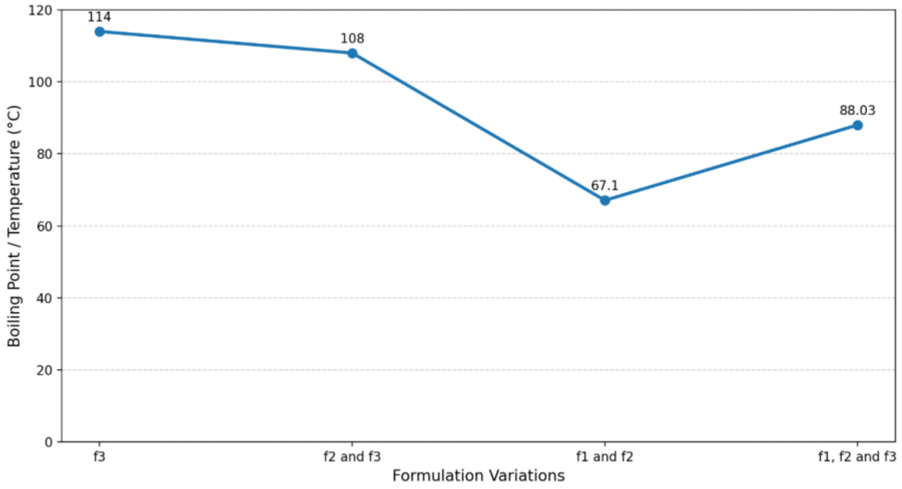

Figure 2. Boiling temperature (°C) based on formulation variations

By contrast, F1+F2 (two left fans) yielded the lowest reported boiling temperature (67.1°C) and the longest time to reach boiling conditions, which is consistent with non-optimal mixing or localised cooling of the flame zone. Finally, when all fans were activated, the boiling temperature increased compared with F1+F2 but remained below F3. This pattern supports the concept of an optimal air supply: beyond a certain point, additional air can act as a diluent, reducing flame temperature and/or diverting heat away from the pot via increased convective loss (over-aeration) (Z. Li et al., 2023; Pan, 2025).

3.3 Water remaining after boiling (mass balance of evaporation)

Figure 3 demonstrates that the water remaining after boiling can be interpreted as an indirect indicator of the amount of water that evaporated during heating. Based on the dataset, the F2+F3 configuration left the smallest remaining volume (477 mL), indicating the largest evaporation (523 mL). This was followed closely by F3, which left 500 mL (equivalent to 500 mL evaporated). When all fans were operated, the remaining water was 637 mL (about 363 mL evaporated), whereas F1+F2 left the highest remaining volume (800 mL), indicating the lowest evaporation (200 mL).

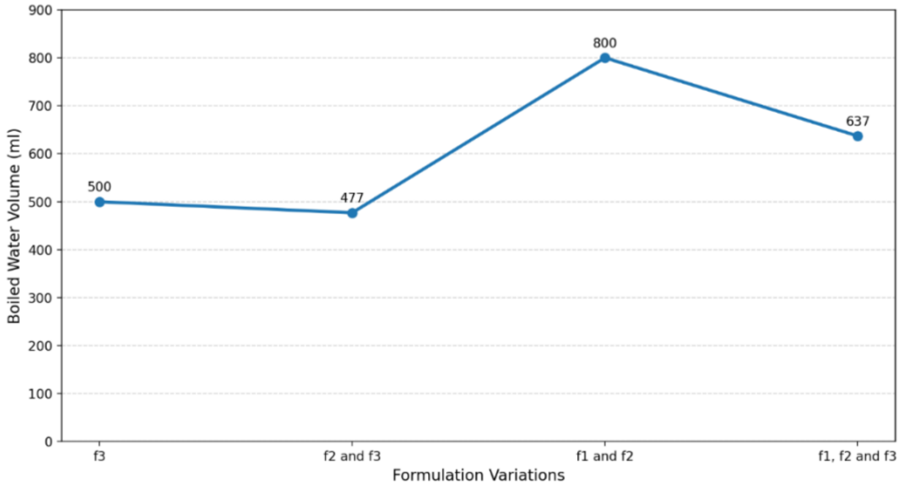

Figure 3. Boiled water volume (ml) across formulation variations

From a heat-transfer standpoint, greater evaporation generally implies that more thermal energy was delivered to the water, particularly when boiling conditions are achieved and maintained. Therefore, interpreting "higher remaining water" as "better efficiency" is not physically consistent with the evaporation process; instead, the most coherent interpretation is that F2+F3 and F3 transferred the greatest amount of heat to the pot, as reflected by their higher evaporation and/or faster boiling performance, while F1+F2 transferred the least heat, consistent with its lower boiling temperature and markedly longer boil time. Nonetheless, evaporation should not be treated as a standalone proxy for overall stove efficiency, because a configuration may evaporate more water while still losing a substantial fraction of heat through the exhaust stream; for this reason, evaporation must be interpreted together with indicators of heat loss (e.g., the measured heat-loss/exhaust temperature) to draw a balanced efficiency conclusion.

3.4 Boil time (heating rate)

The boil time is the most direct operational metric for user performance. The results show a strong advantage for F3, which reached boiling in 556 s, almost twice as fast as F2+F3 (1090 s), and far faster than all fans (1612 s) and F1+F2 (2870 s), as depicted in Figure 4.

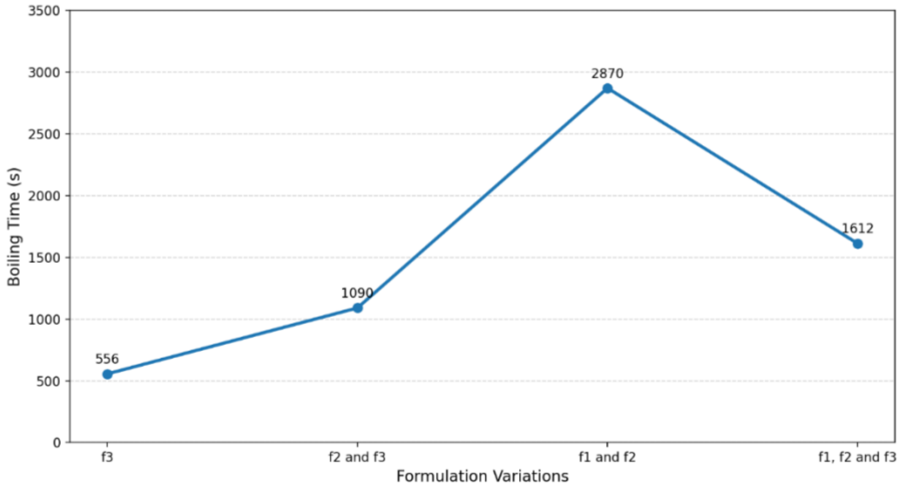

Figure 4. Boiling time (s) across formulation variations

This indicates that airflow direction and mixing quality are at least as important as total airflow magnitude. The superiority of F3 suggests that its air jet may enhance the entrainment of pyrolysis gases and promote more complete oxidation near the combustion core, thereby increasing the effective heat flux to the pot. Meanwhile, all-fan operation likely increases total airflow, but the high "heat-loss temperature" suggests that more energy is leaving the system through the exhaust rather than being transferred to the pot, a signature of over-aeration and elevated convective loss (Glassman et al., 2014).

3.5 Pellet burns duration (fuel consumption behaviour)

Burn duration indicates how quickly the fuel is consumed under each airflow condition. Here, F1+F2 yields the longest burn (2870 s), while all fans yield the shortest (1612 s). This trend is expected: increasing oxygen supply and turbulence typically accelerate the overall reaction rate, consuming fuel faster, as shown in Figure 5.

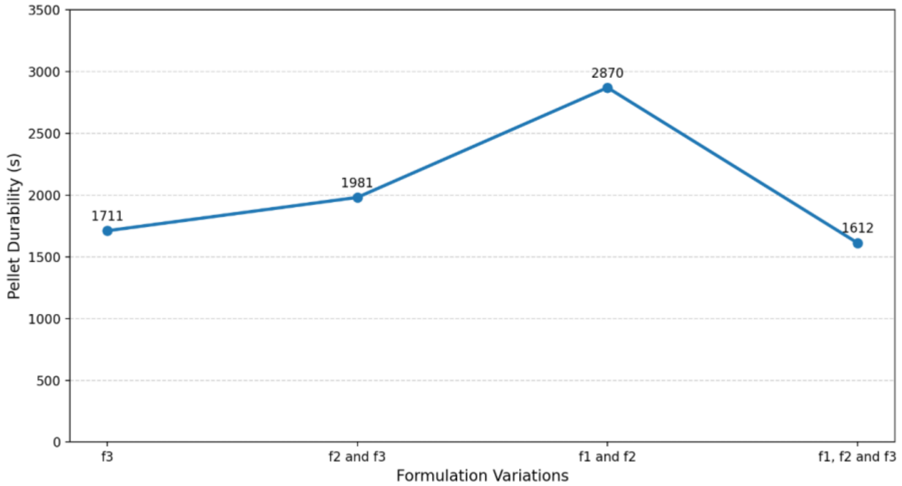

Figure 5. Pellet durability (s) across formulation variations

However, longer burn duration is not automatically "more efficient." A long burn can also mean a lower heat release rate (weak combustion), which aligns with F1+F2's poor boiling performance. Conversely, a shorter burn duration can indicate high power output, which may be desirable for fast cooking but may also increase losses if heat is not effectively captured by the pot and chimney design.

3.6 Residual mass and combustion completeness

The residual mass shows a pronounced variation across fan configurations, with an especially extreme value recorded under F1+F2 (370.73 g), as illustrated in Figure 6.

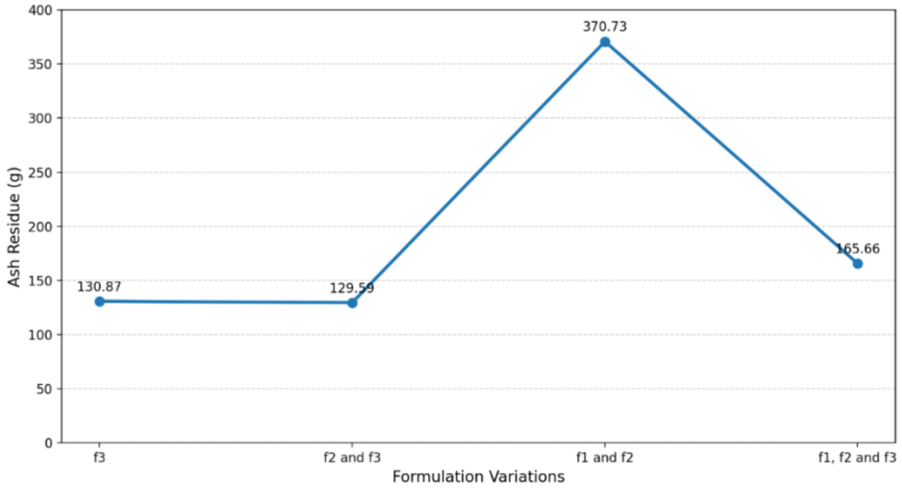

Figure 6. Ash residue (g) across formulation variations

In the biomass combustion literature, true ash, the incombustible mineral fraction of the fuel, typically remains relatively stable and constitutes only a small percentage of the original mass in clean wood pellets. Consequently, a residual value of this magnitude strongly indicates that the reported quantity is more appropriately interpreted as total residual solids, comprising not only mineral ash but also unburned char and partially reacted pellets, rather than ash alone. When interpreted in this manner, the results become more physically consistent: the markedly high residual solids under F1+F2 suggest incomplete fuel conversion, limited char oxidation, and overall weaker combustion performance, which is corroborated by the same configuration producing the lowest boiling temperature and longest boiling time. In contrast, the comparatively lower residual solids observed under F3 and F2+F3 imply a more effective conversion of solid fuel into combustible gases and released heat, reflecting a more complete combustion process. This interpretation is consistent with established biomass combustion theory, which holds that inadequate air–fuel mixing or insufficient oxygen availability in critical reaction zones increases char carryover and residual solid accumulation (Permana & Hidayat, 2021).

3.7 Stove (combustion-chamber) temperature

Figure 7 shows that fan configuration has a clear and significant influence on the rocket stove's combustion-chamber temperature. In general, modifying airflow direction and distribution alters oxygen availability and mixing quality, which in turn affects combustion intensity and the extent to which heat is retained within the chamber. With only the right fan (F3) running, the chamber temperature reached 110°C, indicating that a single, directed airflow can sustain combustion, although heat distribution in the chamber may remain uneven. When the lower-left and right fans (F2+F3) were operated simultaneously, the temperature increased to 124.3°C, suggesting that supplying air from two directions improves mixing and strengthens oxidation reactions, thereby supporting a more stable and energetic combustion process.

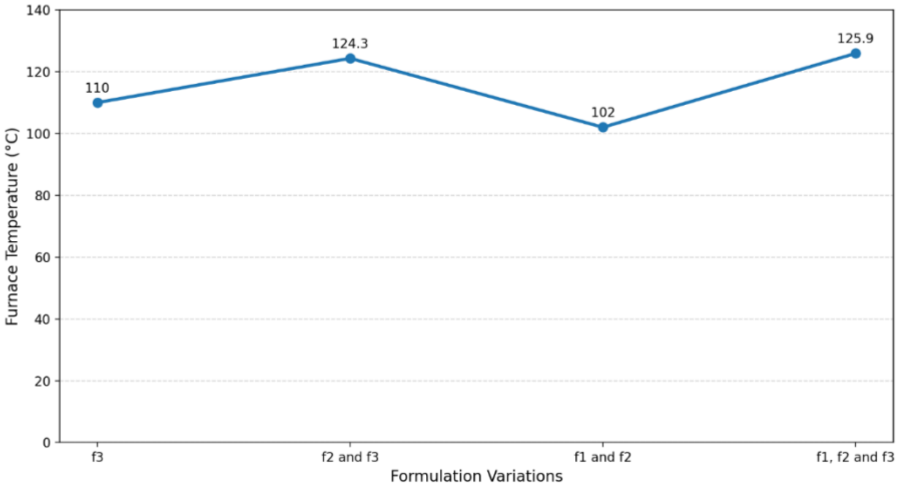

Figure 7. Furnace temperature (°c) across formulation variations

In contrast, the two-left-fan configuration (F1+F2) produced the lowest chamber temperature (102°C). This indicates that the airflow pathway in this configuration may be less effective at concentrating the reaction zone and maintaining heat in the combustion core, resulting in a weaker thermal environment inside the stove. The maximum chamber temperature (125.9°C) occurred when all fans (F1, F2, and F3) were activated, suggesting that a more uniform air supply can increase combustion intensity and sustain higher internal temperatures. However, this condition should be interpreted with caution, as excessive airflow can also raise convective heat losses and reduce overall heat utilisation if a larger fraction of energy is transported out of the system with the exhaust stream.

3.8 Discussion

The present results confirm that forced-draft air supply configuration is a primary determinant of combustion stability, heat transfer to the pot, and overall thermal utilisation in a pellet-fueled rocket stove. Across the four configurations, the right-fan-only setting (F3) consistently produced the most favourable operational performance, most notably the fastest boiling time (556 s) and the highest reported boiling temperature (114°C), while also exhibiting the lowest measured heat-loss temperature (62°C). This combined pattern suggests that F3 provides an airflow field that improves air–fuel mixing and flame anchoring near the core combustion zone, enabling more effective oxidation of pyrolysis gases and directing a larger fraction of released heat toward the pot rather than into the exhaust. These findings align with combustion fundamentals: thermal performance improves as air supply approaches an optimal air–fuel ratio, but deteriorates when the stove experiences either oxygen deficiency or excessive dilution and convective loss under over-aeration (Sheykhbaglou et al., 2024; Simanjuntak et al., 2021; Susastriawan & Saptoadi, 2023).

A key insight from the dataset is that more airflow is not always better. Although activating multiple fans can increase oxygen availability and raise chamber temperature, as observed under F1+F2+F3, which yielded the highest stove temperature (125.9°C), this configuration also produced the highest heat-loss temperature (116°C) and a slower boiling time than F3. This suggests that under all-fan operation, the combustion chamber may become more energetic, but the additional air can increase gas velocities and sensible heat transport out of the system, thereby reducing the fraction of heat captured by the pot. Such behaviour is consistent with prior work emphasising that forced-draft stoves require careful control of inlet positioning and airflow rate to avoid excess-air penalties, including lowered flame temperature and increased exhaust losses (Deng et al., 2020; Kalak, 2023; Saosee et al., 2022). In other words, the results indicate that high chamber temperature (thermal intensity) does not automatically translate into useful cooking output if heat is not effectively retained and transferred.

The water-mass balance further supports this interpretation. Configurations F2+F3 and F3 produced the highest evaporation (i.e., lowest remaining water), indicating greater heat delivered to the pot during the test period. However, evaporation alone cannot be taken as a direct proxy for efficiency, because a configuration can deliver high heat while still losing a substantial fraction through the exhaust stream. Therefore, the most reliable interpretation emerges when evaporation is considered jointly with boiling time and heat-loss temperature: F3 achieves rapid heating while maintaining the lowest measured heat-loss temperature, suggesting superior heat utilisation compared to multi-fan settings. This combined reading is consistent with the design logic of rocket stoves, in which performance depends not only on combustion intensity but also on the flow path, insulation, and effective heat transfer between hot gases and cookware (Katerla & Sornek, 2025; Pandit et al., 2025).

The residual mass results also provide indirect evidence of combustion quality. The extremely high "ash" value under F1+F2 (370.73 g) is unlikely to represent mineral ash alone for wood pellets and is more plausibly interpreted as total residual solids (ash + unburned char + partially reacted pellets). Under this interpretation, the F1+F2 configuration reflects incomplete conversion and weak oxidation, which is consistent with its low boiling temperature and longest boiling time. Conversely, lower residual solids under F3 and F2+F3 indicate more complete conversion of fuel to heat and combustible gases. This pattern aligns with biomass combustion theory and experimental findings that inadequate mixing or poor oxygen delivery in critical zones increases char carryover and residual char (Chen et al., 2025; Y. Li et al., 2024). Practically, these results imply that airflow direction and inlet placement can be as important as airflow magnitude in minimising residual solids and improving overall cooking performance.

Taken together, the study supports the conclusion that the rocket stove operates best under a balanced forced-draft condition, represented here by F3, that promotes stable combustion and effective heat transfer while limiting exhaust heat loss. This finding complements earlier reports that forced-draft pellet gasifier stoves can approach the usability of gas stoves under well-tuned air supply, but their performance remains sensitive to inlet configuration and flow control (Chen et al., 2025; Y. Li et al., 2024). In the context of household energy transitions, optimising such configurations is relevant for improving biomass stove adoption by increasing convenience (faster boiling), reducing fuel consumption, and potentially reducing emissions, thereby supporting broader renewable energy goals (Achakulwisut et al., 2023; Gayen et al., 2024; Holechek et al., 2022; Østergaard et al., 2022).

3.9 Limitations and future work

Several limitations should be acknowledged to ensure appropriate interpretation. First, the experiment appears to be reported as single-point values; without repeated trials and dispersion metrics, it is not possible to quantify measurement uncertainty or statistically test differences across configurations. Second, some reported values raise potential instrumentation and definition concerns, particularly "boiling temperatures" exceeding 100°C and the unusually high "ash" mass, suggesting that the temperature sensor may not reflect bulk water temperature at atmospheric pressure, and that residual mass may include unburned char or partially reacted fuel rather than mineral ash alone. Third, airflow was reported at two velocities (14 m/s and 21 m/s), but the results are presented without clear separation by airflow speed; thus, the relative contributions of fan velocity and configuration cannot be isolated. Fourth, the study focuses primarily on thermal and residual indicators; although the introduction frames emissions reduction as a motivation, direct emissions measurements were not included, limiting conclusions about emission performance. Finally, the heat-loss temperature is informative but does not fully capture total losses without additional data, such as exhaust mass flow rate and chimney/pot heat-exchange characteristics.

Future studies should implement replicated experiments under each configuration to enable statistical comparison and robust uncertainty reporting, and standardise and document measurement protocols, including thermocouple locations, calibration procedures, and a clear operational definition of "ash" versus "residual solids." To more directly address performance mechanisms, future work should separate the experimental design into factorial conditions, fan configuration × airflow velocity, so that the independent effects of inlet placement and flow rate can be quantified. In addition, incorporating emissions monitoring (CO, CO_2, PM, and potentially NOx) would allow the study to link air-supply optimisation not only to heating performance but also to clean-combustion outcomes, which are central to household energy policy and health impacts. Finally, design-oriented investigations, supported by CFD where appropriate, should evaluate inlet geometry, secondary-air staging, insulation thickness, and pot–skirt/heat exchanger enhancements to reduce exhaust losses under high-air conditions, consistent with prior evidence that optimal inlet positioning and controlled excess air are critical for maximising efficiency in rocket-stove and gasifier-stove systems.

4. Conclusion

This study highlights the critical role of forced-draft air-supply configurations in optimising the combustion and thermal performance of pellet-fuelled rocket stoves. The findings suggest that the right fan only (F3) configuration consistently offers the best performance in terms of boiling time, boiling temperature, and heat-loss temperature. This configuration improves air-fuel mixing, enhances combustion stability, and directs heat more efficiently to the cooking pot, minimising energy losses. In contrast, configurations with more airflow (e.g., F1+F2 or all fans) often led to higher chamber temperatures but also resulted in increased heat loss, longer boiling times, and reduced combustion efficiency, demonstrating that excess air supply can undermine stove performance. Additionally, residual mass data indicated that the F3 and F2+F3 configurations led to more complete fuel conversion, suggesting that optimised air-supply configurations contribute to both efficient combustion and reduced ash residue. These insights can guide the design and operational strategies for biomass stoves, offering sustainable, cost-effective solutions for household energy use, especially in rural areas transitioning away from fossil fuel reliance.

Author's declaration

Author contribution

Rafki Irianto: Conceptualisation, Methodology, Investigation, Formal Analysis, Writing – Original Draft, Writing – Review & Editing, Visualisation, Supervision. **Yolli Fernanda:** Conceptualisation, Investigation, Data Curation, Writing – Review & Editing, Software, Validation. **Primawati:** Methodology, Software, Validation, Formal Analysis, Writing – Review & Editing. **Dori Yuvenda:** Supervision, Validation, Writing – Review & Editing, Resources.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Conflict of interest

The authors declare that there are no competing interests related to the research or publication of this article.

Ethical clearance

Not Applicable

AI statements

This research was written entirely in its original form, and no data were generated using generative AI. However, Grammarly was used to improve the manuscript's readability and clarity.

Publisher's and Journal's Note

Researcher and Lecturer Society as the publisher, and the editor of Journal of Engineering Researcher and Lecturer state that there is no conflict of interest towards this article publication.

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