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Efficiency and Electrical Power Consumption Analysis of Gasification Stove Fueled by Used Cooking Oil as A Renewable Energy Alternative

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Abstract

Gasification stoves that utilize used cooking oil as fuel represent a significant innovation in renewable energy. People generally perceive used cooking oil as cooking oil that is no longer suitable for frying, often discarding it as waste or selling it to collectors for export and biodiesel production. However, used cooking oil can be repurposed as stove fuel, presenting an advancement in appropriate waste-to-energy technology. This approach enables cooking oil that is no longer used for frying to serve as a renewable fuel source for stoves. This study aims to analyze the efficiency of used cooking oil stoves by employing a gasification mechanism to accelerate heating. The efficiency evaluation includes thermal efficiency, measured using the Water Boiling Test method, along with values for Fuel Consumption Rate (FCR), Combustion Input Power (P_{in}), and Combustion Output Power (P_{out}). Thus, our study is the first to comprehensively evaluate the performance of used cooking oil (UCO)-fueled gasification stoves by analyzing these metrics, addressing a research gap in prior studies. Testing and analysis were conducted using water samples of three different volumes: 1 liter, 2 liters, and 3 liters. The results indicate thermal efficiency rates of 30.49 % for 1 liter of water, 15.54 % for 2 liters, and 16.45 % for 3 liters. The highest recorded FCR value is 1 liter/hour, the largest Pin value is 8,246.10 watts, and the highest Pout value is 1,481.28 watts. The decline in thermal efficiency and output power is attributed to the stove's design. Specifically, the blower pipe air hole is positioned perpendicular to the blower pipe within the combustion chamber. As a result, the flames primarily strike the combustion chamber walls, with only a portion of the reflected heat directed toward the container holding boiling water. This leads to excessive heating within the combustion chamber, while the temperature of the flames reaching the water container remains relatively lower. The electrical power consumption of the stove is measured at 10.89 watts. As a contribution, our study provides an alternative cooking solution that supports Indonesia's energy diversification efforts by reducing reliance on LPG and alleviating the government's subsidy burden.

Keywords:
renewable energy, stove efficiency, used cooking oil stove, waste-to-energy

1. Introduction

Global population growth is driving a steady increase in energy consumption, leading to greater dependence on fossil fuels and worsening environmental problems associated with their use (Dias et al., 2024). Over the past few decades, fossil fuel reliance across various sectors has gradually expanded, giving rise to two critical challenges: significant greenhouse gas (GHG) emissions, which contribute to environmental degradation, and the depletion of oil reserves. The global energy sector is responsible for 73.2 % of all anthropogenic GHG emissions, underscoring the urgent need for sustainable solutions. Reducing dependence on fossil fuels is essential to achieving international targets, such as those set in the Paris Agreement (Sathish, 2024). According to the International Renewable Energy Agency (IRENA) report, if the business-as-usual (BAU) scenario continues, nearly one billion people will still lack access to clean energy by 2030 (Nyarko et al., 2025).

Economic development can be pursued sustainably through investment in renewable energy technologies (Mensah et al., 2024). In the long term, national and international strategies aim to reduce emissions to net-zero by 2045–2060 by improving energy efficiency, expanding renewable energy installations, and integrating various energy sectors (Manske et al., 2025). China serves as an example of such efforts, with an ambitious goal of achieving net-zero carbon emissions by 2060. As a result, the incorporation of renewable energy into China's existing energy infrastructure is becoming increasingly unavoidable (Zhang et al., 2024). In recent years, industrialized countries have intensified their efforts to achieve carbon neutrality. However, this ambitious goal requires profound changes in both societal structures and energy systems. The energy sector is undergoing a transformation aimed at enhancing efficiency, promoting the adoption of renewable energy sources (RES), and integrating clean energy vectors that do not emit GHG (Catania et al., 2024). Industrialization can contribute to environmental sustainability, provided it is driven by renewable energy, which has significant potential for sustainable development.

The adoption of renewable energy plays a crucial role in mitigating climate change, reducing GHG emissions, and fostering a cleaner environment (Nulambeh & Jaiyeoba, 2024). Renewable energy production is a key element of the Sustainable Development Goals (SDGs) aimed at combating climate change (Yang et al., 2025). Projections suggest that by 2030, renewable energy will account for more than 60% of the global energy mix, with annual growth expected to exceed 12% between 2022 and 2030 (Wang et al., 2024). According to a recent International Energy Agency (IEA) report, the global economy is gradually progressing toward the goal of "adding as much renewable power in the next five years as it has in the last twenty" (Loutfi, 2024). Additionally, demand for alternative fuels continues to rise across various sectors due to the depletion of fossil fuel reserves, driven largely by growing energy needs in industrial and transportation sectors (Galusnyak et al., 2024). As fuel composition regulations evolve, the mandatory proportion of sustainable components is expected to increase over time, eventually becoming the dominant element in fuels. Furthermore, the hydroprocessing of vegetable oils for fuel is of great industrial significance (Główka et al., 2024).

On the other hand, the world is grappling with environmental challenges, including the accumulation of garbage and organic waste. Food waste constitutes a significant portion of urban solid waste and has become a global issue, primarily due to inefficient food distribution and consumption management. Improper disposal of food waste in landfills has exacerbated widespread environmental problems. However, with effective waste management strategies, a substantial portion of this waste can be transformed into a valuable renewable energy source (Hossain et al., 2024b). The disposal of biodegradable waste from industries, forestry, agriculture, and livestock contributes to landfill expansion, leading to the release of methane gas, a major driver of GHG emissions. To mitigate this impact, many European countries have enacted landfill bans. Additionally, various types of biodegradable waste can now be converted into chemical compounds and useful products, reducing environmental pollution (Hossain et al., 2024a). If not managed properly, the generation of plastic waste and used cooking oil (UCO) poses a serious environmental risk, contributing to global waste disposal challenges. Simultaneously, increasing energy demand and shifting geopolitical landscapes have made fossil fuel dependency a pressing concern. A promising solution to these dual challenges is the conversion of waste into liquid fuel (Kumar et al., 2024). Furthermore, improper disposal of waste oils disrupts the natural composting of food waste, diminishing its biodegradation efficiency and leading to soil and water pollution (Nkosi et al., 2024).

UCO is cooking oil that has been used multiple times for frying and is ultimately no longer suitable for consumption due to its harmful effects on human health. In addition, UCO can also damage soil, water, and drainage systems when improperly disposed of in the environment. Research by Fujita et al. (2015) revealed that 51% of households dispose of UCO in drainage channels, 17% in soil, 15% give it to household helpers, and 11% rely on city recycling programs. The remaining oil can cause crust formation along the inner surface of pipes, reducing the cross-sectional area, decreasing wastewater discharge, and accelerating blockages. Furthermore, UCO diminishes water quality, which can lead to the decline of aquatic ecosystems, including fish, plants, and other aquatic organisms. UCO also negatively impacts soil composition by causing compaction, reducing absorption, killing essential worms and microbes needed for soil fertilization, and hindering seedling growth. Additionally, UCO affects plant morphology and increases toxic content in vegetation.

According to a report from the Central Statistics Agency in 2021, the average annual per capita cooking oil consumption was 11.58 L/capita/year, reflecting a 12.1% increase from 2015's 10.33 L/capita/year. Several countries with high cooking oil consumption, including China, Malaysia, the United States, Europe, Taiwan, Canada, and Japan, collectively generate 16.54 million tons (Mt) of UCO annually from two primary sources: commercial UCO from hotels, restaurants, and catering services; and domestic UCO produced by households. Cooking oil usage results in 40%–60% UCO production, yet only 18.5% is successfully repurposed. Recent studies have actively explored various methods to utilize UCO, including soap production, asphalt softening, and biodiesel processing (Irsyad et al., 2023). UCO production in Indonesia reaches approximately 1.2 million kiloliters per year, with major cities such as Jabodetabek, Bandung, Semarang, Surakarta, Surabaya, and Denpasar collectively generating around 204.2 thousand kiloliters annually (Sari, 2023). This indicates that Indonesia has an abundant supply of UCO, most of which is exported to European countries for biodiesel processing.

Liquid UCO transitions into gas when heated beyond its boiling point of 175–180 °C (Tamrin, 2013). The flashpoint of UCO ranges between 240–300 °C, while its mass density is 0.898 kg/L. Additionally, UCO has a viscosity of 7–30 Pa·s and a calorific value of 9,197.29 kcal/kg (Hasan et al., 2022). UCO is burned at temperatures exceeding 300 °C, generating a combustible gas that, when supplied with oxygen in a combustion chamber, undergoes complete combustion, producing a stronger flame. The fire generated from burning UCO can be utilized for cooking and heating applications. Based on this concept, a stove fueled by UCO can be developed, which forms the main objective of this research. A stove is a common cooking appliance used in homes and restaurants to heat and cook food. Its role is critical in both domestic and commercial food industries, as it enables proper food preparation and ensures meals are cooked and ready for consumption.

Table 1 shows previous studies on gasification stoves, focusing on heating time and the amount of UCO required to boil water at specific volumes (Suwarno et al., 2024). However, prior studies have not evaluated the performance of gasification stoves using UCO. This study addresses this gap by examining stove performance, including thermal efficiency, Fuel Consumption Rate (FCR), input power, and output power. The goal of this research is to develop a UCO-fueled gasification stove prototype with high thermal efficiency, low FCR, and a balanced input-to-output power ratio. Thermal efficiency determines the stove's cooking quality—greater efficient results in faster cooking times with lower fuel consumption. FCR serves as an indicator of fuel efficiency—a lower FCR value translates to greater fuel economy and optimized stove performance. Input and output power reflect stove efficiency—if both values are equal, the stove operates at optimal efficiency.

Currently, most Indonesian households rely on LPG-fueled stoves, utilizing either 3 kg or 12 kg LPG cylinders. According to the Indonesian Ministry of Energy and Mineral Resources, domestic LPG demand has reached 8 million tons per year, yet Indonesia only produces 1.2 million tons, necessitating imports of 6.7 million tons annually—77% of total consumption. Furthermore, government subsidies continue to support 3 kg and 12 kg LPG cylinders. Increasing LPG demand would result in a greater subsidy burden for both the government and Pertamina (Direktorat Jenderal Minyak Dan Gas Bumi, 2008). Thus, as a contribution of our study, the development of a UCO-fueled gasification stove will support government efforts to diversify LPG usage for cooking purposes.

Table 1. Previous research on UCO stoves.

Previous studies	Boiling Time (Minutes)	Combustion temperature (°C)	FCR (Liters/Hours)	Output power (Watt)
Gasification of UCO in a pressure stove (Tamrin, 2013).	-	252	-	-
Performance and sustainability of UCO stoves for domestic water boiling (Suwarno et al., 2024).	9 (0.5 liters of water)	-	0.1	270

2. Methods and Materials

Figure 1 presents the design scheme of the UCO stove, which consists of a combustion chamber, fuel tank, blower fan, air flow pipe from the blower, and air hole pipe within the combustion chamber. The most crucial components of this stove are the blower and the air hole pipe leading to the combustion chamber, as they determine the intensity of the fire produced. These elements affect the heating speed and duration, directly influencing cooking time.

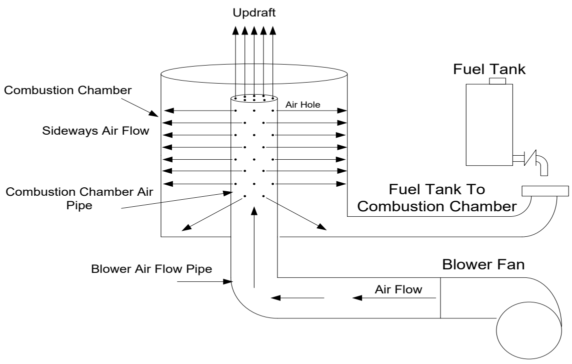

Figure 1. Design scheme of a gasification stove fueled by UCO.

Figure 1 shows that the air holes in the combustion chamber pipe are perpendicular to the pipe, directing the airflow towards the sides or the combustion chamber wall. This design concept aims to optimize the combustion process, ensuring complete combustion within the chamber by maintaining a sufficient air composition, which helps eliminate smoke. Additionally, the fire is guided by the airflow exiting the pipe, directing it towards the combustion chamber wall, where it bounces upwards. This turbulence enhances heat distribution above the combustion chamber. The fire, mixed with the airflow, is then directed upwards by the air entering through the upper pipe holes, ensuring effective heat transfer to the water container, facilitating heating or cooking. Secondly, the fire is directed by the airflow exiting the pipe toward the combustion chamber wall and bounces upwards, creating turbulent heat flow above the combustion chamber. Thereafter, the fire, mixed with the airflow, is directed upwards by the airflow entering through the upper pipe air hole, striking the water container and enabling heating or cooking.

The designed and fabricated UCO stove, shown in Figure 2, undergoes performance testing to evaluate its effectiveness. Experimental prototype testing and the Water Boiling Test (WBT) method are used to assess its performance. The pan used in the testing has a diameter of 18 cm and is made of aluminum, with a thermal conductivity value of 307.7 W/m·K (Prihartono & Irhamsyah, 2022). It has a capacity of 5 liters. The analysis begins with measuring and collecting data on several key parameters, including water volume, fuel volume, water temperature, and boiling time.

Various instruments are employed for measurements: temperature gauges are placed on the furnace to determine the combustion temperature and on the surface of the boiling water to measure its temperature. Additionally, a voltmeter and an ammeter assess electricity consumption, a stopwatch records boiling time, and a measuring cup determines the volume of water and UCO used in the experiment.

Figure 2. UCO gasification stove when boiling 1 liter of water.

Subsequently, the collected data is analyzed using Equations 1–8 to determine thermal efficiency, FCR, input power, output power, and the electrical power generated by the UCO stove. Input energy refers to the amount of energy required, specifically the heat supplied (kcal/hour) Q_n. It is calculated by multiplying the water mass (kg) M_W by the specific energy (kcal/kg) E_S and dividing the result by the cooking time (hours) T, as shown in Equation 1 (Aryansyah et al.. 2022).

$$Q_n = \frac{M_W \,.\, E_S}{T} \tag{1}$$

Sensible heat is the thermal energy needed to raise the temperature of water, measured before and after boiling (Aryansyah et al.. 2022). Sensible heat (kcal) SH is determined by multiplying water mass (1 kg/liter) M_W, the specific heat capacity of water (1 kcal/kg**.** °C) C_P, and the temperature difference between the boiling water temperature (°C) T_f and the initial water temperature before boiling (°C) T_i as shown by Equation 2.

$$SH = M_W \,.\, C_P \,.\, (T_f - T_i) \tag{2}$$

Latent heat is the amount of energy required to evaporate water, calculated using Equation 3 (Aryansyah et al.. 2022). Latent heat (kcal) LH is obtained by multiplying the weight of evaporated water (kg) W_e by 539.4 kcal/kg, which represents the latent heat of water vaporization HFG.

$$LH = W_e \,.\, HFG \tag{3}$$

Heat energy input refers to the thermal energy available in the fuel (kcal) QF, calculated by multiplying the weight of fuel used (kg) WFU by the heating value of the fuel (kcal/kg) HVF, as shown in Equation 4 (Aryansyah et al., 2022).

$$QF = WFU \,.\, HVF \tag{4}$$

Thermal efficiency is the ratio of the calorific value absorbed by the water to the calorific value contained in the fuel (Aryansyah et al., 2022). Thermal efficiency (%) η It is a function of sensible heat (kcal) SH, latent heat (kcal) LH, and the heat energy available in the fuel (kcal) QF, as shown in Equation 5.

$$\eta = \frac{SH + LH}{QF} \,.100\% \tag{5}$$

Fuel consumption rate (kg/hour) FCR is determined by dividing the required heat energy (kcal/hour) Q_n by the heating value of the fuel (kcal/kg) HVF and the thermal efficiency (%) η, as shown in

Equation 6 (Aryansyah et al., 2022). To convert the fuel consumption rate from kg/hour to liters/hour, the value is divided by 0.88, given that 1 kg of UCO is equivalent to 0.88 liters of UCO.

$$FCR = \frac{Q_n}{HVF \cdot \eta} \tag{6}$$

Input power (W) P_i represents the amount of energy supplied to the stove based on the fuel used (Aryansyah et al., 2022). As shown in Equation 7, it is calculated by multiplying the fuel consumption rate (kg/hour) FCR by the heating value of the fuel (kcal/kg) HVF.

$$P_i = FCR \cdot HVF \tag{7}$$

Output power (W) P_o refers to the amount of energy produced by the stove for cooking (Aryansyah et al., 2022). It is a function of input power (W) P_i and thermal Efficiency (%) η, as shown in Equation 8.

$$P_o = P_i \cdot \eta \tag{8}$$

The calculated results are then evaluated to draw conclusions about the stove's performance, including comparisons with other stoves—for example, assessing the output power of UCO stoves in comparison to LPG stoves.

3. Results and Discussions

As shown in Table 2, the experiment was conducted three times for each water volume: 1 liter, 2 liters, and 3 liters. The resulting data was averaged to determine thermal efficiency, FCR, input power, and output power. After the calculations, the thermal efficiency, FCR, input power, and output power were derived and are presented in Table 3. Based on these results, comparison graphs were created to illustrate the relationship between the volume of boiled water and thermal efficiency, FCR, input power, and output power. These graphs were then analyzed to draw conclusions, as discussed in the following section.

Table 2. Measurement results before and after boiling.

Attempt	Before Boiling			After Boiling			Boiling time (Minutes)
	Initial volume of water (Liters)	Initial fuel volume (Liters)	Initial water temperature (℃)	Final volume of water (Liters)	Final fuel volume (Liters)	Final water temperature (℃)	
1	1	0.058	30.9	0.95	0.016	105.8	5.43
2	1	0.059	31.4	0.95	0.017	102.0	3.23
3	1	0.058	30.7	0.93	0.016	104.5	3.21
1	2	0.080	31.6	1.99	0.016	100.1	8.48
2	2	0.080	31.0	1.97	0.017	99.9	10.10
3	2	0.080	31.4	1.92	0.016	102.0	8.38
1	3	0.090	31.0	2.91	0.020	101.0	11.17
2	3	0.090	31.3	2.83	0.020	102.0	13.52
3	3	0.090	31.5	2.89	0.020	104.0	12.48

Table 3. Thermal efficiency, FCR, input power, and output power of the UCO stove.

Volume of water boiled (Liters)	Thermal efficiency (η) (%)	FCR (Liters/hour)	Input power (Pi) (Watt)	Output power (Po) (Watt)
1	30.49	0.60	4,860.63	1,481.28
2	15.54	0.99	8,035.76	1,237.09
3	16.45	1.01	8,246.10	1,344.37

3.1 Thermal Efficiency

Figure 3 compares the volume of water boiled with thermal efficiency. When boiling 1 liter of water, the thermal efficiency is 30.49%. However, for 2 liters and 3 liters, the thermal efficiency decreases to 15.54% and 16.45%, respectively. This decline occurs because the FCR is directly proportional to the volume of water heated—the more fuel used, the higher the FCR. Consequently, the input power increases, leading to a reduction in both thermal efficiency and output power (Aryansyah et al.. 2022).

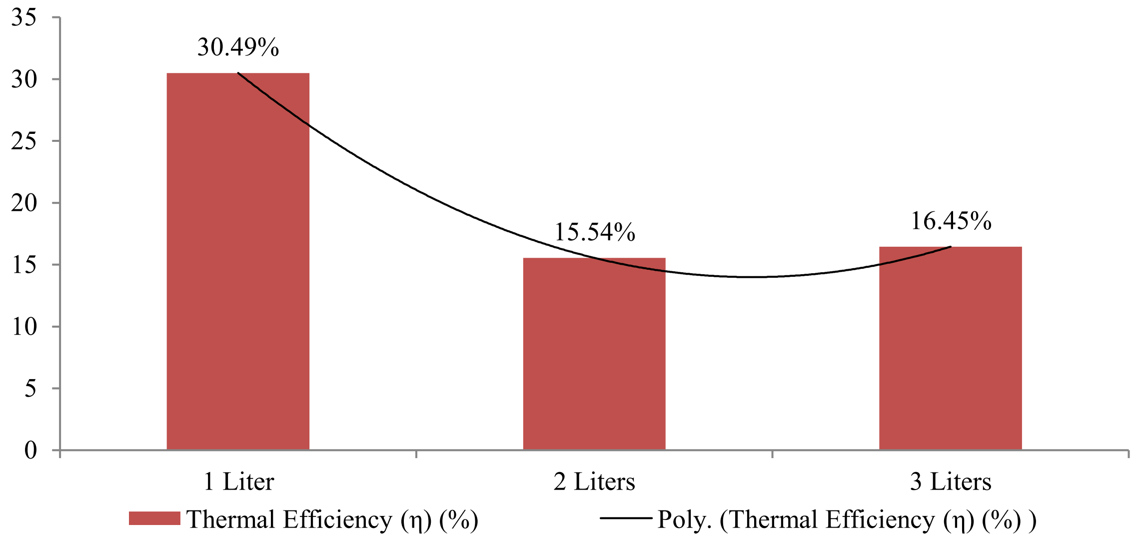

Figure 3. Thermal efficiency.

In previous research by Aryansyah et al. (2022) on biomass stoves, thermal efficiency analysis using the WBT method showed that thermal efficiency improved with increasing water volume. However, in this study, which examined a gasification stove using UCO, data indicate that thermal efficiency decreases as water volume increases. The blower pipe air hole, as shown in Figure 1, is positioned perpendicular to the blower pipe within the combustion chamber. This configuration directs airflow towards the combustion chamber wall, causing the fire to primarily impact the wall rather than directly heating the water container. As a result, the combustion chamber reaches an extremely high temperature of 301.5 °C, while the temperature of the flame directed at the water container is lower, measured at 272 °C.

When heating 2 liters of water, the combustion chamber temperature rises to 494.9 °C, and when heating 3 liters, it reaches 485 °C. At such high temperatures, the combustion chamber wall experiences significant heat transfer, causing the reflected heat directed at the water container to decrease. This results in stagnation in temperature increase for 2- and 3-liter water. Conversely, when heating just 1 liter of water, the combustion chamber temperature remains at 301.5 °C, preventing excessive heat transfer. The temperature of the heated water container reaches 246.6 °C, and the heating duration is only 5 minutes, making the process more efficient in terms of UCO consumption. The lower FCR for 1 liter of water further contributes to this efficiency. The stove's thermal efficiency directly impacts cooking quality. Higher thermal efficiency means shorter cooking times and reduced fuel consumption.

3.2 Fuel Consumption Rate (FCR)

Figure 4 illustrates the FCR of the UCO stove. Analysis shows that UCO consumption increases as the volume of water being boiled rises. For 1 liter of water, the FCR is 0.6 liters per hour; for 2 liters, it is 0.99 liters per hour; and for 3 liters, it reaches 1.01 liters per hour. As more UCO fuel is used, the FCR value increases, leading to lower thermal efficiency. FCR serves as an indicator of efficient fuel usage; the lower the FCR value, the more economical and efficient the fuel consumption, ultimately optimizing stove performance and cooking quality.

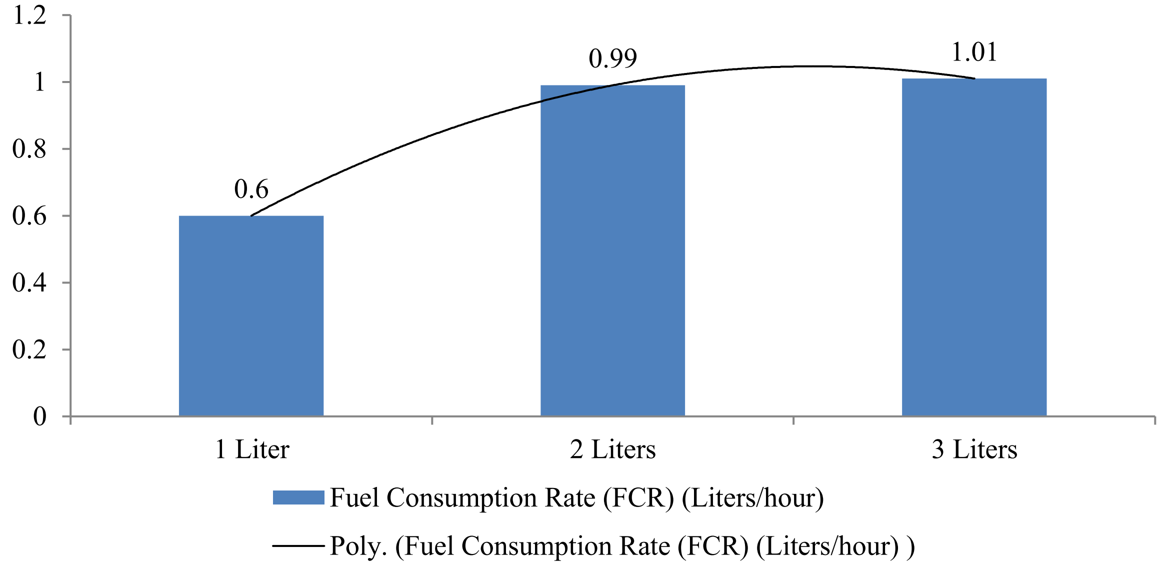

Figure 4. FCR of UCO.

3.3 Input Power (P_{in}) and Output Power (P_{out})

Figure 5 illustrates that input power increases as the volume of water being heated rises. Meanwhile, output power tends to be lower than input power and varies depending on the water volume. For example, heating 1 liter of water requires an output power of 1,481.28 watts; heating 2 liters requires 1,237.09 watts; and heating 3 liters requires 1,344.37 watts. The lower output power compared to input power is due to increased fuel consumption, which raises the FCR and, in turn, reduces output power and thermal efficiency. Based on this study, the highest thermal efficiency value for the UCO stove is 30.49%. In comparison, the thermal efficiency of an LPG stove is 52.85%, with an output power of 2,225 watts (Lubis et al., 2024).

Additionally, an experiment was conducted to compare the temperature and heating time between LPG stoves and gasification stoves using UCO as fuel. In the LPG stove experiment, boiling 1 liter of water resulted in a measured temperature of 263 °C with a heating time of 3.59 minutes. In contrast, boiling 1 liter of water with a gasification stove using UCO reached a temperature of 246.6 °C, with a heating time of 5.24 minutes. From these results, it was determined that the LPG stove's heating temperature was 16.4 °C higher than that of the gasification stove using UCO, and the boiling time with the LPG stove was 1.65 minutes shorter. However, UCO presents advantages as it is derived from vegetable oil waste, which is abundant in Indonesia and can be repurposed as an alternative fuel for stoves. This makes it an environmentally friendly energy solution that enhances renewable energy sustainability. Input and output power indicate stove efficiency; if input and output power are equal, the stove's efficiency is considered optimal.

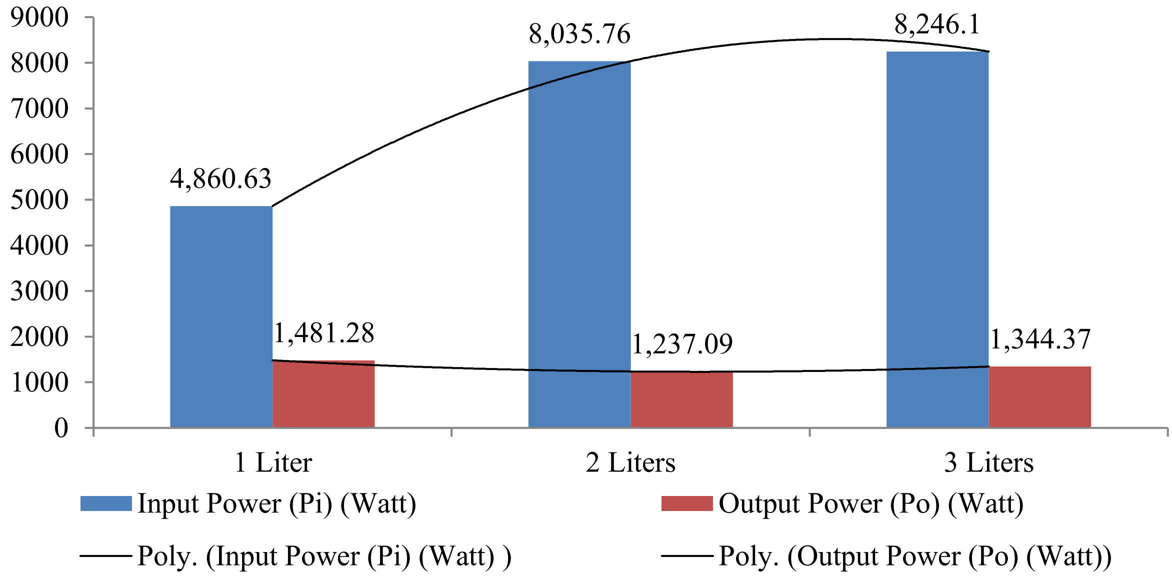

Figure 5. Input power (P_{in}) and output power (P_{out}) of UCO stove.

3.4 Electrical Consumption of UCO Stove

This UCO stove uses an electric blower to deliver pressurized air into the combustion chamber, generating flames with optimal heat. Therefore, it is important to analyze the electricity consumption of this stove. Measurements of the stove's electrical parameters indicate that the blower fan operates at a measured direct-current (DC) voltage of 12.38 volts (DC) and a current of 0.88 amperes (DC), resulting in a power consumption of 10.89 watts (DC). Therefore, the UCO stove is considered energy efficient, as it requires only 10.89 watts of electricity to generate a maximum heat output power of 1,481.28 watts. Low electrical power usage is a strong indicator of the stove's efficiency.

4. Conclusions

In conclusion, when boiling 1 liter of water, the thermal efficiency of the UCO stove was 30.49%. However, as the volume of water increased, thermal efficiency declined to 15.54% when boiling 2 liters and 16.45% when boiling 3 liters. This decrease is attributed to the increase in fuel consumption rate (FCR), which is directly proportional to the growing volume of water heated. The more fuel used, the higher the FCR, leading to lower thermal efficiency. Fuel consumption also rises with increasing water volume. The FCR for boiling 1 liter of water is 0.6 liters per hour; for 2 liters it is 0.99 liters per hour; and for 3 liters it reaches 1.01 liters per hour. As more UCO fuel is consumed, the FCR value increases, contributing to reduced thermal efficiency.

Additionally, input power increases as the volume of heated water grows, whereas output power remains lower than input power. Heating 1 liter of water requires an output power of 1,481.28 watts; heating 2 liters requires 1,237.09 watts; and heating 3 liters requires 1,344.37 watts. The lower output power compared to input power is a result of increased fuel consumption, which raises FCR and reduces thermal efficiency. Despite this, the UCO stove demonstrates energy efficiency, as it requires only 10.89 watts of electricity to generate a maximum heat output power of up to 1,481.28 watts, operating at a measured voltage of 12.38 volts (DC) and a current of 0.88 amperes (DC).

To optimize the heat of the fire, it is necessary to redesign the stove, especially the nozzle air hole from the blower, so that the fire can be directed directly upwards to the heated container, and not the fire resulting from the reflection of the combustion chamber wall. By changing the design of the stove, it will allow the fire to hit directly the heated water container, so that heating becomes faster, and the fuel used is more efficient. We determined that the blower pipe air hole is positioned perpendicular to the blower pipe within the combustion chamber. Consequently, airflow from the pipe directs flames toward the combustion chamber wall, causing most of the fire to hit the chamber wall rather than directly heating the water container. The reflected flames then reach the container, contributing to inefficiencies in heat transfer. This design results in a combustion chamber temperature of 301.5 °C, while the temperature of the fire reaching the boiling water container is lower, at 272 °C. To optimize heat transfer, a redesign of the stove—particularly the nozzle air hole of the blower—is necessary. Adjusting the nozzle design to direct flames upwards toward the heated container, rather than relying on reflected fire from the combustion chamber wall, would improve heating speed and fuel efficiency.

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