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Effectiveness of Electric Heaters on Stoves Fueled by Used Oil

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***Abstract*— This research aims to analyze the effectiveness of designing a stoves using used fuel oil, which has the ability to burn faster and produce less smoke. The findings show that used oil becomes more flammable as its temperature increases. Therefore, in this research, an electric heater was added to heat the oil before the oil enters the combustion chamber. The method used in this research was experimental. The experiment involved heating the oil using an electrical system at temperatures of 80°C, 100°C, and 120°C. Each test was conducted three times to calculate the combustion rate, fuel consumption, stove power, and thermal efficiency, using the average results from each experiment. The results indicate that when the stove uses used oil to boil 1 liter of water, the flame temperature varies according to the oil's heating temperature. At 120°C, the flame temperature reaches 530.5°C; at 100°C, it reaches 501.2°C; and at 80°C, it reaches 476.7°C. The highest burning rate was recorded at 7.62 grams per minute, with a cooking time of 5.46 minutes for 1 liter of water at 80°C. At 100°C, the cooking time was 5.30 minutes with a burning rate of 7.57 grams per minute, while at 120°C, the burning rate was 7.50 grams per minute with a cooking time of 5.16 minutes. The shortest boiling time for 1 liter of water was achieved at an oil heating temperature of 120°C, taking 310 seconds. The boiling times at 100°C and 80°C were 318 and 328 seconds, respectively. In terms of fuel consumption, the most efficient operation occurred at 120°C with a consumption of 0.144 ml/s, followed by 100°C at 0.146 ml/s and 80°C at 0.147 ml/s. The maximum power output of the stove when heating 1 liter of water was recorded at 80°C, reaching 48,140.80 Watts. At 100°C, the power produced was 47,353.57 Watts, while at 120°C, it reached 47,212.39 Watts. The highest thermal efficiency was measured at 120°C with a value of 3.33%, followed by 100°C at 3.21% and 80°C at 2.83%.**

Keywords— ***Heater; electricity; stove; used oil***

I. INTRODUCTION

The increasing demand for sustainable energy solutions has led to growing interest in alternative fuel sources such as waste cooking oil and waste engine oil. Many households and industries discard used oil, which poses environmental hazards. Utilizing this waste as fuel can provide an eco-friendly and cost-effective energy source (Hilda et al., 2023).

The following is previous research that has investigated the potential of used cooking oil as a fuel source. Jambhulkar et al. (2015) analyzed the performance of stoves using spent cooking oil and found that oil preheating improved combustion efficiency. Bhatt and Shrivastava (2022) explored the effects of preheating on ternary biodiesel blends, reporting increased thermal efficiency and reduced emissions. Masoud et al. (2023) examined flame characteristics of preheated waste cooking oil in a jet combustor, showing improved stability and lower pollutant emissions. Bond and Merrin (2022) discussed the application of various heating technologies in cooking appliances, highlighting electric preheaters as a means to enhance fuel efficiency. Srinivasan et al. (2022) investigated fuel preheating effects on biodiesel engines, noting improved combustion and performance metrics. Farid et al. (2023) evaluated the impact of blowers on stoves fueled by used oil, indicating that airflow enhancement contributes to more stable combustion. Singh et al. (2021) developed an energy-efficient oil-fired tilting furnace, demonstrating how recuperators can optimize fuel use. Yadav et al. (2024) performed a cost-performance analysis of preheated waste oil, confirming economic and thermal benefits. Zhao et al. (2020) assessed direct combustion of waste oil using an internal heat recirculation technique, showing promising reductions in emissions and fuel wastage.

Despite advancements in waste oil utilization, limited studies have specifically examined the role of electric heaters in enhancing combustion performance in household stoves. Most research has focused on biodiesel applications or industrial-scale combustion rather than small-scale cooking appliances (Rahmadani & Lumbantoruan, 2023).

This study introduces an electric heater to preheat waste oil before combustion, a technique not extensively explored in existing literature. By systematically analyzing its impact on combustion rate, fuel efficiency, and emissions, this research bridges the gap between industrial preheating techniques and household cooking applications.

The findings contribute to the development of more efficient and environmentally friendly cooking stoves, reducing waste oil disposal issues and promoting sustainable energy use. This study can inform stove design improvements and policy-making to encourage the adoption of waste oil as a viable fuel source (Aris, 2023).

Compared to previous studies, this research highlights the enhanced efficiency of stoves using electric preheaters. While Jambhulkar et al. (2015) demonstrated that preheating waste cooking oil improved combustion efficiency, their study lacked a detailed analysis of specific temperature variations. Bhatt and Shrivastava (2022) focused on ternary biodiesel blends rather than direct combustion of waste oil, making this study more relevant for practical stove applications. Similarly, Masoud et al. (2023) emphasized flame characteristics but did not analyze cooking time and power consumption, which are critical factors in household use. Bond and Merrin (2022) acknowledged the potential of electric preheaters but did not apply them specifically to waste oil stoves.

This study extends previous findings by systematically analyzing different preheating temperatures and their direct impact on combustion rate, power output, and thermal efficiency. Unlike Yadav et al. (2024) and Zhao et al. (2020), who explored economic feasibility and emissions reduction, respectively, this research provides a more comprehensive evaluation by integrating thermal performance and combustion characteristics.

II. METHOD

The method used in carrying out this research is the experimental method. Carrying out experimental research means that the process involves searching for the influence of certain variables under strictly observed and controlled conditions. Research using this method means carrying out experiments directly to search for and confirm data on variables that change over time. this research. The purpose of this research is to analyze the combustion rate on used oil stoves using electric heaters.

Experimental procedures

1. Prepare tools and materials before carrying out the data collection process.

2. Put 1 liter of oil into the oil tank, then heat the oil according to the temperature variations here using temperatures of 80°C, 100°C, 120°C, setting the temperature on the Rex C100 digital thermostat.

3. When it is at the desired temperature, turn the tap to release the heated oil in the tank, then distribute it using a pipe and go to the furnace and mix in a little gasoline.

4. then light the oil burner using a match.

5. Collect data and record the data needed in the research.

6. The experiment was repeated three times, and the average results were used to obtain the best results.

Data collection procedures

1. Before collecting data, first set the thermostat temperature to the temperature that will later be used for research, namely: 80°C, 100°C, 120°C. and each temperature will be tested three times, and the average results will be used to get the best results and will be used to calculate the burning rate. The mass of oil before burning is 1 liter, then the data that will be taken later is the mass of oil after burning, flame temperature, boiling water temperature, boiling time.

2. To make it easier to retrieve the data, it will later be entered into a table to make it easier to carry out calculations later.

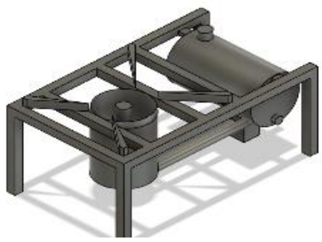

Figure 1. Design of used oil stove test equipment with additional heater

III. RESULTS AND DISCUSSION

Before carrying out the testing and data collection process, the tool is tested first and each component is checked to see whether

it is functioning properly to ensure that the fuel oil stove test tool can run well without any problems during the data collection process. This testing process involves testing the electric heater to see whether it can conduct heat, checking the oil flow from the tank to the furnace, testing the stove flame and checking the air blower.

After determining the wind speed fan that will be used during the research, then prepare the fuel, namely used oil. The used oil is put into the fuel tank which will then be preheated to the desired temperature then when the oil is hot it flows through the tap through a pipe to the combustion furnace. Then the tap is adjusted so that it does not flow too much or according to the burning needs in the stove. The process of lighting the stove in the combustion chamber requires a trigger, namely a match and 10ml pertalite to ignite the fire which is inserted into the stove burner so that the oil can burn. After burning, the blower is turned on with an adjusted speed setting The following is the test results data in Table 1.

TABLE I. STOVE TEST RESULTS DATA WITH VARIATIONS IN OIL HEATING

Oil Heating Temperatur (°C)	Test to	Initial water Temp (°C)	Oil Volume before combustion (ml)	Oil Volume after combustion (ml)	Flame Temp (°C)	Boiling Water Temp (°C)	Time the water boils (min.s)
80°C	1	30.1	1000 ml	952	468.6	96.9	5.58
	2	30.0	1000 ml	951	496.7	99.3	5.44
	3	30.0	1000 ml	951	489.1	97.1	5.36
Rata-rata		30.0	1000ml	951.3	484.8	97.7	5.46
100°C	1	30.1	1000 ml	955	515.0	102.5	5.23
	2	30.0	1000 ml	954	500.1	99.9	5.44
	3	30.0	1000 ml	951	508.4	101.3	5.27
Rata-rata		30.0	1000ml	953.3	507.3	101.2	5.30
120°C	1	30.1	1000 ml	955	538.6	103.9	5.22
	2	30.1	1000 ml	955	530.1	102.6	5.16
	3	30.0	1000 ml	955	549.4	105.1	5.11
Rata-rata		30,1	1000 ml	955.0	538.7	103.8	5.16

The following is a figure of the test results for a stove made from used oil.

Figure 2. The flame from the test results of a stove fueled by used oil

From the test and calculation data, it can be analyzed using graphs to make a conclusion regarding the effect of the oil heating temperature of 80°C, 100°C and 120°C to get good fire temperature results as well as combustion rate, air cooking time, as well as stove power and also the stove's thermal efficiency. Here are some graphic analyzes:

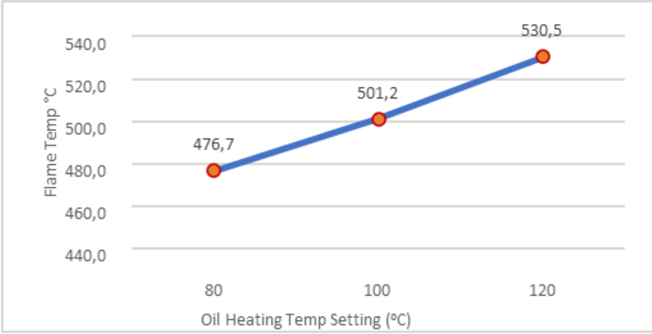

Figure 3. Graph of Oil Heating Setting Against Flame Temperature

In the graph above, it can be seen that the oil heating temperature has an effect on the flame temperature produced on the used oil fuel stove. The highest average temperature for boiling 1 liter of water is when it boils with an oil heating setting of 120°C, the fire burns up to a temperature of 530.5°C, while at an oil temperature setting of 100°C the fire burns up to a temperature of 501.2°C, and at the oil heating setting of 80°C the flame burns to a temperature of 476.7°C.So the largest flame temperature is the oil heating setting of 120°C.

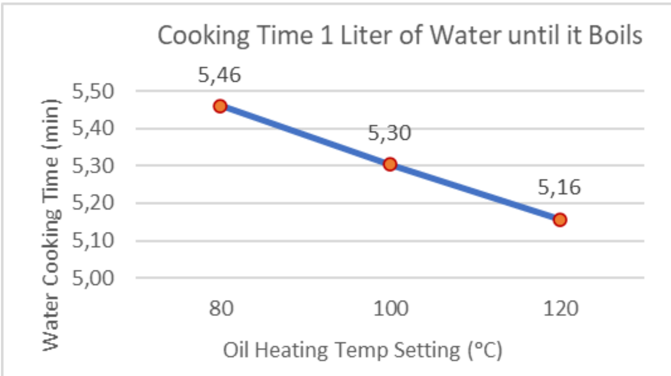

Figure 4. Graph of Oil Heating Setting Against Water Cooking Time

From graph 4 it can be concluded that the time required to cook 1 liter of water, the fastest time is obtained by using an oil heating temperature of 120°C with a time of 5 minutes 15 seconds, then by heating the oil with a temperature of 100°C the time is 5 minutes 30 seconds. seconds, and at a setting of 80°C the time obtained is 5 minutes 46 seconds

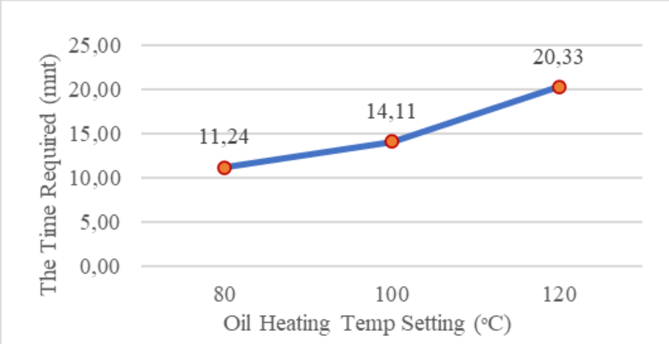

Figure 5. Graph of Oil Heating Setting Against The Time Required for the oil to warm up

The graph shows the time it takes to heat the oil from the initial temperature of 34°C to the oil temperature of 80°C, namely 11.23 minutes, then at 100°C, namely 14.11 minutes, and for 120°C with a time of 20.33 minutes.

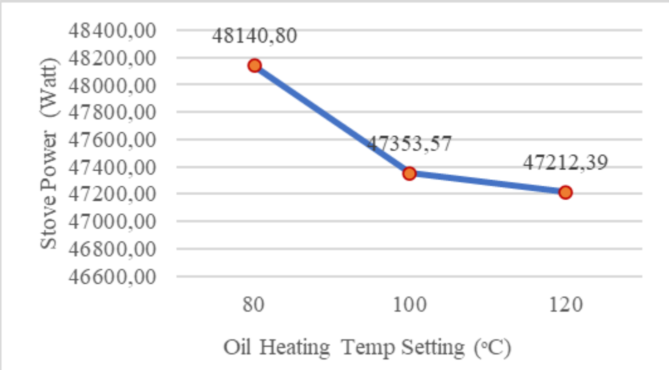

Figure 6. Graph of Oil Heating Setting Against Used oil Stove Power

In graph 6, it can be seen that the greatest power produced by the stove when cooking 1 liter of water is by heating the oil at 80°C, which reaches 48,140.80Watts, then at 100°C it reaches 47,353.57 Watts, and at 120°C it reaches 47,212.39 Watts

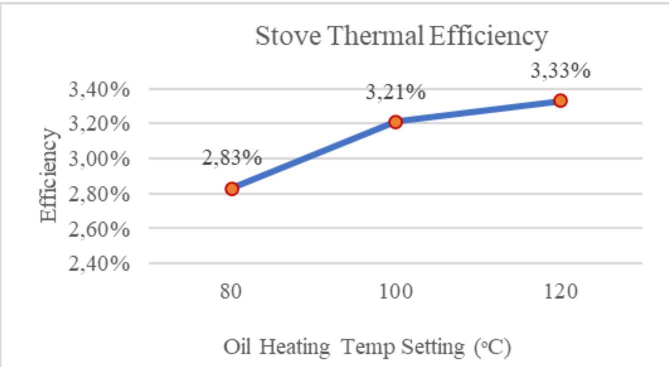

Figure 7. Graph of Oil Heating Setting Against Stove Thermal Efficiency

The graph above shows that the thermal efficiency of the stove for cooking 1 liter of water until it boils is greatest at a heating temperature of 120°C, namely 3.33%, then an oil heating temperature of 100°C is 3.21% and for 80°C it is 2.83%.

IV. CONCLUSIONS

The research findings demonstrate that integrating electric heaters into used oil stoves significantly enhances combustion efficiency, reduces fuel consumption, and improves thermal efficiency. The highest thermal efficiency was observed at 120°C, where the flame temperature reached 530.5°C, resulting in faster cooking times and reduced emissions. However, the study also revealed that increasing oil heating temperature slightly decreased power output. Despite this, the overall benefits of preheating, such as improved energy transfer and optimized fuel use, outweigh the drawbacks.

For further research, it is recommended to explore ways to shorten the preheating duration without compromising efficiency. Investigating alternative heating technologies, such as induction or infrared heating, could enhance performance. Additionally, future studies could focus on optimizing fuel-air mixing and burner design to further improve stove efficiency and minimize heat loss. Long-term durability testing and economic feasibility studies should also be conducted to assess the practicality of large-scale implementation of this technology..

REFERENCES

[1] M. Aris, "Optimasi Pembakaran Minyak Jelantah/Waste Cooking Oil dengan Penambahan Preheater pada Burner dan Filtrasi pada Minyak Jelantah," Doctoral dissertation, Universitas Lampung, 2023.

[2] A. N. Bhatt and N. Shrivastava, "Experimental Investigation and Neural Network Modelling of Diesel Engine Using Hexanol Blended Ternary Waste Cooking Oil Biodiesel with Moderate Preheating," *Sustainable Energy Technologies and Assessments*, vol. 52, p. 102285, 2022.

[3] T. C. Bond and Z. Merrin, "Appliances for Cooking, Heating, and Other Energy Services," in *Handbook of Indoor Air Quality*, Singapore: Springer Nature Singapore, 2022, pp. 1-36.

[4] A. Farid, H. Wibowo, A. Wibowo, R. Hidayat, M. Mustaqim, I. Santosa, and B. Hermani, "Peningkatan Kualitas Nyala Api pada Kompor Blower Rumah Tangga Berbahan Bakar Minyak Jelantah," *Jurnal Engineering*, vol. 14, no. 2, pp. 1-7, 2023.

[5] L. Hilda, R. Lubis, S. T. Syafiruddin, L. S. Nada, and G. R. Arafah, *Renewable Energy: Oli Bekas sebagai Bahan Bakar*, Samudra Biru, 2023.

[6] G. Jambhulkar et al., "Performance Evaluation of Cooking Stove Working on Spent Cooking Oil," *International Journal of Emerging Science and Engineering*, vol. 3, no. 4, pp. 26-31, 2015.

[7] S. M. Masoud, A. M. Attia, H. Salem, and R. M. El-Zoheiry, "Investigation of Jet A-1 and Waste Cooking Oil Biodiesel Fuel Blend Flame Characteristics Stabilized by Radial Swirler in Lean Pre-Vaporized Premixed Combustor," *Energy*, vol. 263, p. 125830, 2023.

[8] W. Rahmadani and P. Lumbantoruan, "Pemanfaatan Oli Bekas untuk Bahan Bakar Kompor sebagai Energi Listrik Alternatif dengan Prinsip Termoelektrik," *Jurnal Redoks*, vol. 8, no. 2, pp. 141-151, 2023.

[9] P. Singh, H. Singh, and A. K. Singh, "Design and Development of an Energy-Efficient Oil-Fired Tilting Furnace with an Innovative Recuperator," *International Journal of Metalcasting*, pp. 1-13, 2021.

[10] G. R. Srinivasan et al., "Effect of Fuel Preheating on Engine Characteristics of Waste Animal Fat-Oil Biodiesel in Compression Ignition Engine," *Polymers*, vol. 14, no. 18, p. 3896, 2022.

[11] P. S. Yadav, S. Kumar, and R. Gautam, "A Comprehensive Analysis on Cost, Combustion, Performance and Emissions for Diesel Engine Fueled with Preheated Esters of Waste Cooking Oil," *Clean Technologies and Environmental Policy*, pp. 1-21, 2024.

[12] N. Zhao et al., "Direct Combustion of Waste Oil in Domestic Stove by an Internal Heat Re-Circulation Atomization Technology: Emission and Performance Analysis," *Waste Management*, vol. 104, pp. 20-32, 2020.