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Production of oil from plastic waste through thermal degradation process

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Abstract

The production of bio-oil from plastic waste through the thermal degradation process is a sustainable and innovative approach that addresses both environmental and waste management challenges. Pyrolysis is one of the thermal degradation processes that involve heating organic materials in the absence of oxygen, leading to the decomposition of complex organic compounds into simpler products, including bio-oil. In this study, healthcare waste, which typically consists of various organic materials such as medical plastics, syringes, bandages, and medical glucose bottles among other disposable items, is considered. Among these, medical glucose bottles are chosen as feedstock for pyrolysis due to their significant contribution to daily waste in the medical field and their negligible environmental and human health concerns. The pyrolysis process involves heating the medical glucose bottles to high temperatures between 400 and 500 °C in a controlled environment. This conversion process results in the production of bio-oil, char, and gases from the medical glucose bottles. The maximum yield rate of medical glucose bottle waste (MGBW) oil at 450°C of heating temperature will be solid (21%), liquid (27%), and gas (43%), with a calorific value of 42.5 MJ/kg, which is comparable to diesel. The bio-oil obtained from this process has several potential applications, such as in furnaces, and it can also be suitable for CI engines as an alternative fuel.

1. Introduction

Global plastic production has skyrocketed beyond 368 million metric tons per year, leading to an unprecedented environmental crisis. Celebrated for their durability and versatility, plastics have weaved themselves into all human life activities and economies, from packaging, consumer goods to industrial applications. However, these very characters equate them to a recalcitrant and unequivocal in their environmental compartments, where degradation might take several centuries, resulting in serious environmental pollutions [1]. The quantity of plastic waste lays an increasing threat to marine life, disturbance in food chains, and to the whole environment as a result of generation in landfills and oceans [2].

Traditional strategies to manage waste—land-filling and incineration—have not proven to be very effective ways for managing this growing problem of plastic waste. Landfilling literally means to bury in the ground. Among the many types of land-management infrastructures, landfilling stands out as one with the most serious cases of land occupation and long-term environmental risks, due to possible leachate contamination and GHG emission. Incineration reduces the volume of waste but causes the emission of hazardous pollutants including dioxins, furans, and heavy metals into the atmosphere, which poses serious harmful health and environmental impacts. These problems have called for the development and use of more effective and sustainable means of managing plastic wastes over the years.

In recent years, there has been an increasing focus from researchers on converting plastic waste into products through methods such as thermal degradation or pyrolysis. Pyrolysis is a thermochemical route based on the cracking of organic materials — mainly plastic waste — at high temperatures without any supply of oxygen. Pyrolysis of the organic constituents of the polymer decomposes the long polymeric chains into low molecular weight pyrolytic liquid, yielding gaseous and solid products. That pyrolytic oil can be further refined into several different types of fuel, including diesel and gasoline, thus presenting both a double benefit in waste reduction and energy recovery.

Much efforts have centralized on the potential of pyrolysis as a solution for plastic waste problem, where many studies proved it to be effective for the conversion of wide varieties of plastic wastes, including polyethylene and polypropylene, into high-quality oil. The described process is influenced by temperature, heating rate, type of reactor, and the presence of catalysts, among other parameters, linked to the pyrolytic oil composition and yield [3]. For example, it is evidenced that an increase in the pyrolysis temperature enhances the yield of liquid hydrocarbons in general, but, on the other hand, several studies showed that this means an increase in the amount of gaseous by-products produced [4],

Another approach that has been taken to increase the quality of pyrolytic oil content and minimize unwanted by-product formation is catalytic pyrolysis, in which catalysts aim to decrease the activation energy of the pyrolysis reaction. Catalysts such as zeolites, alumina, and silica-alumina promote selectivity of reaction to lighter production of hydrocarbons, which are more desirable as fuel constituents [5]. Besides, catalysts can reduce the pyrolysis temperature, which in turn reduces the energy requirements of the process and makes the whole process economical, too [6].

Despite these optimistic results, there are still many challenges that regard plastic waste pyrolysis. One of the main problems is related to the fact that plastic waste streams are highly heterogeneous and often consist of a mixture of different types of plastics contaminated with food residues and other non-plastic waste materials, which consequently affects variability in the efficiency of the pyrolysis process and quality of the resulting pyrolytic oil. As a solution to this, the focus of researchers turned to the effect of pretreatment operation, such as washing, sorting, shredding, on the pyrolysis process itself, or generally handling the feed to clean it of contaminants as source of lowered measures of inconsistent nature of feedstocks, which leads to more predictable and higher-added quality outputs. Contaminants may be reduced with this increased predictability in feedstock, hence it provides a consistent nature of feedstock, lowering quality deterioration [7].

The second challenge is solid and gaseous by-product management. The solid residue, also known as char, is generally carbon-rich and can be used either as a fuel or to improve the soil [6]. However, the importance needs to be given to how it is disposed of and its use to avoid the environment from any kind of devastation. Moreover, the gaseous by-products, chiefly made of non-condensable hydrocarbons like methane, ethylene, and propylene, can be used as a fuel for the pyrolysis process, which will be just more appreciable overall energy efficiency [8]. However, in the presence of poisonous gases, e.g., hydrogen chloride produced from the pyrolysis of PVC, it could be a health danger where proper gas-cleaning technology is required [9].

Pyrolytic oil finds its potential utility not just as a fuel. Some studies have researched the use of pyrolytic oil for manufacturing aromatics, olefins, and waxes, for example, from the feedstock in chemicals with a known value in the petrochemical industry [10]. To this, an additional overall value is enabled to the process of pyrolysis and the development of a circular economy where waste materials are recycled continually into other products [11].

The pyrolysis of plastic waste is also in line with the global imperative of reducing dependence on fossil fuels and mitigating climate change, besides being environmentally friendly and economically sound. With the conversion of plastic waste into oil, pyrolysis offers an alternative source of energy that may very well substitute part of the usual fossil fuels, thus reducing greenhouse gas emissions [12]. In this way, pyrolysis, as a waste management practice, could be brought forward to make the economy more sustainable and contribute to the international agreement by which environmental goals, such as the ones set by the Paris Agreement, could be met [13-20].

This research aims to identify the parameters effecting yield and quality of oil produced through thermal degradation to understand the optimization of the pyrolysis process, making it applicable on a large scale. In this way, the study shows to advance along with technology, being in the development of sustainable solutions for waste management by plastics and supporting the transition toward a circular economy. Such research results may have stronger implications for the waste management industry and the wider energy sector, underlining the potential role of pyrolysis at the core of efforts to alleviate the crisis of global plastic wastes.

1.1 Healthcare Waste Generation

Medical waste generation is the generation of waste in the medical sector, including hospitals, clinics, laboratories, and other medical facilities. Medical waste, also referred to as bio-hazardous waste or medical waste in general, is unique in its composition and may contain infectious and other dangerous substances; therefore it requires special treatment and disposal methods is required. The generation of medical waste is influenced by a variety of factors, so understanding and managing this waste is critical to public health and environmental safety.

1.1.1 Plastic Waste:

- Single-Use Plastics: Many healthcare things are planned for single utilize to avoid cross-contamination. This incorporates plastic syringes, intravenous packs, tubing, and different disposable medical gadgets.

- Packaging Materials: The bundling of restorative supplies and pharmaceuticals regularly includes plastic materials. This incorporates rankle packs, plastic wraps, and holders.
- Individual Defensive Gear (PPE): PPE such as expendable gloves, covers, outfits, and confront shields are commonly made from plastic materials to supply a boundary against diseases.

1.1.2 Non-Plastic Wastes:

- Paper and Cardboard: Regulatory and office waste, as well as packaging for a few restorative supplies, may incorporate paper and cardboard.
- Materials: Utilized cloths, clothing, and other materials from understanding care contribute to non-plastic squander.
- Glass: A few therapeutic gears, such as certain research facility instruments or glass holders for solutions, may produce glass squander.
- Metal: Surgical disobedient, plate, and other metal therapeutic gadgets contribute to metal squander.
- Sharps: Needles, surgical tools, and other sharp objects, in spite of the fact that regularly made of metal, are categorized independently due to their potential for causing harm and carrying contaminations.

1.2 Thermal Degradation

Thermal degradation refers to the breakdown of a material due to exposure to high temperatures. This process can occur in various substances, including polymers, organic compounds, and even biological materials. The mechanisms and outcomes of thermal degradation depend on the specific material involved. Thermal degradation of polymers refers to the "molecular weakening caused by overheating." At elevated temperatures, the long-chain backbone components of the polymer can start to break apart (molecular scission) and interact with each other, leading to changes in the polymer's properties. This process is one aspect of a broader range of degradation mechanisms that polymers can experience due to various factors, including:

- Heat (thermal degradation and thermal oxidative degradation when oxygen is present)
- Light (photodegradation)
- Oxygen (oxidative degradation)
- Weathering (typically UV degradation)

1.3 Slow Pyrolysis

One of the earliest methods of pyrolysis involves slowly heating the feedstock at a low temperature below 400°C, in the absence of oxygen, over the course of several days. The maximum amount of char is produced through this moderate heating process. Torre faction and carbonization are additional categories for the moderate pyrolysis process. The Torre faction process operates at very low, carefully controlled temperatures (200°C-300°C) and involves a shorter residence time compared to the carbonization process, which functions at higher temperatures (over 300°C to 400°C). During the carbonization process, the feedstock or CW undergoes slow pyrolysis, resulting in highly stable carbonaceous products like charcoal or char, along with non-condensable gases that are excellent fuels. Charcoal has long been used as a reductant in the metallurgical industry's purification and sintering processes. Char, produced by moderate pyrolysis, also generates activated carbon as a byproduct and is known for its high porosity. Thermal Torre faction transforms the feedstock or CW into coal-like materials that are extremely brittle, require less energy, and can also be burned as fuel.

2. Method

2.1 Material Selection

We choose medical glucose bottles (**Figure 1**) due to their significant waste generation in day-to-day hospital activities. Additionally, they are specifically designed containers for storing glucose solutions in the medical field, ensuring that they do not cause any issues for the environment or humans during the process. These bottles are typically made from materials such as polyethylene terephthalate (PET) or polypropylene. Therefore, medical glucose bottles are chosen as the feedstock for the pyrolysis process. The materials were obtained from several hospitals in Villupuram and Vadalur. Before the process, all materials are cut into 5-10 mm blocks with scissors.

Figure 1. Medical glucose bottles wastes (MGBW)

2.2 Pyrolysis Oil Production Method

Low-heating-rate, or slow, pyrolysis of late is a thermochemical process that finds wide interest due to its potential in converting biomass and organic waste materials to valuable products such as biochar, bio-oil, and syngas. This process works by increasing the feedstock's temperature in the absence of air, which prevents combustion and allows the materials to thermally crack into fractions. Pyrolysis oil, also known as bio-oil, is one of the major products in this process that might offer sustainable options for energy generation and chemical production.

The slow pyrolysis is in a relatively low temperature range, usually 400–600 °C, and a slower heating rate compared to other pyrolysis techniques, for example, fast pyrolysis or flash pyrolysis. The most benefitting point of this is the extended retention time at moderate temperature that assures the controlled thermal degradation of the feedstock [21]. This results in producing biochar primarily and bio-oil and syngas as secondary products. Because of its controlled and gradual nature, slow pyrolysis is outstandingly effective at making biochar—an extremely carbon-rich solid useful in the restoration of soil, carbon removal, and renewable energy sources [22-24].

Bio-oil may be described as a complex blend of water, organic acids, alcohols, aldehydes, ketones, phenols, and other oxygenated compounds that are produced from slow pyrolysis. It yields dark brown, viscous liquid that can either be directly used as a fuel or further upgraded to more valued chemicals. Bio-oil composition and quality vitally depend on feedstock kind, temperature conditions, and heating rate at pyrolysis. For instance, woody biomass often yields a bio-oil that is of high energy content and low in water content; hence it is much more viable for applications in fuels.

Besides bio-oil, the slow pyrolysis process produces syngas, which is a mixture of gases and consists mainly of carbon monoxide, hydrogen, methane, and carbon dioxide. On the other hand, syngas can be used as a fuel for the generation of heat or power, while it may act as a feedstock in chemical synthesis. It has, on other occasions, lower yields and energy contents, especially when associated with slow pyrolysis, usually due to the low temperature and slow heating pace. Still, its yield makes up a high ratio of the entire product, contributing to the total energy efficiency brought about by the process. Perhaps, one of the most critical advantages of slow pyrolysis is that it can carbon sequestrate into a biochar. Biochar is a stable, carbon-rich solid that can stay in the soil for hundreds to thousands of years; it is considered a carbon sink. That forms a really important byproduct under slow pyrolysis, other than carbon sequestration, as a soil-fertility enhancer, water-retention enhancer, and enhancer of soil microbial activities.

Although the characteristics and yield of bio-oil from slow pyrolysis are challenging in their own right, the process tends to yield high-oxygen-content bio-oil, which results in minimizing the energy density and stability of the oil. Thus, additional upgrading or refining would be necessary to make it suitable for use either as transport fuel or for high-value applications. These research works are on various upgrading methods such as catalytic upgrading, hydrogenation, and blending with conventional fuels for quality improvement of the bio-oil and to explore more usage of this.

Slow pyrolysis is a flexible and sustainable method for processing biomass, organic wastes, and other waste products into a triplet product of biochar, bio-oil, and syngas. It is a potential tool that will have a major role in waste management, renewable energy production, and carbon sequestration[25-26]. However, the optimization of yield and quality of bio-oil face several challenges, while the ongoing research and technological advancements are improving efficiency and viability for large-scale applications.

2.3 Slow Pyrolysis Process Set-Up

Figure 2 reveals that the basic setup for a pyrolysis experiment or even a small-scale pyrolysis unit. The apparatus shown here is usually used to convert materials, like plastic wastes, into oil through their thermal degradation [27].

Probably, the large cylindrical vessel on the left acts as a reactor vessel where plastic waste is most likely heated without oxygen to initiate the process of pyrolysis[30]. The vessel is most likely sealed to shut off oxygen from entering into the system, something very important if one wants to ensure that the process would result in pyrolysis rather than combustion.

Condensation Unit: All this, with the attached tubing and associated parts, appears to be a condensation system. These green and transparent tubes may pipe these gases, which emanate as by-products from the reactor due to the process of pyrolysis, out into some cooler area where they condense into liquid oil.

Collection Container: On the right, the small metal container should catch the condensed oil. This container collects some liquid product after having passed through cooling and then condensing the gaseous by-products.

Heating Source: Below the reactor vessel, there is a small structure that could act as the source of heat in the reactor, raising its temperature to start the pyrolysis process.

Figure. 2 slow pyrolysis process set-up.

3. Results

The production of bio-oil from healthcare waste through pyrolysis is an innovative and environmentally significant process with the potential to address waste management and energy needs. Below is a hypothetical results and discussion section for such a study:

The MGBW oil temperature range will be analysis by the TGA (Thermo Gravimetric Analysis) in Graph in **Figure 3**, Proximate analysis in **Table 2**, Ultimate analysis in **Table 1**, oil yield (%) at temperature range will be analysed by chart in **Figure. 4** and **Table 3** and also analysis the properties of MGBW oil in **Table 4**, such as calorific value, density, viscosity, flash point and pour point.

3.1 Thermo Gravimetric Analysis (TGA)

The thermo gravimetric analysis (TGA) will be analysed the temperature of medical glucose wastes in between 400 ⁰C TO 600 ⁰C by using graph is given below in **Figure 3** TGA curve for Waste Medical Glucose Bottle.

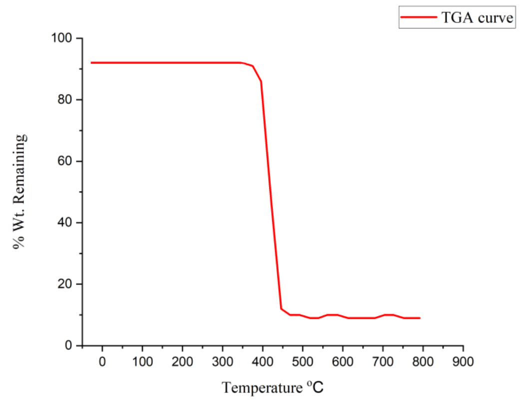

Figure 3 TGA curve for Waste Medical Glucose Bottle

3.2 Ultimate and Proximate Analysis:

Ultimate and proximate analysis MGBW is very important to determine numerous properties of MGBW such as carbon, hydrogen, nitrogen, sulphur in elemental analysis shown in **Table 1** and moisture, volatile matter, ash, fixed carbon in proximate analysis shown in **Table 2.** The heating rate and volatile constituents are the vital factors for MGBW pyrolysis

The ultimate analysis for Medical Grade Bottle Waste (MGBW) reveals its elemental composition in **Table 1**. Carbon constitutes the highest proportion at 84.71%, followed by hydrogen at 13.81%. Nitrogen content is negligible at 0.00%, while sulfur is present in trace amounts at 0.07%. This analysis provides crucial insights into the chemical makeup of MGBW, which is essential for understanding its behavior during pyrolysis and the properties of derived products such as pyrolysis oil.

Table 1. Ultimate Analysis for MGBW

Parameters	Ultimate(%)
Carbon (C)	84.71
Hydrogen (H)	13.81
Nitrogen (N)	0.00

The proximate analysis of Medical Grade Bottle Waste (MGBW) provides insights into its composition regarding various components shown in **Table 2.** Moisture content is negligible at 0.00%, indicating a dry nature. Volatile matter constitutes the majority at 99.86%, implying the presence of combustible components. Ash content is minimal at 0.05%, representing the inorganic residue after combustion. Fixed carbon is present in a minor amount at 0.09%, reflecting the non-volatile combustible matter. This analysis aids in understanding the thermal behavior and potential energy yield of MGBW during pyrolysis or combustion processes.

Table 2. Proximate Analysis for MGBW

Parameters	Proximate (%)
Moisture	0.00
Volatile	99.86
Ash	0.05

3.3 MGBW Oil Yield Rate:

Pyrolysis of medical glucose bottle waste in a batch-type fixed-bed reactor was conducted within the temperature range of 400–600 °C. The oil yield rate of medical glucose bottle waste was analysed using thermo gravimetric analysis (TGA) within the temperature range of 400 °C to 600 °C shown in **Figure 3**.

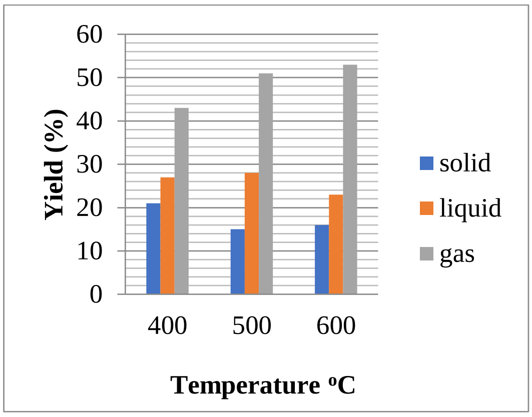

Figure 4 Temperature vs. Yield for MGBW oil by chart

The composition of the oil yield rate at 400 °C is solid 21%, liquid 27%, and gas 43%; at 500 °C it is solid 15%, liquid 28%, and gas 51%; and at 600 °C it is solid 16%, liquid 23%, and gas 53%. Are shown in **Fig, 4** Temperature °C vs. Yield (%) for MGBW oil by chart and

Table 3 Temperature °C vs. Yield (%) for MGBW oil.

Temperature(°C)	Solid (%)	Liquid (%)	Temperature(°C)
400	21	27	400
500	15	28	500
600	16	23	600

3.4 Properties of Pyrolysis Oil From MGBW:

The oil derived from the pyrolysis of the plastic content in medical waste (MGBW) exhibited a strong acrid odor and a dark brown color. Table 4 compares the properties of this pyrolysis oil.

The pyrolysis oil extracted from glucose bottle plastic exhibits several notable properties. Its calorific value stands at 42.5 MJ/kg, indicating a high energy content suitable for fuel applications. The density of this oil, measured at 15°C, is 0.89 g/cm^3, making it relatively light compared to some conventional fuels. In terms of viscosity, the oil measures 1.92 mm^2/s, suggesting it has a relatively low resistance to flow, which can be advantageous for certain combustion systems and engines. The flash point of the oil is 39°C, which is the temperature at which it can vaporize to form an ignitable mixture in air, pointing to necessary precautions for storage and handling due to its flammability. Furthermore, the pour point of the pyrolysis oil is 1°C, indicating the lowest temperature at which it remains fluid. This characteristic is crucial for its usability in colder climates, as it ensures the oil does not solidify easily.These properties collectively highlight the potential of pyrolysis oil from glucose bottle plastic as an alternative fuel, with energy content and physical characteristics that make it comparable to conventional fuels like diesel and kerosene.

Table 4. Properties of MGBW Oil.

Properties	MGBW Oil
CalorificValue (MJ/kg)	42.5
Density (G/cm3 @ 15°C)	0.89
Viscosity (mm2/s)	1.92

3.5 Simulation of Engine Performance with Pyrolosis oil at different temperatures

The performance data for the engine as it follows. At loads of 5kW to 30kW, the engine was tested.
The calorific value of pyrolysis oil varies slightly with temperature.

39,000	kJ/kg	at	400°C
40,000	kJ/kg	at	500°C
38,000	kJ/kg	at	600°C

To calculate Brake Specific Fuel Consumption (BSFC), divide fuel consumption with brake power.
To calculate Brake Thermal Efficiency (BTE), divide brake power by energy input from fuel.

Table 5. Pyrolysis Oil from 400°C

Load (kW)	FuelConsumption (kg/h)	Brake Power (kW)	BSFC (kg/kWh)
5	2.5	4.5	0.55
10	4.3	9.2	0.47
15	6.2	13.8	0.45
20	7.9	18	0.44
25	9.7	22.5	0.43

- Load vs Fuel Consumption: This graph shows how fuel consumption increases with load, indicating that more fuel is required to generate higher power outputs.

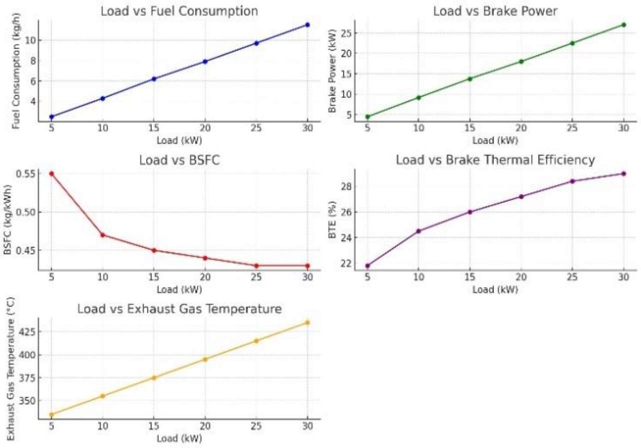

Figure 5 *analysis of loading wave length by graph for* Pyrolysis Oil from 400°C

- Load vs Brake Power: Illustrates the relationship between load and brake power, with brake power increasing proportionally with load.
- Load vs BSFC: Demonstrates that the Brake Specific Fuel Consumption decreases as the load increases, showing improved fuel efficiency at higher loads.
- Load vs Brake Thermal Efficiency (BTE): Shows that the engine's efficiency improves with increasing load, with BTE gradually increasing up to 30 kW.
- Load vs Exhaust Gas Temperature: Indicates that the exhaust gas temperature rises with increasing load, reflecting higher combustion temperatures at greater loads.

Table 6. Pyrolysis Oil from 500°C

Load (kW)	FuelConsumption (kg/h)	Brake Power(kW)	BSFC(kg/kWh)
5	2.2	4.8	0.46
10	4.1	9.7	0.42
15	5.9	14.4	0.41
20	7.6	19	0.4
25	9.4	23.5	0.4

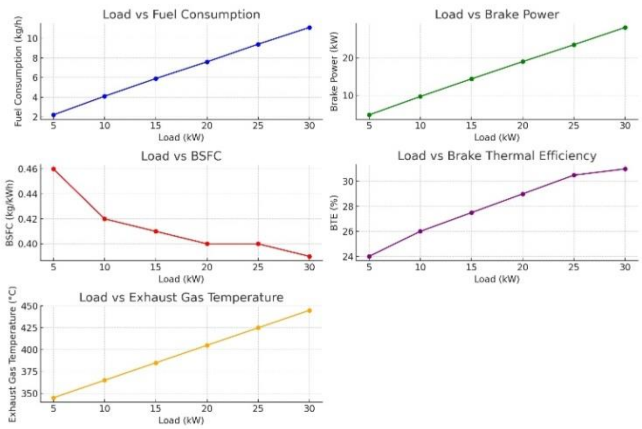

Figure 6 *analysis of loading wave length by graph for* Pyrolysis Oil from 500°C

From figure 6 it is observed that the Load vs Fuel Consumption: This graph shows that fuel consumption increases linearly with load, indicating more fuel is required to generate higher power outputs.

- Load vs BP: This graph illustrates the relationship between load and brake power, showing a direct proportional increase as load increases.
- Load vs BSFC: This graph demonstrates that Brake Specific Fuel Consumption (BSFC) decreases as the load increases, indicating improved fuel efficiency at higher loads.
- Load vs BTE: This graph shows that Brake Thermal Efficiency increases with load, peaking at the highest load of 30 kW.
- Load vs EGT: This graph indicates that the exhaust gas temperature rises steadily with increasing load, reflecting higher combustion temperatures at greater loads.

Table 7 Pyrolysis Oil from 600°C

Load (kW)	Fuel Consumption (kg/h)	Brake Power (kW)	BSFC (kg/kWh)	BTE (%)	ExhaustGas Temperature (°C)
5	2.6	4.6	0.57	21	330
10	4.4	9.1	0.48	23	350
15	6.3	13.6	0.46	24.5	370
20	8	17.8	0.45	26	390
25	9.8	22.3	0.44	27.2	410

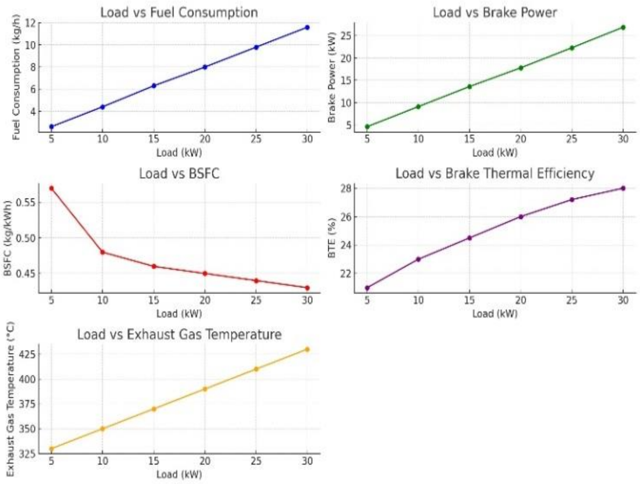

Figure 7 *analysis of loading wave length by graph for* Pyrolysis Oil from 600°C

From figure 7 it revels that the Load vs Fuel Consumption: Shows that fuel consumption increases linearly with load, reflecting the need for more fuel to generate higher power.

- Load vs Brake Power: Illustrates the relationship between load and brake power, which increases steadily with load.
- Load vs BSFC: Demonstrates that Brake Specific Fuel Consumption (BSFC) decreases as the load increases, indicating improved fuel efficiency at higher loads.
- Load vs Brake Thermal Efficiency (BTE): Shows that Brake Thermal Efficiency increases with load, with efficiency improving up to the highest load of 30 kW.
- Load vs Exhaust Gas Temperature: Indicates that exhaust gas temperature rises steadily with increasing load, reflecting higher combustion temperatures as the load increases.

These graphs provide a visual representation of how the engine's performance changes with varying loads using the provided fuel data.

The Brake Thermal Efficiency (BTE) generally increases with load across all temperature ranges, but it is slightly lower for pyrolysis oil produced at 600°C, likely due to higher fuel consumption and less efficient combustion.

The Brake Specific Fuel Consumption (BSFC) tends to decrease as the load increases, which is typical for internal combustion engines, indicating better fuel efficiency at higher loads.

4. Conclusion

In this study, healthcare waste will be recycled through the pyrolysis process, specifically targeting medical glucose bottle waste. Thus, it is used as the feedstock for the pyrolysis process. The pyrolysis process involves heating the medical glucose bottles to high temperatures, around 450°C, in a controlled environment.

This results in the conversion of the medical glucose bottles into bio-oil, char, and gases. The maximum yield rate of medical glucose bottle waste (MGBW) oil at a heating temperature of 450°C consists of solid (21%), liquid (27%), and gas (43%), with a calorific value of 42.5 MJ/kg, comparable to diesel.

The bio-oil derived from this method presents numerous potential uses, including its application in furnaces and its suitability as an alternative fuel for compression ignition (CI) engines. Additionally, the pyrolysis oil can be proposed as a viable substitute for conventional diesel, contributing to the effective management of Medical Grade Bottle Waste (MGBW) and promoting environmental safety. After simulation in the engine it is concluded that

- 1.Brake Thermal Efficiency (BTE):

  Among all the produced pyrolysis oils, the one at 500°C functioned the best as an engine fuel as it had the highest Brake Thermal Efficiency over all loads.In general, the efficiency was found lower for those oils produced at 400°C and 600°C. The oil that came in last place as far as overall lowest efficiency is concerned is that which showed results through analysis.
- 2.Brake Specific Fuel Consumption (BSFC):

  If we look at the BSFC values of various pyrolysis oil samples, we will find that minimum BSFC corresponds to oil obtained from pyrolysis conducted at 500°CThe higher BSFC values in oils from 400°C and 600°C are proof of less efficient utilization of this fuel by them.
- 3.EGT (Exhaust Gas Temperature):

  For different pyrolysis oils, their EGTs appear almost equal; however slightly higher temperatures could indicate full combustion of fuels at high loads.

Recommended Pyrolysis Oil:

From what has been depicted above, pyrolysis oil produced at a temperature of 500 degrees Celsius should be used in running engines because it has extremely high Brake Thermal Efficiency and low BSFC and thus enables exploitation rates per kilogram of fuel burned to maximize energy generation.

Author contributions

Thamizhvel R: Conceptualization, Methodology, Software **Naveen Raj S:** Data curation, Writing-Original draft preparation, Software, Validation. **Krishna raj S:** Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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