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FAST PYROLYSIS OF BIOMASS WITH A CONCENTRATED SOLAR POWER: A REVIEW

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Abstract. *Indonesia's biomass energy potential is estimated at around 49,810 MW and is very adequate for the development go renewable energy. An example of a biomass conversion technique is pyrolysis which converts biomass into bio-oil. The optimum temperature for the pyrolysis process is 300-600 ^{0}C. Parameters that affect the pyrolysis process such as pretreatment of the material, moisture content and particle size of the material, the composition of biomass compounds, the effect of temperature, heating rate, gas flow rate, type of pyrolysis, and pyrolysis reactor. This is a thermochemical technique in which biomass waste is converted into solid fuel (char), producer gas (syngas), and liquid (bio-oil) without oxygen in a reactor. This article contains a comprehensive review of biomass conversion techniques to bio-oil using the solar energy-based fast pyrolysis method. Furthermore, the exposure used was based on the publication source, year, origin country, research methodology, and focus area. Most research has been empirical and mainly focused on fast pyrolysis and its influencing factors. There are several studies, information, and research recommendations described in this article.*

Keywords: Bio-oil, Fast Pyrolysis, Solar Energy

1. Introduction

Biomass is a biological material used as a fuel source, either directly or processed through biomass energy conversion techniques. It is one of the best solutions in renewable energy to substitute fossil resources in various applications such as thermal energy production, energy sources, fuels for transportation, chemicals, and biomaterials production (Bridgwater, 2003). In theory, Indonesia's biomass energy potential is estimated at around 49,810 MW and is very adequate for development into renewable energy. The use of biomass offers various benefits, as it is available in each country in various forms. Therefore, it guarantees a secure supply of raw materials for the energy system. The utilization of biomass for alternative energy reduces the environmental impact of current problems such as Carbon Dioxide (CO_2) increase in the environment due to fossil fuel usage (Li *et al.*, 2008). Furthermore, one of the conversion techniques that convert biomass into bio-oil is pyrolysis.

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Pyrolysis involves the thermochemical conversion of biomass waste into solid fuel (char), producer gas (syngas), and liquid (bio-oil) without oxygen presence in a reactor (Ohliger *et al*., 2013). It involves the decomposition of organic material, without air or oxygen. According to Basu (2010), biomass pyrolysis generally takes place from 300 ^{0}C to 600 ^{0}C. This technique is more efficient and flexible than other thermochemical conversion processes. The pyrolysis technique is cheaper, environmentally friendly, and easier to use and the results obtained are more optimal. Furthermore, the liquid produced in this process is the initial product of bio-oil, which in subsequent treatment may become biodiesel or bioethanol (Basu, 2010). This process can also convert biomass into bio-oil, biochar, and gas products.

Research by Novita *et al*. (2014), involved the design of a pyrolysis device to produce bio-oil, through the use of a gas stove and firewood burning stove. Burning stoves use gas and firewood, however the operating costs are quite high and firewood is difficult to collect. This high cost, increases the cost of production of bio-oil. Therefore, to reduce these operational costs, several studies have designed a concentrated solar energy-based pyrolysis reactor that is renewable, sustainable and environmentally friendly. Furthermore, the use of solar energy in pyrolysis is more efficient than heat energy (Mondal *et al*., 2018). Solar energy is clean, cheap, safe, unlimited, and renewable, with tremendous economic potential in Indonesia.

For combustion in the bio-oil reactor, solar energy can be used as a heat source. When a solar collector alongside a concentrated solar power (CSP) device is applied, the intensity is increased. The thermal energy source using CSP produces gases with a high heating value. The rate of heat increase ranges between 10 - 500 0C/s and the resulting temperature is 800 -1600 0C, using a labor-scale solar furnace with a maximum power of 1.5 KW. The higher the temperature, the more gas is produced (Weldekidan *et al*., 2020). Furthermore, CSP is a renewable energy technology with great potential because of its ability to generate heat and electricity as well as easy storage of thermal energy in thermal storage devices (Monnerie *et al*., 2020).

Solar energy application involves photon and thermal energies. Photon energy can be converted into electricity in the presence of a solar cell, while solar thermal energy can be used in cookers, dryers, water heaters, power plants, seawater distillation, and others (Sen, 2008). According to Jiang (Jiang *et al*., 2005), temperature changes in solar cells occur due to temperature, cloud conditions, and wind speed in the environment around the solar panel placement area.

The solar collector is a device required to convert solar radiation energy into thermal energy for various purposes. A prism is a type of solar collector which has the ability to receive the intensity of solar radiation from all positions, therefore, it is expected that this energy utilization will be more effective. This solar collector absorbs energy from solar radiation and converts it to heat in the collector pipes, thereby increasing water temperature. Natural convection also occurs based on the thermosiphon effect, due to differences in fluid density (King *et al*., 2005). CSP is a technology that collects sunlight with a collector, then converts it into heat or electricity. A solar concentrator is a device used to collect light over a large area and focus its energy on a single focal point to increase the temperature to a higher level

The absorbent plate will capture most of the solar radiation and a small part will be reflected. The absorbed radiation will turn into heat energy which is concentrated by focusing it into a smaller area. When concentrated light is converted to heat it generates electricity, which drives a heat engine connected to an electric generator. CSP generally requires large amounts of direct solar radiation, and its energy generation drops dramatically with cloud cover. Therefore, pyrolysis with the parabolic CSP is economically feasible, environmentally friendly, effective in dry countries, and has agricultural potential (Giwa *et al*., 2019).

2. Biomass Source

Biomass includes wastes of wood, agriculture, plantation, forest products, organic components from industries, and households. Some of its chemical elements include charcoal (C), hydrogen (H), acids or oxygen (O), nitrogen (N), sulfur (S), ash, and water, all of which are bound in a chemical compound. Due to its beneficial properties, it is considered sustainable. Biomass energy sources have several advantages compared to fossil energy.

In this research, biomass waste used was often given treatment to facilitate the next process. These treatments include:

1) Raw materials were dried in a dryer, thereby reducing the moisture content to about 5-8%.
2) Grinding materials with various sizes of 2-5 mm, olive husks, corn cobs, and tea dregs The sample is reduced in size and sieved to obtain particle sizes between <0.5 and> 2.2 mm (Demirbas, 2004).

To determine the composition of biomass, proximate and ultimate analyzes are often carried out. Proximate analysis is performed to determine the moisture content, volatile matter, fixed carbon, non-volatile biomass fraction, ash content, and inorganic residue after combustion. Biomass with a high volatile fraction will produce a higher bio-oil yield compared to biomass with high fixed carbon content. Biomass which has high fixed carbon can produce high biochar (Vassilev *et al*., 2010).

The ultimate analysis test produces more comprehensive data than proximate analysis. This test determines the amount of carbon, hydrogen, nitrogen, sulfur, and oxygen (CHNSO). The ratio of elements obtained from the final analysis provides a better comparison among the raw materials which is used to ascertain the calorific value (Vassilev *et al*., 2010). Some of the proximate and ultimate analyzes carried out on biomass waste are shown in Table 1.

Table 1. Basic Composition and Physical Properties of Biomass (Vassilev *et al.*, 2010).

Biomass Types	C (wt%)	H (wt%)	O (wt%)	N (wt%)	S (wt%)	Ash (wt%)	Moisture (wt%)	HHV (MJ/kg)
Rice Husk	48.36	5.13	32.79	0.72	0.31	12.50	6.80	16.79
Corncob	49.32	5.35	44.7	0.63		1.49	7.36	16.66
Birchwood	48.45	5.58	45.46	0.20	–	0.30	5.26	17.02
Walnut peel	50.58	6.41	41.21	0.39	–	1.40	8.11	19.20^{a}
Safflower	59.05	8.87	26.72	3.03	–	2.33	6.04	23.86^{a}
Sesame Stalks	48.62	5.65	37.89	0.57	–	7.26	9.53	19.10^{a}
Soybean Meal	52.46	6.17	26.51	8.72	–	6.15	9.15	23.23
Mixed Wood	47.58	5.87	42.10	0.20	0.03	2.10	7.76	–
Rubber Wood	49.50	6.10	44.60	–	–	–	–	–
Straw	36.89	5.00	37.89	0.40	–	19.80	–	16.78
Coconut shell	47.97	5.88	45.57	0.30	–	0.50	–	19.45
Pine Wood	45.92	5.27	48.24	0.22	–	0.35	7.99	18.98
Almond peel	47.63	5.71	44.48	–	–	2.18	–	–
Beech Wood Powder	50.8	5.9	42.9	0.3	0.02	0.4	6	–
Olive husks	50.90	6.30	38.60	1.37	0.03	2.80	8.50	–
Timber wood	47.72	5.54	44.85	0.89	–	1.00	–	–
Pine	50.33	6.21	43.07	0.34	0.05	0.26	5.49	
Jatropha seeds	55.8	4.78	31.13	7.35	0.93	4.7	8.1	
Castor Seed	29.28	3.91	29.84	-	0.03	2.2	37.37	
Coffee Waste	46.1	5.6	29.1	5.2	-	2.5	11.3	

The chemical structure and composition of biomass are highly dependent on the origin and type of material (Vassilev *et al*., 2010). The decomposition also depends on moisture content (<8%), particle size (<5 mm), density (ρ), ash content, lignocellulose composition, and heating value of the material. Other important factors affecting the thermochemical process of materials are temperature (the higher the temperature, the faster the process), pressure (the greater the pressure, the higher the temperature), speed of temperature increase (heating rate), and duration of the combustion process. Hemicellulose, cellulose, and lignin begin to decompose at 200 ^{0}C - 250 ^{0}C, 280 ^{0}C – 350 ^{0}C, and 300 ^{0}C - 350 ^{0}C respectively, and end at 400 ^{0}C – 450 ^{0}C. Several studies have shown the effect of material particle size, moisture content, and temperature on the amount of bio-oil and charcoal produced (Table 2).

Table 2. Biomass Size, Moisture Content, and Temperature for Rice Husk and Corn Cob Pyrolysis

Material Type	Particle Size(mm)	Moisture Content (% wt)	Temperature (^{0}C)	Heating Rate (^{0}C/min)	Bio-oil (%)	Biochar (%)	Ref
Corn Cob	0.425 - 0.6	7.36	400 – 450	7 – 40	17.99–21.05	67.84 - 72.8	Chintala *et al.*, (2017)
Corn Cob	0.5 – 2.2	19.4 – 36.6	676.85	10 K/s	-	45.5 – 65.7	Demiral *et al.*, (2012)
Rice Husk	1.68 - 3.36	6	500 – 600	10	18 – 30.4	30 – 38.5	Demirbas (2004)
Rice Husk	90–600 µm	7.7	465	10	56	24	Huang *et al.*, (2018)
Rice Husk	0.63 – 1	6	450	10	70	28	Ji-lu (2007)

From Table 2, it is observed that the particle size, temperature, and moisture content of the material influenced the amount of bio-oil produced. However, the data above cannot be used as an appropriate reference because further research is required.

According to the research of Huang (2018), the chemical composition of corn cobs (wt%) is hemicellulose 29.9%, cellulose 33.8%, lignin 30.7%, carbon 17%, and Volatile 80.9% Demiral *et al*. (2012). Rice husk contains 24.3% hemicellulose, 34.4% cellulose, 19.2% lignin, 70.5% volatile compounds, and 16.6% fixed carbon (Alvarez *et al,* 2018). Theoretically, high volatile fraction biomass is more suitable for bio-oil production, whereas biomass with high fixed carbon is more suitable for biochar production (Madadi, 2017).

3. Fast Pyrolysis

Pyrolysis involves heating a substance in the absence of oxygen to decompose its material components. Therefore, the shell is heated at significantly high temperatures in the absence of oxygen will cause the decomposition of complex compounds that compose hardwood. This is followed by the production of substances in three forms, namely char, bio-oil, and gases (Soltani, *et al*., 2015). Fast pyrolysis is used for bio-oil and gas production, and there are two main types: flash and ultra-fast. The purpose of fast pyrolysis is to prevent further breakdown of products into non-condensable compounds. Therefore, the parameters affecting it need to be carefully observed to increase the bio-oil yield. The Important parameters that affect the fast pyrolysis process include the water content, size of the material, type of reactor, reactor material, heat source, temperature, and heating rate.

The parameters mainly influencing fast pyrolysis include heat transfer speed, and the fine size of biomass particles. Pyrolysis temperature exerts the greatest effect on the characteristics of bio-oil produced, which increases with increasing temperature from 450 to 550 ^{0}C. Furthermore, the levoglucosan concentration in bio-oil decreased significantly with increasing pyrolysis temperature, while the increase after analytic pyrolysis decreased. Pyrolysis temperature and residence time greatly influence bio-oil characteristics (Kato *et al*., 2016).

Fast pyrolysis carried out on rice husks is performed at a temperature of 400-600 ^{0}C using continuous pyrolysis with a cone-shaped reactor and direct charcoal removal. The highest bio-oil yield is at 450 ^{0}C by 70% due to material capacity and heat transfer that occurs in the tool (WikiPedia, 2022).

Other factors affecting fast pyrolysis include system design and procedure (Alvarez, 2014), bio-oil quality, application (Czernik & Bridgwater, 2004) and fractionation method (Mohan, 2006). The cost for solar pyrolysis will be effective if the conditions for fast pyrolysis of biomass are optimal (Table 3).

Concentrated sunlight radiation is capable of producing high temperatures to cataylse biomass pyrolysis (Piatkowski, *et al*., 2011). Solar energy which is applicable in biomass pyrolysis, produces fuel (bio-oil) which is easy to store and transport (Chueh , *et al*., 2010). This energy has the potential to produce bio-oil having high heating value with lower CO$_2$ emissions, compared to conventional pyrolysis (Nzihou, *et al*., 2012).

Table 3. Reactor Type, Temperature and Pyrolysis Types that affect Bio-oil yield (Mondal *et al.*, 2018)

Biomass Type	Reactor type	Pyrolysis temperature (^{0}C)	Bio-oil Yield (%)	Pyrolysis Type
Wine Dregs	Stainless steel fixed-bed reactor	550	27.6	Fast pyrolysis
Pine hard and soft wood	Tubular vacuum pyrolysis reactor	450	55.0	Fast pyrolysis
Rice Husk	Fluidized-bed reactor	450	60.0	Fast pyrolysis
Wooddust	Cyclone reactor	650	74.0	Fast pyrolysis
Corn cob	Fluidized-bed reactor	550	56.8	Fast pyrolysis
Potato peel	Stainless steel fixed-bed reactor	550	24.8	Steam pyrolysis
Sawdust	Conical spouted bed reactor	500	75.0	Flash pyrolysis
Pinewood	Auger reactor	450	50.0	Fast pyrolysis
Furniture powder waste	Fluidized-bed reactor	450	65.0	Fast pyrolysis
Sugar Cane Waste	Fixed-bed fire-tube heating reactor	475	56.0	Fast pyrolysis
Corn cobs and stalks	Bubbling fluidized bed reactor	650	61.6	Fast pyrolysis
Laurel (Laurus nobilis L.) extraction	Fixed-bed reactor	500	21.9	Fast pyrolysis
Jute stick continuous feeding	Fluidized bed reactor	500	66.7	Fast pyrolysis
Apricot Pulp	Fixed-bed reactor	550	22.4	Fast pyrolysis

Table 4. First Research Results and Recommendations.

References	Research Results	Further Research Recommendations
Weldekidan, *et al.* (2020)	Biomass and solar energy sources are combined to produce heat energy, electricity, transportation fuels, chemical materials, and biomaterials using pyrolysis. 1) Raw materials: Chicken manure and rice husks with sizes of 280 and 500 µm 2) Pyrolysis Reactor: concentrated solar radiation to produce pyrolysis gas with high calorific value, using a laboratory-scale solar furnace with a max power of 1.5 KW 3) Temperature: 800–1600°C, heating rate: 10 to 500°C/s 4) Yield: the gas produced increases to 10 to 39%, reduces the yield of bio-oil from 48% to 41% wt, and bio-charcoal 42% to 18% wt. 5) The specific energy of a gas at a material particle size of 280 µm is 7255kJ/kg 6) The gas produced from this solar pyrolysis reactor can be used directly as fuel for engines and power plants 7) The higher the temperature, the more gas produced. The resulting gas has a high calorific value hence it can be used directly as fuel in the engine.	1) It does not explain the performance of solar pyrolysis to the quality of bio-oil produced 2) High temperatures will reduce the amount of bio-oil yield but increase the amount of gas produced 3) Specifically, concentrated solar is used to produce gases with very high temperatures

4. Further Research Recommendations

Several studies have developed a pyrolysis technique that converts solar energy into concentrated thermal energy using concentrated solar power. Pyrolysis involving solar energy, which is the energy of the future, produces renewable energy that is cheap, environmentally friendly, acceptable, with appropriate technology, and easy application. Some research summaries and recommendations for further research are shown in Table 4-7.

Table 5. Second Research Results and Recommendations

References	Research Results	Further Research Recommendations
(Monnerie *et al*., 2020).	Concentrated solar thermal technology can be considered renewable energy technology, because of its ability to generate heat and electricity as well as heat storage in the device. Conventionally, this approach is widely used for electricity generation. When combined with a proper conversion process, it can also be used to produce methanol. 1) Methanol with a large combustion speed produces higher efficiency compared to conventional fuels 2) The simulation results show that this tool is capable of producing 27.81 million liters of methanol with 350 MW of solar power 3) CSP with solar thermal collecting glass covers an area of 880685 m^2	CSP is considered a very promising renewable energy technology because of its ability to generate heat and electricity and its direct connection to thermal storage devices
Pozzobon *et al*., (2016)	1) Raw material: beech wood, wood fiber 2) The tool used is the Energy Concentrated solar radiative heat flux above 1 MW/m2 which is capable of producing temperatures above 1200°C, charcoal gasification, and heat cracks. An artificial sun, and a new reaction chamber that monitors the mass of the sample during the process and can trap the resulting tar using a liquid nitrogen-cooled tar condensing device 3) Combustion temperature: 1200-1500°C 4) The resulting light gas was analyzed by micro-GC analysis	CSP is capable of producing temperatures higher than 1200^0C, which can change the composition of charcoal, tar, and water vapor. This research creates an artificial sun and a new reaction chamber. The equipment used is microGC, radiometer, radiative heat flux with a surface temperature of about 1500^0C.
Mondal *et al*., 2018	The utilization of biomass energy becomes attractive because fossil energy is running low 1) The pyrolysis process can convert biomass into liquid, solid, and gas products. The use of solar energy for the pyrolysis process is better at producing heat energy. 2) Biomass type, reactor type, and pyrolysis temperature affect the yield of bio-oils, ranging from 21.9 to 75%. 3) Bio-oil can be recommended as an alternative fuel for transportation engines 4) Bio charcoal and non-condensing gas can be used as a candidate fuel for power generation and industrial heating 5) Solar energy-based pyrolysis is the most appropriate technology used for hilly areas and remote areas. Solar thermal pyrolysis is a promising technology to meet global energy needs, but there are several challenges that should be faced.	1) The weakness of bio-oil is that it can't be used directly in engines 2) Achievement of lower reactor temperatures during inactive solar radiation; 3) Solar energy storage problems; 4) Lower energy conversion efficiency; 5) Significant heat loss due to air convection over the reactor surface; 6) Reactor material compatibility issues
Zeaiter *et al*., (2018)	1) This study examines the integration of concentrated solar thermal power with the waste tire pyrolysis process. 2) One of the highlights is the application of CSP to produce heat energy, thereby reducing the use of fossil energy. The integration between CSP and Fresnel Reflectors technology (LFRs) can generate hot air. 3) The resulting temperature is 520 - 550 ^{0}C using SAM solar energy in Lebanon could provide an average of 47.14% of the pyrolysis reactor's annual energy requirements. 4) Solar energy storage in summer can increase by 60.8% and decrease by 26.6% in winter 5) Analysis of solar energy requirements for the pyrolysis process of tires can provide 47% of the energy needed by the reactor.	Recommendation: 1) Optimization in measuring the focus area of the solar thermal concentrated in the pyrolysis reactor 2) Storage of absorbed solar thermal energy

Table 6. Third Research Results and Recommendations

References	Research Results	Further Research Recommendations
Joardder *et al*., (2017)	Integration of solar assisted heating reactor in pyrolysis, which illustrates the application and feasibility of solar integrated pyrolysis technology. possible challenges and scope of future development of integrated solar pyrolysis technology are described. The advantages of using solar pyrolysis are: 1) High heat flux to heat the pyrolysis reactor quickly to high temperature. 2) The focal area is relatively small to reduce secondary reactions in various areas. 3) Renewable heat sources reduce heating costs of pyrolysis reactors and also protect reserves of non-renewable energy sources. 4) No burning of fossil fuels, therefore this system produces no emissions and is considered environmentally sustainable 5) Improved yield quality due to the absence of contamination of pyrolysis gas with combustion products 6) The reactor and gas do not need to be calculated at the optimal temperature because the heating system used is quite easily.	1) Proper design is essential to transfer heat throughout the biomass during pyrolysis 2) Extensive research is required to complete the CSP and evenly heat the reactor surface for material decomposition
Ndukwu *et al*., (2020)	1) Solar energy and biomass produce energy that is sustainable and does not damage the environment. 2) The characteristics of this two-energy raw material are used by the pyrolysis method to produce transportable liquid and gas fuels, while bio-char which is considered a by-product has been widely used in soil improvement. 3) Combining biomass and solar energy can produce high energy density fuels from low energy density feedstock. 4) The effectiveness of the solar pyrolysis process depends on the solar thermal system, reactor configuration, and reaction dynamics 5) This research discusses the benefits of solar-biomass pyrolysis, available optical concentration devices, conceptual heating modes, solar thermal orientation configurations and existing reactors, as well as some basic model equations applied in solar biomass pyrolysis.	1) Current reactor designs are not sufficient to propel solar pyrolysis towards commercialization. 2) Better designs are needed that will increase the quantity of biomass processing. 3) Such reactors must operate under dynamic rather than isothermal conditions and modeling must reflect dynamic conditions. 4) Integration of nanoscale particles in reactors and concentrators
Sobek & Werle (2020)	1) From the thermogravimetric data (TGA), the heating rates shown in solar pyrolysis are obtained: 5, 10, 15, and 20 K/min. 2) NETZSCH kinetic neo software is used to approach the kinetics of lignocellulosic biomass 3) The TGA data is enriched with the gas analyzer indication and the results of the investigated solar pyrolysis experiments in the laboratory reactor design itself. 4) The methodology presented consists of (1) conversion analysis: Friedman, Kissinger-Akahira-Sunose and Ozawa-Flynn-Wall analysis which yields the real activation energy $E\alpha$, varying between 185.37 to 375.56 kJ/mol with a reaction rate of 0.1 –0, 9, (2) identification of the reaction model with a general master plot method showing that the decomposition is driven by three-dimensional diffusion (D3) with a transition to the three-dimensional phase boundary (R3) and reaction sequence based models (F1, F2), Fn) at the end of the conversion. Finally, (3) the development of a kinetic model is carried out based on experimental observations, resulting in modeling of the 3 main reactions of the formation of pyrolysis products. 5) The activation energy of CO_2 release in the first step is 159.92kJ/mol and in the second step is 256.78 kJ/mol, this energy release is observed at 250 ^{0}C and 440 ^{0}C. 6) The formation of CO follows the reaction mechanism R3 with an activation energy of 181 kJ/mol and a pre-exponential factor of 12.16 log (1/s). The results of the kinetic model and the isoconversion method were tested using the Fisher-Snedecor test.	This kinetic modeling application requires a deeper study and is applied to the calculation of the CSP-based CSP pyrolysis reactor with different material characteristics.

Table 7. Fourth Research Results and Recommendations

References	Research Results	Further Research Recommendations
Zeng *et al.*, (2017)	1) Research temperatures were 600, 900, 1200, and 2000 °C, heating rate 50 ° C/s, and argon flow rate 6 NL/minute. 2) Gas products were analyzed by micro-GC, charcoal characterized by CHNS, while bio-oil was analyzed by CHNS, Karl-Fischer titration, and GC-MS analysis. 3) An increase in temperature will significantly increase the yield of gaseous products and LHV, which is due to the tar reaction in the formation of H_2 and CO. 4) The characteristics of charcoal and vegetable oils are very temperature dependent. Its high energy content indicates that the charcoal and oil obtained can be used as valuable solid and liquid fuels. 5) The temperature produced by CSP is 900 °C, the bio-oil yield ranges from 38% to 53% which is the cause of the uncertainty of the bio-oil water content.	Further research is needed on the performance of solar energy-based pyrolysis techniques therefore, it can determine the characteristics of bio-oil.
Morales *et al.*, (2014)	1) This research studied the pyrolysis of orange peels due to solar radiation which was applied as an energy source using a concentrator solar parabolic. 2) The Monte Carlo ray-tracing method is used for optical analysis that can provide a detailed description of the 3-dimensional performance of the solar thermos system 3) The average surface irradiation of the pyrolysis reactor is 15.65 suns. To ensure optimal operating conditions, the peak irradiance was calculated by the ray-tracing method. 4) The reflectivity of biomass (37.85%) and the difference in ambient and reactor temperature (36.23%) is the main caused of heat loss. Optical and thermodynamic principles are applied to heat balance analysis. 5) The peak temperature reached by the solar pyrolytic reactor is 465°C at the focal point 6) The total weight loss of orange peels was 79% by weight with an average radiation rate of 12.55 kW/m^2. 7) Compounds produced for the energy, chemical, and pharmaceutical industries are identified in bio-oils such as (Z) -9-octadecenamate, diisoostyl phthalate, squalene, d-limonene, and phenol.	The solar pyrolytic process can be an important method of producing solar liquid fuel because of its potential to convert an unlimited amount of solar energy into chemical energy. The use of solar pyrolysis can reduce greenhouse gas emissions.

Solar pyrolysis can be used for various needs, depending on the expected results. The pyrolysis process with a temperature of 350 - 600 ^{0}C produces a high yield bio-oil, while the pyrolysis temperature above 700 - 2000 ^{0}C produces gas that is used for electrical energy. The utilization of solar energy for pyrolysis is helpful in produce high temperatures, so this process must continue to be developed.

5. Conclusion

Fast pyrolysis is used for bio-oil and gas production, and there are two main types: flash and ultra-fast. The purpose of fast pyrolysis is to prevent further breakdown of products into non-condensable compounds. Pyrolysis involves the thermochemical conversion of biomass waste into solid fuel (char), producer gas (syngas), and liquid (bio-oil) without oxygen presence in a reactor. The Important parameters that affect the fast pyrolysis process include the water content, size of the material, type of reactor, reactor material, heat source, temperature, and heating rate. CSP is a renewable energy technology with great potential because of its ability to generate heat and electricity as well as easy storage of thermal energy in thermal storage devices. The use of solar energy to heat the pyrolysis reactor still requires further development. In-depth studies are also needed on the use of solar energy in pyrolysis, supporting factors, mathematical models, optimization of heat transfer, proper reactor design, characteristics of the bio-oil produced, optimal temperature, heat transfer speed, and unstable bio-oil conditions which need to be upgraded in order to become fuel-based. With several literature reviews carried out, this research needs to be developed in order to ascertain the correct methods, reactor designs, CSP installation, performance test of the pyrolysis reactor with CSP, raw material characteristics, temperature, heat rate, and others.

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