Journal of Applied Sciences and Emerging Technologies Vol. 1, Issue 1, 2023

# Investigation of the Parameters on the Fast Pyrolysis of Barley Waste spent grains in a Fixed Bed Reactor for the Production of Bio-Oil

**Muhammad Wasif Ishaq Shah[1]**

[1*] Assistant Distiller, Murree Brewery Company Pvt. Limited, Pakistan
wasif028@yahoo.com

Received date:28-02-2023
Accepted date:15-05-2023
Published date:08-08-2023

**Abstract:** Waste material is the most abundant, cost-effective, and easily accessible renewable source of energy. The most frequent technique of garbage disposal, which includes landfilling and incineration, contributes to the degradation of both the land and the air. Pyrolysis of waste material results in the production of biofuels such as solid, liquid, and gaseous fuels, while at the same time reducing the amount of air pollution produced. The barley waste discarded grains are the primary subject of this investigation, with an emphasis placed on the effect that key variables have on the fuel that is recovered. Temperature was discovered to be the most important variable in this process, and researchers determined that the ideal temperature range to be between 550 and 650 degrees Celsius. It was discovered that the product oil that was obtained was comparable to furnace oil and that it could be utilized as an alternative fuel.

**Keywords:** Biomass, Barley Spent Grains, Fast Pyrolysis, Bio-oil

## 1. Introduction

The rate and nature of urbanization in emerging nations like Pakistan significantly affects fuel consumption. Greater energy consumption leads to better incomes in metropolitan areas. There is a rising concern over the disposal of organic solid waste, particularly municipal garbage and livestock manure, because of its potential to contribute to environmental degradation. Thus, they too are steadily raising their output. The breakdown of these materials into ammonia, greenhouse gases, and odorous compounds is a significant contributor to water and air pollution because of the presence of heavy metals and pathogens in the waste. Because of this, commercial fuel production requires a shift from the standard level of production used for traditional fuels. The most traditional approach is direct combustion of biomass, which results in 100% biomass combustion but only 10% efficiency. Gasification is similar in that it totally converts biomass to a gas that may be burned. Disposal of solid biomass is becoming increasingly problematic as it is both labor-intensive and resource-intensive to handle. Because of this, a novel method has emerged called pyrolysis, which converts low-energy-density trash into high-energy-density crude bio oil and is thus safe to use. While a variety of organic solid wastes are suitable for pyrolysis, discarded grains from the production of barley have become increasingly popular in recent years.

An increase in disposable objects, many of which take an extremely long time to decompose in nature, has greatly increased the difficulty of dealing with solid biomass. It is safe to say that pyrolysis is a reliable method for dealing with solid biomass in this situation. Using anaerobic decomposition, we are able to transform low-energy-content garbage into high-energy-content bio-fuel while also recovering valuable compounds. BSG, or brewery solids, are the leftovers from the brewing process. This substance is the solid residue left over from making wort, and it is composed of the husks of barley and wheat. Due to its high fibre and protein content, ESR has traditionally been used as animal feed. The influence of its nutritional worth, however, makes this waste appealing for food and its protection, as does its low price and abundance. However, the ESR becomes useful when it is used as a component and a potential source of a bioactive chemical that has positive effects on health. Researching potential new applications for BSG is vital from both the brewery's and the environment's perspectives, given the growing significance of recycling and reusing industrial waste and products. Focusing on the possible health benefits connected with the components and the usage of these by-products in foods by manufacturers, this review presents existing understanding of BSG, including how valuable ingredients are created, engineered, and manufactured.

Table 1.1: Ultimate and Proximate Analysis of Barley Waste Spent Grains

| **Description** | **Barley Spent Grains (%age)** |
|---|---|
| Volatile Matter | 81.22 |
| Fixed Carbon | 9.22 |
| Moisture | 6.18 |
| Ash | 3.40 |
| Carbon | 48.12 |
| Hydrogen | 6.23 |
| Nitrogen | 3.98 |
| Sulfur | 0 |
| Oxygen | 41.67 |

The primary non-fermentable by-product that is readily available from the brewing process is known as brewers waste grain (BSG for short). After the barley has been separated from the wort and filtered, this is the solid residue that is left over from the process. According to the estimates provided by the United Kingdom's Environment Agency, brewers in the United Kingdom produce more than 250 million tons of wet BSG on an annual basis. BSG is either disposed of in landfills or used as animal feed, most frequently for cattle but also for pigs, goats, fish, and other types of animals and poultry. As a result of the high levels of fibre (60%) and protein (20%) that it contains, it is utilized in the farming industry as animal feed. Wet BSG typically includes between 67 and 81% water by weight (w/w), which is a significant amount of moisture. BSG is difficult to store and transport because it degrades at a quick rate due to the activity of microorganisms. This is because it has a high percentage of fermentable sugars and a high percentage of moisture. Therefore, in order to be taken into consideration as a possible source of energy feedstock, measures must be implemented to drastically reduce its moisture content.

## 2. Materials and Methods

At present, experimental work is conducted using a fixed bed reactor that features a reactor tank, condensation mechanism, and separation system. A reactor with a permanent bed that is not employed on a large scale in industry. However, its straightforward design, manageability, and upkeep make it a valuable tool in the lab.

The reactor's internal dimensions were (13.5 inches long by (3 inches wide by 4.5 inches in diameter), all of which were made of stainless steel. It is true that there is no hard and fast rule regarding the L/D ratio when building a fixed bed reactor. On a smaller or experimental scale, however, the L/D ratio is increased so that no internal tank pressure will build up. Figure shows a schematic of a fixed bed reactor (2.1)

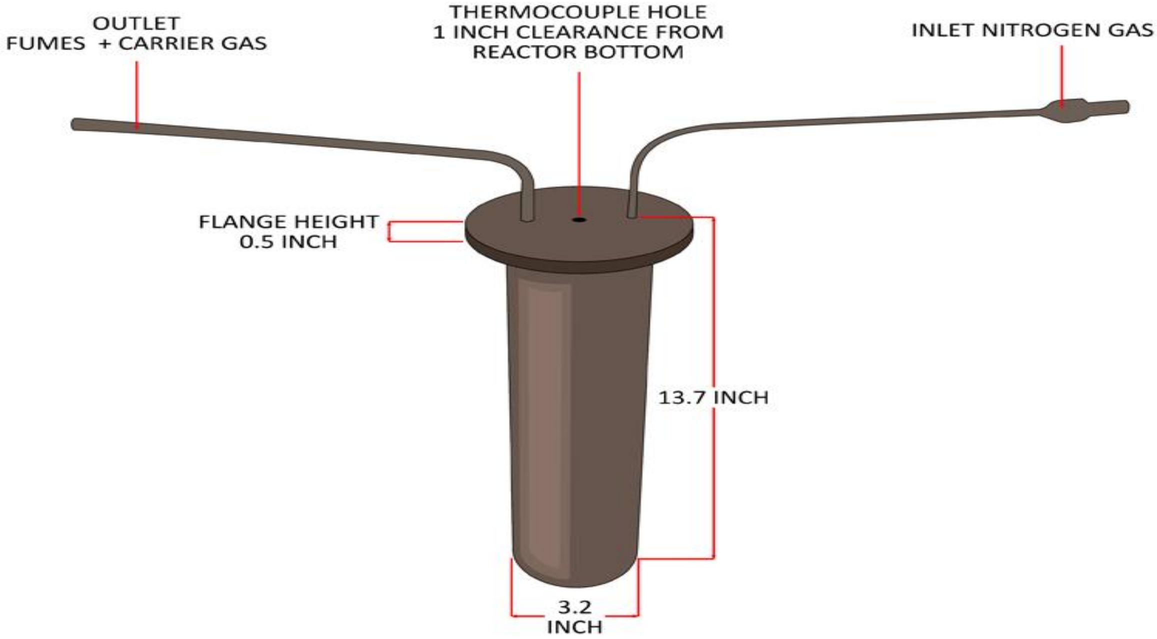


Figure 2.1: Schematic Diagram of Fixed Bed Pyrolysis Reactor

The reactor tank's wall is made of stainless steel and can withstand temperatures up to 750 degrees Celsius, a thickness of 0.2 inches. The tank's head has an input for nitrogen purging, an exit for venting gases produced by the pyrolysis reaction, and a 12.5-inch stainless steel capsule where a thermocouple can be attached for accurate temperature readings.

The thermocouple sensor was positioned so that it would make contact with the reaction zone and provide a reliable reading. Silicon binder and high temperature rubber rings were used to create a completely airtight seal around the entire reactor. The reactor has two condensers, and instead of using a straight condenser, a spiral condenser was chosen because it allows for longer contact time between the fumes or vapours and the condensing air, leading to a higher product yield. The schematic diagram of the full pyrolysis experimental setup produced University of Gujrat is given in Figure. (2.2).

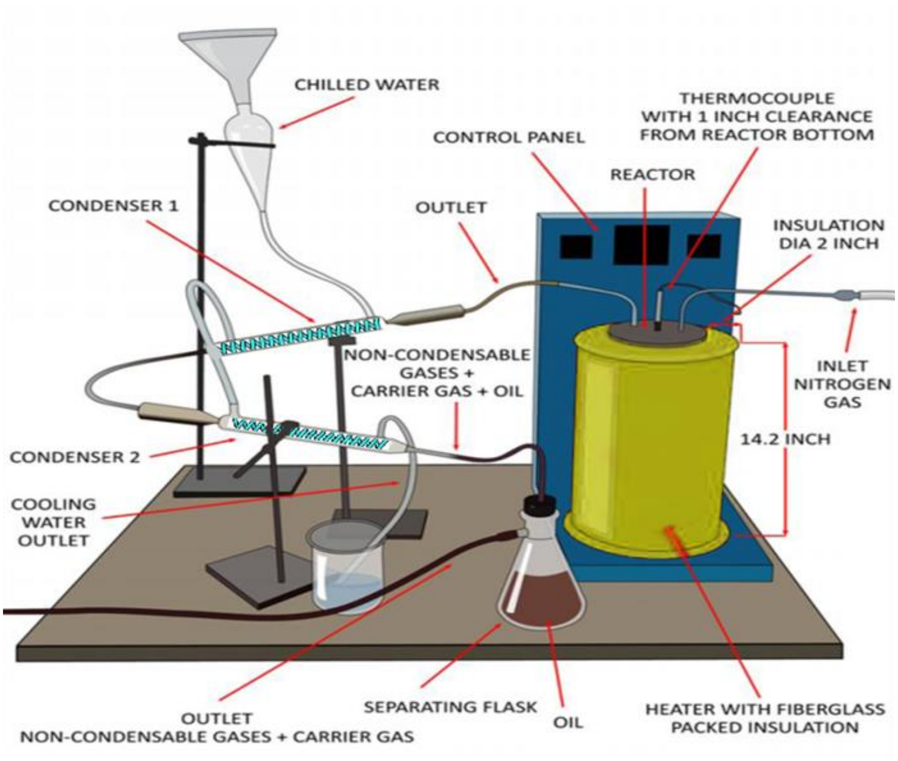


Figure 2.2: Schematic Diagram of Modified Experimental Setup

are both effective in diagnosing rolling element bearings [16, 17]. It has been found that using statistical characteristics to assess vibration and ultrasonic data for detecting the existence of quirks in low-speed bearings [18]. However, kurtosis and peak factor did best at low rates (under 200 rpm). From its development, the statistical approach exhibited much attention in attaining bearing damage tracking, with findings free of load and speed changes.

This approach is an intelligent tool for both assistance and Quality control applications. For fault determination of rotating hardware, a review of vibration feature extraction strategies is required [19]. Ball bearings have been studied for the arrangement and improvement of localized faults [20]. Statistics such as kurtosis, skewness, and standard deviation have been employed as characteristics in roller bearings to detect early defects. [21] Presents a survey of soft computing procedures in CBM. [22] Offered an AI-based technique for detecting bearing faults under changing speed and load situations. [23] Developed a unique approach for enhanced convolution-bearing defect diagnostics utilizing neural networks and transfer learning. Signal processing techniques such as variation mode decomposition (VMD) were studied in [24]. The defect diagnostic model and denoising performance of the joint learning mechanism were examined in [25]. Hasan adopted the method of transfer learning-based framework for fault detection [26]. Wavelet packet decomposition (WPD) was studied in [27]. The empirical wavelet transformation (EWT) was used to assess rolling bearing incipient faults [28].

## 3. Results and Discussion

The current study maintains a steady heating rate of 20 degrees Celsius per minute, with an operational temperature maximum of 550 degrees Celsius to 700 degrees Celsius. This experiment has the potential to examine three different flow rates (1, 2, and 3 Lit/min). Therefore, a grand total of 12 tests were conducted. At first, a 30-gram sample was extracted and placed in the reactor's sample cup; next, the reactor's body was sealed with a silicon ring to prevent the fumes from escaping. The reactor's second outlet is piped to the condenser portion, where vapours are removed by spiral condensers, and the inlet is connected to a cylinder of nitrogen. Afterwards, the bio-oil is stored in a tank, and the non-condensable gases are released into the air through a separate pipe that leads from the tank. The heating rate is maintained at a constant 550 degrees Celsius and 1 litre of nitrogen per minute throughout all experimental runs. In order to eliminate oxygen from the reactor, nitrogen gas is continuously purged in, and it took 35 minutes to reach 550 degrees Celsius. Once that point is reached, the exhaust from the reactor exits through the condenser's hose. As they approached that area, the vapours in the air condensed and became a liquid. The experiment takes about 1 hour and 40 minutes to finish at this temperature. After observing a decrease in fume output, the heater was turned off and the reactor was allowed to cool; once it had cooled, the reactor's cover was removed and its solid waste residue was weighed.

The maximum temperature and flow rate were also changed throughout the 12 tests. At 650°C and 10mm in thickness with a flow rate of 1Lit/min, the highest oil output was observed. Although our maximum temperature in our experiments was 700 C, we found that oil production began to drop off sharply at at 650 C.

When it comes to influencing output, temperature is king. Even after 60 minutes, the black residue that remains has an oily surface, indicating that the pyrolysis process was not complete at temperatures between 550 and 600 degrees Celsius.

For optimal biodegradation of organic matter during pyrolysis, the temperature should be 650 °C. If we increase the temperature over that point, then the yield of the oil continues on diminishing. At greater temperatures, additional noncondensable gases, including short-chain hydrocarbons, are produced.

How temperature affects the percentage of yield is depicted in Figure (3.1). That's how output shifts when you change the temperature or the flow rate. According to this graph, the optimal conditions for extracting bio-oil are 650 degrees Fahrenheit and a flow rate of 1 litre per minute.

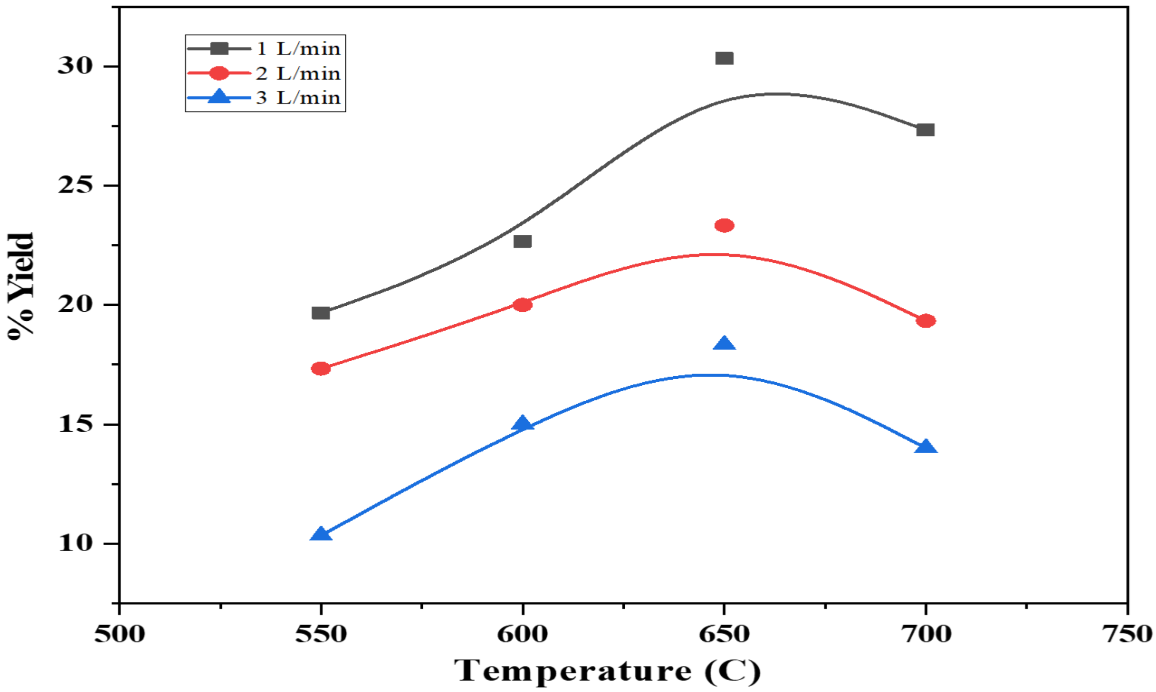


Figure 3.1: Effect Temperature vs % Yield of Derived Oil

Flow rate has been found a big effect on the Pyrolysis process as we discuss earlier and shown in the graph that at higher flow rates the yield is minimum because at high flow rate the carrier gas travel through the condenser with less contact time and fewer fumes is condensed. Maximum yield is achieved at low flow rates because the vapors in the condenser have more time to contact the condenser walls and transform from a gas to a liquid. And in this research, we find that a flow rate of 1 L/min results in a higher yield percentage than a rate of 2 L/min or 3 L/min. the influence.

Table 3.1 FTIR Result of Bio Oil

| **Wavelength (cm-1)** | **Groups** |
|---|---|
| 2927 | Aromatic, Cyclic enes |
| 1636 | Quinolones |
| 1022 | C-F group |
| 1263 | Hydroxyl group |
| 3380 | Imino-moiety of piperozinyl group |
| 1702 | Carbonyl of acids |
| 1456 | O-C-O group of acid |
| 912 | Amines |

The results of a GC-MS (Gas Chromatography/Mass Spectrometry) examination of bio-oil extracted from pyrolyzed barley waste wasted grains can be obtained from a lab at the University of Gujrat, as indicated in table below (3.2).

| **COMPOUNDS** | **Weight %** |
|---|---|
| 2,2,3,3-Tetramethylhexane | 16.75 |
| 2,2-Dimethylpropionic acid, 4-methylpentyl ester $$ Pivalic acid, 4-methylpentyl ester $$ 4-Methylpentyl pivalate | 11.49 |
| 3-Methyl-4-heptanone | 5.33 |
| 2,2,3-Trimethylbutane | 3,58 |
| 3,7-Dimethyldecane | 3.41 |

| | |
|---|---|
| Cyclopropaneoctanoic acid, 2-[(2-pentylcyclopropyl)methyl]-, methyl ester | 2.87 |
| 2,2,3-Trimethylbutane | 4.24 |
| Cyclo-propane octanoic acid | 2.63 |
| Pentane, 2,2-dimethyl- 2,2-Dimethylpentane | 8.03 |
| Hexane, 2,4-dimethyl- 2,4-Dimethylhexane | 3.88 |
| 7-Hexadecenoic acid, methyl ester, | 4.69 |
| 4,4-Dimethyl octane Octane, 4,4-dimethyl | 2.72 |
| Acetic acid, (acetyloxy)- Glycolic acid, acetate | 2.02 |
| 3,5-Dimethylpyrazole-1-methanol 3,5-Dimethyl pyrazole-1-carbinol 1H-Pyrazole-1-methanol, 3,5-dimethyl | 1.88 |
| 2-Methylaminomethyl-1,3-dioxolane1,3-Dioxolan-2-yl-N-methylmethanamine | 0.47 |
| 3-Oxabicyclo[3.2.0]heptane-2,4-dione,3-Oxabicyclo[3.2.0]heptane-2,4-dion | 0.42 |
| Propanedioic acid, oxo-bis(1-methylethyl) ester Diisopropyl 2-oxomalonate | 0.46 |
| Formic acid, hexyl ester, n- Hexyl formate, n-Hexyl methanoate | 0.68 |
| Eicosen-1-ol, 9-Icosen-1-ol | 0.53 |
| 14-Tricosenyl formate | 0.41 |
| 6-Pentadecen-1-ol | 0.44 |
| 11-Dodecen-1-ol monofluoroacetate | 0.92 |

| | |
|---|---|
| 4H-1,3-Benzodioxin-4-one,2-(1,1-dimethylethyl)hexahydro-5-methyl-4a-(2-propenyl) | 1.23 |
| Propanoic acid, 2-oxo-, ethyl ester, Pyruvic acid, ethyl ester | 0.15 |
| 14-Methyl-8-hexadecenal | 1.4 |
| Hexane, 2,4,4-trimethyl- 2,4,4-Trimethylhexane | 1.16 |
| 3,7-Dimethyloctahydro-2-benzofuran-4-ol | 1.22 |
| Methyl 8-(2-hexylcyclopropyl)octanoate | 1.14 |
| 6,9-Pentadecadien-1-ol | 1.05 |
| Methyl 15-methylheptadecanoate | 2.17 |
| 7-(2-Octyl-1-cyclopropen-1-yl)-1-heptanol | 1.43 |
| 14-Methyl-8-hexadecyn-1-ol | 1.96 |
| 15-Octadecadienyl acetate | 1.9 |
| 28-Heptatriacontadien-2-one | 2.08 |
| 4-Pentyl-1-(4-propylcyclohexyl)-1-cyclohexene | 2.1 |
| Octadecanoic acid, 17-methyl-, methyl ester | 1.34 |
| 5-Cyclohexadecen-1-one | 1.4 |
| 1-Cyclohexylethylamine, 1-Cyclohexylethanamine | 0.18 |
| Pentane, 2,3-dimethyl- 2,3-Dimethylpentane 3,4-Dimethylpentane | 0.1 |
| Formic acid, butyl ester, n-Butyl formate, Butyl formate | 0.16 |
| Imidazole, 4-fluoro-5-Fluoro Imidazol, 4-fluoro- 4-Fluoro-1H-imidazole | 0.12 |

| | |
|---|---|
| Propane-1,3-diamine, 2-t-butyl- 2-tert-Butyl-1,3-propanediamine | 1.58 |
| Cyclobutylamine, Aminocyclobutane, Cyclobutanamine | 0.12 |

According to these findings, the oil contains a wide variety of functional groups, including aldehydes, ketones, carboxylic acids, esters, alkenes, alkanes, etc. A number of oil components, including kerosene, gasoline, and diesel fuel, have been spotted as well.

## 4. Conclusion

The following conclusions can be drawn from the present research work, It was discovered that temperature is the significant parameter that affects the percentage yield of bio-oil. It was discovered that the largest amount of oil was obtained at 650 degrees Celsius, and that the yield decreased as the temperature was raised even further. The flow rate has a significant impact on the percentage yield. When the flow rate is low, the product yield is at its highest because the contact duration is lengthened and more fumes are condensed in comparison to when the flow rate is high. The researchers found that a flow rate of 1 lit/min produced the best results. The Waste Derived Oil that was obtained had physical attributes that were within the same range as those of other bio oils and fuels of low quality.

## References

1. A. Jereme, C. Siwar, and M. A. H. Bhuiyan, (2013) "Incineration and its implications: The need for a sustainable waste management system in Malaysia," International Journal of Environmental Sciences, vol. 4, p. 367.
2. Biswal, S. Kumar, and R. Singh. (2013). Production of hydrocarbon liquid by thermal pyrolysis of paper cup waste.
3. Bhavanam and R. Sastry,(2011) "Biomass Gasification Processes in Down raft Fixed Bed Reactors: A Review," International Journal of Chemical Engineering and Applications, vol. 2, p. 425.
4. Caglar and B. Aydinli, ( 2009) "Isothermal co-pyrolysis of hazelnut shell and ultra-high molecular weight polyethylene: The effect of temperature and composition on the

amount of pyrolysis products," Journal of Analytical and Applied Pyrolysis, vol. 86, pp. 304-309.

5. C. Sembiring, N. Rinaldi, and S. P. Simanungkalit, (2015) "Bio-oil from Fast Pyrolysis of Empty Fruit Bunch at Various Temperature," Energy procedia, vol. 65, pp. 162-169.
6. Dai, L. Fan, D. Duan, R. Ruan, Y. Wang, Y. Liu, et al., (2017) "Microwave-assisted catalytic fast co-pyrolysis of soapstock and waste tire for bio-oil production," Journal of Analytical and Applied Pyrolysis,
7. F. Abnisa and W. M. A. W. Daud, (2014) "A review on co-pyrolysis of biomass: an optional technique to obtain a high-grade pyrolysis oil," Energy Conversion and Management, vol. 87, pp. 71-85.
8. H. Bennadji, K. Smith, M. J. Serapiglia, and E. M. Fisher, (2014) "Effect of particle size on low-temperature pyrolysis of woody biomass," Energy & Fuels, vol. 28, pp. 7527-7537.
9. Hossain, M. Islam, M. Rahman, M. Kader, and H. Haniu, (2017) "Biofuel from Co-pyrolysis of Solid Tire Waste and Rice Husk," Energy Procedia, vol. 110, pp. 453-458, \
10. I Moreno and R. Font, (2015) "Pyrolysis of furniture wood waste: decomposition and gases evolved," Journal of Analytical and Applied Pyrolysis, vol. 113, pp. 464-473.
11. Imaro Sanna, Sujing Li, Rob Linforth, Katherine A. Smart, John M. Andrésen, (2011) Bio-oil and bio-char from low temperature pyrolysis of spent grains using activated alumina, Bioresource Technology, Volume 102, Issue 22.
12. J.-P. Cao, X.-B. Xiao, S.-Y. Zhang, X.-Y. Zhao, K. Sato, Y. Ogawa, et al., (2011)"Preparation and characterization of bio-oils from internally circulating fluidized-bed pyrolyses of municipal, livestock, and wood waste," Bioresource technology, vol. 102, pp. 2009-2015.
13. J. Abid, (2013) "Effect Of Temperature And Particle Size On Pyrolysis Yield From Paper Mulberry (Broussonetia Papyrifera)," Arid Agriculture University, Rawalpindi.
14. Lidja D.M.S. Borel, Taísa S. Lira, Jânio A. Ribeiro, Carlos H. Ataíde, Marcos A.S. Barrozo, (2018) Pyrolysis of brewer’s spent grain: Kinetic study and products identification, Industrial Crops and Products, Volume 121, ,
15. M. Troschinetz and J. R. Mihelcic,(2009) "Sustainable recycling of municipal solid waste in developing countries," Waste management, vol. 29, pp. 915-923.

16. O. Bičáková and P. Straka, (2016) "Co-pyrolysis of waste tire/coal mixtures for smokeless fuel, maltenes and hydrogen-rich gas production," Energy Conversion and Management, vol. 116, pp. 203-213.
17. P. A. Brownsort, (2009)"Biomass pyrolysis processes: performance parameters and their influence on biochar system benefits.
18. Pongrácz, J.-N. Louis, L. Mikkonen, A. Kauriinoja, J. Ritamäki, D. Docent, et al., (2008) "Biomass and Waste-to-Energy Technologies.
19. Qasim, M. H., Ali, N., Khan, W. A., & Haider, B. (2018). Co-Pyrolysis of Organic Solid Waste in Fixed Bed Reactor. JOURNAL OF FACULTY OF ENGINEERING & TECHNOLOGY, 25(1), xx-xx.
20. R. Singh, B. Biswal, and S. Kumar, (2012) "Determination of activation energy from pyrolysis of paper cup waste using thermogravimetric analysis,".
21. S. Luo, B. Xiao, Z. Hu, S. Liu, Y. Guan, and L. Cai,(2010) "Influence of particle size on pyrolysis and gasification performance of municipal solid waste in a fixed bed reactor," Bioresource Technology, vol. 101, pp. 6517-6520.
22. S. Fang, Z. Yu, Y. Lin, Y. Lin, Y. Fan, Y. Liao, et al., (2016) "Effects of additives on the co-pyrolysis of municipal solid waste and paper sludge by using thermogravimetric analysis," Bioresource technology, vol. 209, pp. 265-272.
23. S. Fang, Z. Yu, X. Ma, Y. Lin, Y. Lin, L. Chen, et al., (2017) "Co-pyrolysis characters between combustible solid waste and paper mill sludge by TG-FTIR and Py-GC/MS," Energy Conversion and Management, vol. 144, pp. 114-122.
24. S. Breyer, L. Mekhitarian, B. Rimez, and B. Haut, (2017)"Production of an alternative fuel by the co-pyrolysis of landfill recovered plastic wastes and used lubrication oils," Waste Management, vol. 60, pp. 363-374.
25. T. Cornelissen, M. Jans, J. Yperman, G. Reggers, S. Schreurs, and R. Carleer, (2008) "Flash co-pyrolysis of biomass with polyhydroxybutyrate: Part 1. Influence on bio-oil yield, water content, heating value and the production of chemicals," Fuel, vol. 87, pp. 2523-2532.
26. W. Tsai, M. Lee, and Y. Chang, "Fast pyrolysis of rice husk: Product yields and compositions," Bioresource technology, vol. 98, pp. 22-28, 2007.
27. Zeng, G. Flamant, D. Gauthier, and E. Guillot, "Solar pyrolysis of wood in a lab-scale solar reactor: influence of temperature and sweep gas flow rate on products distribution," Energy Procedia, vol. 69, pp. 1849-1858, 2015.