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LIQUID FUEL FROM CO-PYROLYSIS OF JATROPHA CAKE WITH BIOMASS WASTE AS ALTERNATIVE FOR FOSSIL FUEL: A REVIEW

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Abstract

Several researchers have reported that oil produced from pyrolysis of biomass generally contains high level of oxygen content at (about 35-60 wt. %), which is associated with low calorific value that may leads to corrosion problem. Many studies have been undertaken to reduce the oxygen content through upgrading techniques such as co-pyrolysis. The reviews indicates;(i) Most of the experiment was

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INTRODUCTION BACKGROUND OF THE STUDY

Fossil fuels such as petroleum and natural gas are predicted to be phased out after 2042, and only coal reserves will be available until at least 2112 [29] This condition has made researchers try to put more attention to find solutions by utilizing alternative energy. One of the interesting options is the use of biomass as energy; biomass is very abundant worldwide and can be easily found in diverse forms such as agricultural residues, wood residues, and municipal solid waste [13]. Biomass is based on its availability and its status as a waste product is one of the prime sources of renewable energy worldwide. Biomass is the major energy *conducted on fixed bed reactor (ii) The co-pyrolysis of biomass with plastic waste (polystyrene) reduces the oxygen content to about (86%) and raised the higher heating value (HHV).* (iii) *By increasing the composition of plastic waste in the feed blend, viscosity of bio-oil changed approaching to those of commercial diesel oil. The use of either plastic in the pyrolysis of biomass increases the liquid yield and also improves the quality in terms of its property. The liquid fuel produced by co-pyrolysis or catalytic co-pyrolysis of biomass with plastics waste has potential for use as a substitute for fossil fuels.*

Source in Nigeria, contributing to about 78% of Nigeria's primary energy supply [34]. Biomass originates from plants or their by-products that are produced completely or partly by photosynthesis such as forestry residues, agricultural by- products or animal wastes that can be used as a source of energy [17].

The use of biomass as an energy source also benefits the environment because it has been recognized as a carbon neutral energy source. The conversion of biomass into energy can be achieved in several ways, such as thermal, biological and physical methods. In thermal conversion, pyrolysis is one of the most promising processes that can be used to convert biomass to various types of products such as liquid, char and gas. This technique has been recognized as an environmentally friendly method because no wastes are produced during the process. The process has also received more attention because it can produce liquid yield of up to 75 wt. % with conditions of moderate temperature (500°C) and short hot vapor residence time [8]. The liquid from the pyrolysis process has the potential to be applied as fuels or feedstock for many commodity chemicals. Moreover, the byproduct from this process also has other values in other industry sectors. The obtained char can be used in different industries, such as for the production of briquettes, adsorbents, carbon black pigment, and chemicals. The gas produced from the pyrolysis of biomass has a significant calorific value; thus, it can be potentially used as gaseous fuels or to offset the total energy requirements of the pyrolysis plant. The research to produce liquid fuel via the pyrolysis of biomass has been performed since the last four decades. In 1992, the energy crisis has pushed researchers to put more attention to maximize the production of pyrolysis oil by minimizing the byproducts of char and gases [3].

One of the best uses of pyrolysis was achieved in the 1980s [31]. This technique has successfully led to several improvements, such as the high yield of oil production. The technique has later been called fast pyrolysis. Although the issue of oil quantity has been addressed, the improvement in oil quality still requires further research. Currently, several research efforts are focused in finding the suitable technique to produce high-grade pyrolysis oil and to explore more new variations of biomass that can be used as feedstock in the pyrolysis process. The oil produced from the pyrolysis of biomass has a high level of oxygen content and can cause many problems, such as low calorific value, high viscosity, corrosion problems, and instability. The current research finding showed that the technologies to eliminate the oxygen content are still expensive and can cost more than the oil itself. Therefore, the sustainability of this research seems necessary to overcome this cost and to improve the quality of pyrolysis oil that is expected to compete with fossil-based liquid fuel.

METHODOLOGY

The following methodologies were adopted

i. Characterization of various liquid fuel were examined
ii. Literature of past work on production of liquid fuel
iii. Knowledge gaps discovered were enumerated

CHARACTERIZATION OF LIQUID FUELS OBTAINED FROM CO-PYROLYSIS

Reactor

A reactor is an enclosed volume in which a chemical reaction takes place; the type of reactor used also has a large function in the co-pyrolysis process. [9] .Figure 1.1 highlighted the critical features of successful pyrolysis reactors, which have been defined as very high heating rates, moderate temperatures, and short vapor product residence times for liquids. Several comprehensive reviews have been published to explore the type of pyrolysis reactor for liquid production [32; 31; 9; 19]. Each reactor has advantages and disadvantages in operation and scaling. For fast pyrolysis, the fluidized bed reactor is recommended because of its relative ease of scalability and simple operation compared with other reactor types. Most studies on co-pyrolysis were performed using a fixed-bed reactor [21; 1; 23]. [14] noted that the extent of contact between the used feedstock is an important factor to achieve the synergistic effect; therefore, the synergistic effect is more likely to occur when pyrolysis is carried out on a fixed-bed reactor than on a fluidized-bed reactor. However, a new research finding in 2018 stated that the fixed bed reactor is more effective for co-pyrolysis.

Pyrolysis

Biomass can be converted to energy via either biochemical processes such as fermentation or anaerobic digestion, or thermo-chemical processes [28]. Thermal chemical conversion offers some advantages over biochemical transformations such as opportunities for distributed pre-processing, separation and usage of both carbohydrate and lignin, and integration into existing petroleum refineries [11; 27]. The three main methods of thermo-chemical conversion of biomass into energy are direct combustion, gasification and pyrolysis [17; 7; 25]. Pyrolysis is the initial step in the conversion of solid biomass into higher value fuels in liquid and gas forms or even solid char which may be followed by further catalytic upgrading [21; 16]. Pyrolysis technology based on its product yields is the most favorable process and is more economical than gasification [30].

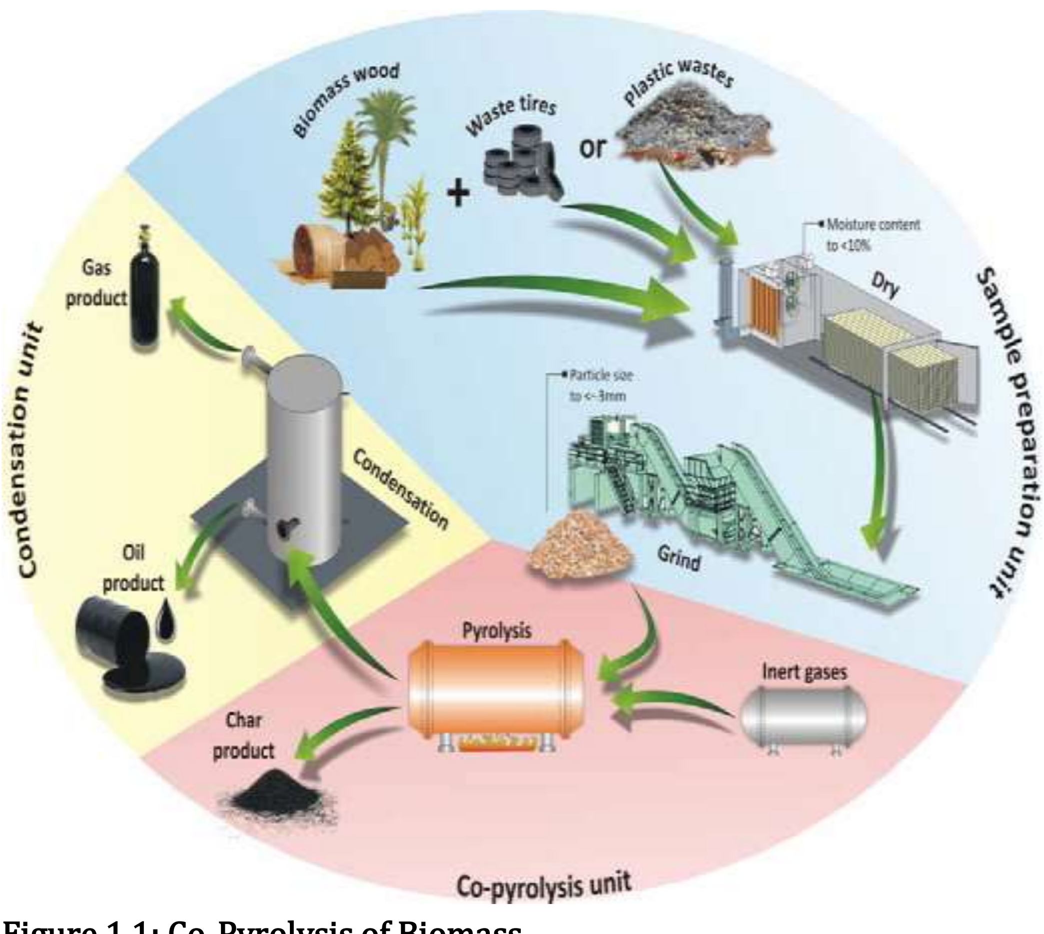

Figure 1.1: Co-Pyrolysis of Biomass

As can be seen from Figure 1.1, there is an optional feature in the co-pyrolysis process: inert gas. Inert gas is used to accelerate sweeping vapors from the hot zone (pyrolysis zone) to the cool zone (condenser). Short hot vapor residence times of less than two seconds are needed to minimize secondary reactions and maximize oil yield [9]. In application, nitrogen (N_2) is an inert gas that is commonly used since it is found to be cheap compared to others. Many studies have proven that the use of inert gases in the pyrolysis process has an effect on liquid yield [4; 12; 1]. The proper setting of the inert gas flow rate is needed to attain maximum oil yield, while very high flow rates of inert gas actually decrease the total oil yield. However, the use of inert gas is dependent on the type of reactor used.

REVIEW OF PAST WORK ON PRODUCTION OF LIQUID FUEL

Alias *et al.* (2016) studied co-pyrolysis of waste tires and biomass reported that waste tires without wire steel were mixed with empty fruit bunches with a ratio of 1:1. The experiment was performed using a fixed bed reactor. Co-pyrolysis was carried out under a nitrogen atmosphere at a temperature of 500°C. Pyrolysis oils were collected in an ice/water condenser. The products of liquid, char, and gas were obtained at levels of 42.80 wt. %, 33.20 wt. %, and 24.00 wt. %, respectively. The liquid product was significantly decreased when the empty fruit bunches were pyrolyzed alone without being mixed with waste tires.

Hassan *et al.* (2016) in their review of recent progress on biomass co-pyrolysis conversion into high quality conversion reported that Co-pyrolysis of biomass with abundantly available materials could be an economical method for production of bio-fuels. However, elimination of oxygenated compounds poses a considerable challenge. Catalytic co-pyrolysis is another potential technique for upgrading bio-oils for application as liquid fuels in standard engines. This technique promotes the production of high-quality bio-oil through catalyst and reduction of oxygenated compounds.

Dijan *et al.* (2016) in their study it yield and composition of bio-oil from co-pyrolysis of corn cobs and plastic waste of high density polyethylene (HDPE) in a fixed bed reactor showed that the mass ratio of plastics to biomass in the feed blend was varied 0:100, 25:75, 50:50, 75:25, and 100:0.

It was found that by increasing HDPE content up to 100% in the feed blend, the yield of bio-oil decreased i.e. 28.05, 21.55, 14.55, 9.5 and 6.3wt% respectively. Also found that by increasing composition of HDPE in the feed blend, viscosity and pH of bio-oil changed approaching to those of commercial diesel oil.

Faisal, (2015) in his study on pyrolysis of oil palm solid waste and co-pyrolysis of palm shell with plastic and tire waste showed that, the use of co-pyrolysis technique can improve the characteristics of pyrolysis oil such as increase in the oil yield, reduce the oxygen content, reduce the water content, and increase the calorific value of oil. Moreover, this technique also benefits to the increase in the quality of byproducts. However, similar with the pyrolysis of palm shell alone, the oil yield from co-pyrolysis also contains the aqueous phase. The result of this study showed that the recovery of liquid fuel from the aqueous phase was successfully performed using a catalytic conversion.

Abnisa (2015) investigated the co-pyrolysis of palm shell and polystyrene (PS) to obtain high-grade pyrolysis oil. The experimental results showed that by adding the same weight ratio of PS in the pyrolysis of palm shell, the yield of oil increased to about 61.63 wt.%, while the pyrolysis of palm shell alone only yielded oil at a level of about 46.13 wt.%. The high yield of oil was obtained with a process temperature of 500°C, a heating rate of 10°C/min, a reaction time of 60 min, an N_2 flow rate of 2 L/min. Moreover, the quality of oil was improved when PS was involved in the pyrolysis of palm shell. For the pyrolysis of palm shell alone, a high heating value (HHV) of oil product was obtained, of about 11.94 MJ/kg. However, pyrolysis of palm shell mixed with PS raised the HHV of oil up to 38.01 MJ/kg.

Cao *et al.* (2015) studied co-pyrolysis of tire waste with biomass concluded that, tire powder with a particle size less than 165 μm mixed with sawdust powder (198-350 μm). The ratios of tire to sawdust in the feed were varied at 0:100, 40:60, 60:40, and 100:0. Feedstock of 100 was put into the fixed-bed pyrolysis reactor. Before heating the reactors, they were first blown for 30 min with nitrogen. The reactor was heated to the designated temperature of 500°C at 20°C/min and held at that temperature for a minimum of 3 ½ hour. The liquid yield reached 45.0 wt. %, 46.2 wt. %, 47.0 wt. % and 47.2 wt. % when tires mass occupied 0%, 40%, 60% and 100%

in the mixture, respectively. The liquid derived from pyrolysis of sawdust alone had a HHV of 28.51 MJ/kg, while the value was increased to 42.44 MJ/kg when tire mass accounted for 60% of the mixture.

Martinez *et al.* (2014) performed the co-pyrolysis of biomass and waste tires using two different reactors, namely, the fixed-bed reactor and auger reactor. The results of their comparison study showed that the fixed-bed reactor produces more liquid yield than the auger reactor for the ratio of 90/10 of biomass/waste tire blend. The experimental results from the fixed-bed reactor also revealed a remarkable upgrade for some liquid properties, such as lower density, higher calorific value, and lower oxygen content.

Yang *et al.* (2014) in their studies of fast co-pyrolysis of low density polyethylene (LDPE) and biomass residue for oil production concluded that the maximum oil relative yield in the case of co-pyrolysis process was obtained at 600 °C, which was significantly higher than the optimum temperature of biomass or LDPE pyrolysis alone. Although, the inorganic elements in biomass improved the decomposition of LDPE

Lieu *et al.* (2014) in their study of a review on co-pyrolysis of biomass: An optimal technique to obtain high grade pyrolysis oil reported that, the oil produced by the pyrolysis of biomass has potential for use as a substitute for fossil fuels. However, the oil needs to be upgraded since it contains high levels of oxygen, which causes low calorific value, corrosion problems, and instability. Generally, upgrading the pyrolysis oil involves the addition of a catalyst, solvent and large amount hydrogen, which can cost more than the oil itself. In this regard, the co-pyrolysis technique offers simplicity and effectiveness in order to produce high-grade pyrolysis oil.

Onal *et al.* (2014) investigated the synergistic effect on product yield and composition when biomass from potato skin was co-pyrolyzed with high density polyethylene (HDPE). Co-pyrolysis of HDPE- biomass mixtures were pyrolyzed with various proportions such as 1:0, 1:1, 1:2, 2:1 and 0:1. The yield of liquid produced during co-pyrolysis enhanced the 23% as the weight ratio of HDPE in the mixture was doubled. The results analyses indicates that produced liquid by co-pyrolysis had higher carbon (26% higher) and hydrogen content (78% higher) and lower oxygen content (86

% less) with a higher calorific value (38% higher) than those of biomass oil.

Burebu *et al.* (2013) in their studies of preliminary research of waste biomass and plastic pyrolysis process presents. This paper presents the results of technical analysis of waste plastics, waste biomass and mixtures biomass/plastic in the ratio 1:1; 3:1 and 1:3. The most common types of plastic waste in municipal waste: high density polyethylene, polypropylene and polystyrene. The results of conducted measurements show that there is an increase in volatile matter, in all the mixtures and their ratios. The largest deviation of volatile matter in relation to the expected theoretical values was observed in the mixtures of pine cone/ polystyrene in the ratio 1:1.

Rutowski *et al.* (2015) in their studies of overview of upgrading of pyrolysis oil of biomass showed that the co-pyrolysis of biomass with industrial waste substantially increases the value of the liquid fuel produced and the thermal efficiency of the process and could potentially be a good solution to improve the bio-oil quality. In addition, the use of a mixture of biomass with fossil fuels reduces the total CO_2 emissions and the environmental impact.

Paradella *et al.* (2013) in their study of the co-pyrolysis of biomass and plastic wastes showed that the adding of a plastic mix improves the overall efficiency of the slow pyrolysis of pine. Therefore, it was possible to achieve higher liquid yields and less solid product than in the classic slow pyrolysis of the biomass. The obtained liquids showed heating values similar to that of heating fuel oil. The gas products had energetic contents superior to that of producer gas, and the obtained solid fractions showed heating values higher than some coals.

KNOWLEDGE DISCOVERED

The following are knowledge gaps discovered in the literature reviewed:

i. None of the research findings investigated the co-pyrolysis of *Jatropha Curcas* seed cake with Plastic waste.
ii. None of the research findings investigated the co-pyrolysis of *Jatropha Curcas* seed cake with tire waste.

iii None of the research findings showed the effect of catalyst in co-pyrolysis technique of the blends of either Jatropha seed cake with Plastic waste or Jatropha seed cake with Plastic waste.

iv None of the research findings determined the physicochemical properties of the liquid fuel produced from Jatropha seed cake with Plastic waste or Jatropha seed cake with Plastic waste.

DISCUSSION OF THE FINDINGS

After reviewing all the available literatures on pyrolysis, catalytic co-pyrolysis techniques, it was observed that the use of co-pyrolysis techniques for pyrolysis of biomass with plastic waste or biomass with tire waste improved the liquid fuel both in quantity and quality. The liquid fuel produced by the co-pyrolysis of biomass with plastics or tire waste has potential for use as a substitute for fossil fuels. It was observed that:

I. None of the researchers carried out experiment on the co-pyrolysis of *Jatropha Curcas* seed cake with either Plastic or tire waste.

II. None of the researchers investigated the effect of catalyst on the co-pyrolysis of the feed stocks.

III. The use of catalyst like zeolite in co-pyrolysis of biomass with plastic or tire waste increases the liquid fuel yield and also improved the quality of the fuel.

JUSTIFICATION OF THE STUDY

The co-pyrolysis technique showed that the liquid fuel obtained during the co-pyrolysis process yields more quantity and quality than the pyrolysis of biomass alone. The use of this technique may overcome the challenges associated with this study. Therefore, there is also need to study the catalytic reforming of biomass waste with either plastic or tire waste for production of liquid fuel. In addition, this approach will alleviate some of the environmental challenges associated with the biomass waste, plastic and tire waste.

CONCLUSION

In conclusion from the review, it has been found that, the pyrolysis oil obtained from biomass sources has high oxygen content which is associated with low calorific value, and this may results to corrosion problem in engines. The oil obtained from the co-pyrolysis of biomass waste with either plastic or tire waste reduces the level of oxygen content in the liquid and improves the fuel quality in terms of energy content. The co-pyrolysis technique also showed that the liquid fuel obtained during the co-pyrolysis process yields more quantity than the pyrolysis of biomass alone. It was also observed that by increasing the composition of plastic waste in the feed blend, viscosity of bio-oil changed approaching to those of commercial diesel fuel. The use of catalyst like zeolite in co-pyrolysis of biomass with plastic or tire waste increases the liquid fuel yield and also improved the quality of the fuel.

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