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VALORIZATION OF ORYZA SATIVA HUSK THROUGH PYROLYSIS TO BIODIESEL

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ABSTRACT

Energy application in the world is in ever increasing demand with majority of the energy supply coming from non-renewable resources. Energy is needed for the transportation of man and his goods and services. Transport fuels are sourced mostly from fossils which are depleting and have its other attendant challenges. There is need for an energy source that is both renewable and sustainable. Rice husk, an agro waste is a lignocellulosic material that can be converted to fuels and a precursor chemical feedstock. This study provides information on the physical and thermochemical properties of rice husk. It also provides the necessary parameters of the pyrolysis- a thermochemical conversion process of rice husks biomass to bio-oil and subsequently its tranesterification to biodiesel. Ordinarily treated and torrefied rice husk biomass were made to undergo pyrolysis at temperatures ranging from 540°C to 800°C at which bio-oil starting yielding establishing that torrefaction is an important pretreatment. Also recorded is a favourable ph of 6.8 which denoted that the bio-oil will be infrastructure-compatible. The bio-oil on transesterification with methanol at 60°C yielded biodiesel with higher heating value of 18.4MJ/kg for the ordinarily treated rice husk feedstock and 21.3MJ/kg for the torrefied rice husk feedstock. The calculated cetane number of the biodiesel was 52.32 for the ordinarily treated rice husk and 58.17 for the torrefied rice husk, a value deduced from the thermal properties of the biodiesel produced. Inculcating biomass derived fuels into the overall energy mix is an economic, cost effective and environmentally friendly venture.

Key Words: Oryza sativa husk, pyrolysis, biodiesel, valorization, bio-oil

INTRODUCTION

The universe is the source and sink of all materials and energy existing today. The misuse or inappropriate handling of any matter may result in environmental degradation, pollution and damage to the ecosystem for man and other inhabitants. Energy application in the world is in ever increasing demand with majority of the energy supply coming from non-renewable resources. Particularly, fossil fuels are employed by industries and consumed in homes as either feedstock or fuel for manufacturing, power, heating, lighting and cooking purposes.

At both ends of the conservation, energy should be harnessed in a sustainable way to ensure availability and safe use for this generation and the next. Use of fossil fuels results in the emission of unhealthy products of combustion as well as greenhouse gases (GHG) which poses a serious negative impact on the climate through global warming. Several efforts are continually being made to establish alternative and sustainable energy sources mainly from renewal resources. Renewable resources comprises hydropower, solar, wind, biomass, geothermal, and these remain largely untapped.

Biomass materials are majorly energy crops, residues of agricultural and forestry activities, industrial and municipal wastes, animal dungs, aquatic plants and algae. Lignocellulosic biomass covers natural materials found in any kind of organic matter that recently originated from photosynthesis. Agricultural residues include cornstalk, rice straw, rice husks, cassava peels, palm kernel shell, empty palm fruit bunches, coconut shell, sugarcane bagasse. These agro-wastes have fuel properties and possess high energy potentials.

Rice production is notably an important part of the crop production sub-sector. Globally, approximately 600 million tons of rice is produced each year (Sutrisno and Hidayat, 2016). The case of rice production in Nigeria is similar to other countries in Asia and Africa where rice production continues to play an important role in their economic development process as a staple food for most farm families (Obianefo et al., 2021). Rice husks is one of the common agro-residue in rice producing countries like China, Thailand, Malaysia, Nigeria etc.

Nigeria is a major producer of rice in Sub Sahara Africa with a lot of government intervention to ensure food security. Nigeria has made efforts to attain self-sufficiency in rice production through banning rice importation to encourage local production and consumption with the immediate effect of raising the local rice price (Obianefo *et al*., 2021). As at 2021, it produced nine million metric tonnes (9 million MT). In 2022, more efforts were added to the revolution as seen in the unveiling of the Rice pyramids in the country. Rice husks is the outer covering produced during rice paddy milling.

Rice husks is about twenty percent (20%) of the totality of the rice crop. For every 1000 kg of paddy milled, about 220 kg (22%) of husk is produced. Rice husks is composed of 20% ash, 38% cellulose, 22% lignin, 18% pentose and 2% other organic components (Sutrisno and Hidayat, 2016) . It is energy dense and an attractive source of bioenergy and a valuable precursor raw materials for chemical industries. To obtain this value added product, two process can be employed which are thermochemical processes and biochemical processes.

There is a potential of biodiesel derivation from rice husks in Nigeria. Harvesting and applying this to the Nigerian energy mix will greatly improve the energy supply value chain.

STATEMENT OF PROBLEM

Agricultural wastes are estimated to be about 12% of all the agricultural processing residue in Nigeria. The traditional agro-waste disposal method of open burning is posing a serious environmental challenge. Ordinary combustion of rice husks is mostly incomplete and products of the combustion cause respiratory problems and emits greenhouse gases. The CO_2 emission from road transportation is about 60% and in the world it accounts for 23% causing global warming. Climate change is currently the most pressing global environmental problem. If the average global temperature increases by more than 2°C, up to one million species could become extinct and hundreds of millions of people could lose their lives.

Oil prices are ever fluctuating and lots of attention is focused on the advent of substitutes to ameliorate the economic impact caused by fossil fuel price and its availability problems and environmental concerns. Hence, the aim of the research work is to evaluate the performance of biodiesel blended at 20% with petroleum diesel from bio-oil produced from pyrolyzed rice husks.

LITERATURE REVIEW

ENERGY DEMAND

Energy is an important factor in all the sectors of any country's economy. Energy plays the most vital role in the economic growth, progress, and development, as well as poverty eradication and security of any nation. Uninterrupted energy supply is a vital issue for all countries today. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible, and environmentally friendly (Oyedepo, 2012).

The recent world's energy crisis is due to two reasons: the rapid population growth and the increase in the living standard of whole societies. The energy crisis, which has engulfed Nigeria for almost two decades, has been enormous and has largely contributed to the incidence of poverty by paralyzing industrial and commercial activities during this period.

Nigeria is Africa's energy giant. It is the continent's most prolific oil-producing country, which, along with Libya, accounts for two-thirds of Africa's crude oil reserves. The country possesses the world's sixth largest reserve of crude oil. Nigeria has an estimated oil reserve of 36.2 billion barrels. It is increasingly an important gas province with proven reserves of nearly 5,000 billion m3. It ranks second to Algeria in natural gas (Oyedepo, 2012). Crude oil consumption in Nigeria has drastically increased. The effect of this increase on the economy relying solely on revenue from oil is tremendous. Also, the Department for Petroleum Resources reported an amount of petroleum of more than 78% of the total energy consumption in Nigeria.

The importance of alternative energy development has increased rapidly due to high international crude oil prices. The Nigerian government launched its Renewable Energy Master Plan (REMP) in January 2007 which provides a roadmap for the gradual move away from fossil fuels and an increase in the role of renewable energy in satisfying the country's energy needs (Popoola, 2013).

In the present predicament as a nation, it is obvious that depending mainly on fossil fuel (petroleum) is not enough to meet the energy needs of the country. Especially the rural areas, which are generally inaccessible due to the absence of good road networks, have little access to conventional energy such as electricity and petroleum products (Oyedepo, 2012).

The Council for Renewable Energy of Nigeria estimates that power outages brought about a loss of 126 billion naira (US$ 984.38 million) annually (Oyedepo, 2012). Apart from the huge income loss, it has also resulted in health hazards due to the exposure to carbon emissions caused by constant use of 'backyard generators' in different households and business enterprises, unemployment, and high cost of living leading to a deterioration of living conditions.

It has been noted that road transportation using fossil fuel is currently the largest source of CO_2 emission in the world. In Nigeria, the CO_2 emission from road transportation is about 60% and in the world it accounts for 23% (Babatunde *et al*, 2019). The global total energy transport use and invariably the CO_2 emission is projected to increase by 80% in 2030 (Babatunde *et al.*, 2019). According to the United Nations' Intergovernmental Panel on Climate Change, the transportation sector was responsible for about 23% of energy-related greenhouse gas emissions in 2004. Passenger vehicles account for about 45% of this total (Atabani *et al.*, 2012).

Development of renewable energy resources appear to be one of the most efficient and effective solutions. Since, Nigeria is blessed with abundant renewable energy resources such as hydroelectric, solar, wind, tidal, and biomass, there is a need to harness these resources and chart a new energy future for Nigeria. Many indigenous researchers have looked into the availability of renewable energy resources in Nigeria with a view to establishing their viability in the country. In this regard, the government has a responsibility to make renewable energy available and affordable to all. Utilization of renewable energy resources can be an alternative solution in response to climate change and energy demand related problems (Babatunde *et al.*, 2019).

BIOMASS

Renewable energy is energy from sources that are naturally replenishing but flow limited; renewable resources are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time (eia.gov, 2022). The use of biomass to produce energy is one form of renewable energy that can be utilized to reduce the impact of energy production and use on the global environment (Babatunde *et al*, 2019).

Biomass is renewable organic material that comes from plants and animals. Biomass contains stored chemical energy converted from the sun in the form of glucose and sugars. Plants produce biomass through photosynthesis. In addition, CO_2 released from biomass conversion processes is resolved into plants by photosynthesis (Kiky, 2014). Lignocellulosic biomass is a mixture of three components (hemicellulose, cellulose and lignin) and minor amounts of other organics.

Biomass has been and continues to be an important fuel in many countries especially for cooking and heating in developing countries. Biomass is considered as clean energy because it contains negligible amounts of nitrogen, sulphur and ash compared to conventional fossil fuels, which results in lower emissions of SO_2, NO_x, and soot than do conventional fossil fuels (Kiky, 2014).

The decline in the dependency on fossil fuels, diminishing of greenhouse gas emissions and reduction of environmental problems from the exploration and usage of fossil fuels are the aspiring goals that have resulted in research efforts in developing technologies to produce more energy from renewable resources such as biomasses (Ige, 2021).

METHODOLOGY

FEED PREPARATION FOR BIO-OIL PRODUCTION

Rice Husk was sourced from Imaab Rice Mill, Kurmi Mashi Industrial Estate, Kaduna South, Kaduna. The Husk was washed to remove impurities and then dried in the sun for 72 hrs. The dried rice husk was then characterized for Proximate and Ultimate Analysis which indicated:

Moisture content

Ash content

Volatile matter &

Fixed Carbon

Ultimate Analysis: This was done using X-ray fluorescence (XRF-EDS) to establish the inorganic matter contents of the rice husks.

Other essential analysis carried out were the following:

X-ray Diffraction XRD on the rice husks

Fourier Transform Infra-red Spectroscopy (FT-IR) on the rice husks and bio-oil.

Rice Husk Ordinary Pretreatment

The Husk was washed to remove impurities and then dried in the sun for 72 hrs.

Rice Husk Torrefaction

The Torrefaction process took as carbonization at 350°C for 4 hours

Catalyst Preparation

Rice husk was ashed in a muffle furnace at 450°C for 8 hours. The resultant ash was mixed with kaolin clay as the binder

Pyrolysis Process

Four different sample types were prepared to undergo the pyrolysis process. The four samples subjected to pyrolysis are:

1. Pyrolysis of ordinarily pretreated rice husk alone
2. Pyrolysis of torrefied pretreated rice husk alone.
3. Pyrolysis of ordinarily pretreated rice husk in the presence of binded catalyst.
4. Pyrolysis of torrefied pretreated rice husk in the presence of binded catalyst.

3kg of the Rice Husk was then channeled to the reactor which was the sealed and then heated at temperatures of 500°C-800°C for the pyrolyzing process. Bio-oil was collected at different temperatures for the four runs and also bio-char at the end.

Pyrolysis Reactor

The reactor is a locally fabricated pyrolyzer, which was made to produce bio-oil, biochar and biogas. It is a fixed bed reactor and the vessel is gas fired. The temperature is controlled by the flow rate of the gas into the burner where the flame is supplied at the bottom of the pyrolyzer.

It is designed with a height of 0.6m and a diameter of 0.23m. The top is made to have an opening of 0.15m diameter where the sample can be manually introduced. The cover of the inlet is designed with flanges where sealants and screw are screw are used to seal it completely before the pyrolysis begins.

The outlet at the top is about 0.5cm in diameter fitted with a hose which allows condensable vapors (oil) and gas to leave the system and attached it is a condenser made of stainless steel material.

The output is then collected at the container after which it is then weighed to calculate the percentage of feed realized as oil. The biochar is collected after the whole process by opening the top completely. The difference between the sum of the oil and char yield becomes the biogas. The pyrolyzer is then washed, dried and prepared for another production.

BIO-OIL PRODUCTION AND CHARACTERIZATION USING ASTM STANDARDS PROCEDURE

Bio-oil required for this research was produced from rice husk ash with a size of 1-3 mm and moisture content of 8-10% on dry-weight basis. The composition of raw bio-oil was determined using the GC-MS (Gas Chromatography Mass Spectroscopy) instrument.

An objective of the characterization experiment is to obtain data for the properties of the sample products. The quality of any fuel is expressed in terms of the fuel properties such as kinematic viscosity, calorific value, flash point and plug point. In this research, the important physical and chemical properties of the bio-oil and the biodiesel were established. These properties include: viscosity, density, flash point, CP (cloud point), PP (pour point), calorific value, cetane number besides some other non-ASTM properties such as refractive index.

1. Determination of the Saponification Value

An American Standard for Testing Material (ASTM) method- D94 -07 (2017) was used for the determination of the Saponification Values of the samples. 2-5g of the sample was weighed into the Erlenmeyer flask or conical flask. 25ml of 0.5M ethanolic KOH was added and the resulting mixture was refluxed for 60 minutes. The resulting solution was subsequently titrated against 0.5M HCl with phenolphthalein as indicator. The resulting end point was obtained when the pink colour changed into colourless. The same procedure was used for the blank. The Saponification value (SV) was then calculated using the expression;

Saponification value (S.V.) = 56.1 (B-S) x M of HCl

Weight of sample

Source (f) : ASTM-D94 -07 (2017)

Where;

B – ml of HCl required by blank

S – ml of HCl required by sample

N – Molarity of HCl

56.1– Molar mass of KOH

2. Determination of acid value

Acid value is defined as the number of milligrams of potassium or sodium hydroxide necessary to neutralize the free acid in 1g of sample. The following sections explain in details the procedure conducted in this research to measure the acid values of bio-oils.

Procedure to prepare phenolphthalein indicator (phph)

Phenolphthalein is a chemical compound with the formula $C_{20}H_{14}O_4$. In titration, it turns colourless in acidic solutions and pink in basic solutions. To prepare titration solution, 0.5 g of phenolphthalein was dissolved in 50% ethanol (ethyl alcohol) solution consisting of 50ml ethanol and 50 ml water. The solution was stored in a stoppered bottle.

Titration procedure

Firstly, a measured amount of the bio-oil was poured into a beaker or Erlenmeyer flask. This was followed by adding 50 ml of 2-Propanol to the measured amount of crude oil. The mixture was then heated to around 50-55 °C to make sure that the oil was well diluted in 2-Propanol. Before the titration is started, 1-3 drops of phph indicator were then added to the mixture. The titration begins with adding the base titrant (KOH solution) with a known normality (0.1 N) from the burette drop by drop to the mixture until the indicator changes, reflecting arrival at the endpoint of the titration. Depending on the endpoint desired, single drops or less than a single drop of the titrant can make the difference between a permanent and temporary change in the indicator. When the endpoint of the reaction is reached, the volume of reactant consumed is measured and used to calculate the acid value of the crude oil. Therefore, acid value can be calculated using the following equation:

$$AV = \frac{MW \times N \times V}{W} \qquad (3.4)$$

where

MW ≡ Molecular weight of potassium hydroxide.

N≡ Normality of potassium hydroxide solution (0.1 N).

V≡ Volume of potassium hydroxide solution used in titration.

W ≡ Weight of oil sample.

Acid values of the sample was also determined by ASTM method (ASTM – D 974(00). 0.2 –

0.5g of sample was weighed into 250ml conical flask. 50ml of neutralized ethyl alcohol was added. The mixture was heated on a water bath to dissolve the sample. The solution was titrated against 0.1M KOH using phenolphthalein as indicator. The acid value was determined after which the free fatty acid was calculated respectively as follows;

Acid Value = . A x M x 56.1 .

Weight of sample (g)

Source (f): ASTM-D 664 – 18e2 (2018)

Where, A = ml of 0.1M KOH consumed by sample

M = Molarity of KOH

W = weight in grams of the sample

3. Ester Value: This is the difference between Saponification value and acid value (mg KOH/g oil). Then;

Free fatty acid = Saponification Value - Acid Value

(Sv – Av)

Where Sv is the Saponification value and Av is the Acid value

Empirical Determination of the saponification number (SN), iodine value (IV) and cetane number (CN)

The saponification numbers (SN), iodine value (IV) and cetane number (CN) of the methyl esters of the bio-oils and biodiesel were calculated empirically from its fatty acid methyl ester compositions with the help of Eqs. (3.2), (3.3) and (3.4), respectively:

$$SN = SUM\left(\frac{560 \times A_i}{MW_i}\right)$$

(Eqn 3.1)

$$IV = SUM\left(\frac{254 \times D \times A_i}{MW_i}\right)$$

(Eqn 3.2)

$$CN = \left(46.3 + \left(\frac{5458}{SN}\right) - (0.225 \times IV)\right)$$

(Eqn 3.3)

A_i is the percentage of each component, D is the number of double bonds and MW_i molecular mass of each component.

CN is given by the relation with the properties of biodiesel as follows:

$$CN = K_5 + K_4\upsilon + K_3\,HV + K_2FP + K_1\rho$$

(Eqn 3.4)

4. Determination of Refractive Index

Abbey Refractometer was used in this determination. A drop of the sample was transferred into a glass slide of the refractometer. Water at 30^0C was circulated round the glass slide to keep its temperature uniform. Through the eye piece of the refractometer, the dark portion viewed was adjusted to be in line with the intersection of the cross. At no parallax error, the pointer on the scale pointed to the refractive index. This was repeated and the mean value noted and recorded as the refractive index

5. Iodine Value: This is a measure of the degree of unsaturation in any vegetable oil or animal fat. It is the weight of iodine absorbed by 100 parts by weight of the sample. It is expressed in (mg/g).

Procedure: The oil sample was poured into a dry glass- stopper bottle of about 250 ml capacity and a small rod was added. The weight (g) of the oil was gotten by dividing the highest expected iodine value by 20. 10ml of carbon tetrachloride and 20ml of wiji's solution was added into the bottle and dissolved.

The stopper which was moistened with potassium iodine solution was inserted and kept in the dark for 30 minutes. 15ml of potassium iodide solution and 100ml of water was mixed and titrated with 0.1M of thiosulphate solution using starch as indicator just before the end point. A blank was carried out at the same time commencing with 10ml of carbon tetrachloride.

Calculation:

Iodine Value = (Blank Titre – Sample Titre) * 12.69

Weight of sample (g) (0.5g)

Where: B = blank titre value = 49.14 cm3,

S = sample titre value = 5.04

6. Peroxide value

This is the measure of its content of oxygen. It is expressed in Mol/Kg.

Procedure: 2g of oil sample and 1g of powdered potassium iodide was added into 2 test tubes containing

20ml of solvent mixture each (2 vol. glacial acetic acid + 1 vol. of chloroform) i.e.

(60:30). Step 1 was carried out in a blank tube (without sample). The tubes were placed in a water bath and allowed to boil vigorously for 30 seconds. The contents were poured quickly into a conical flask containing 10ml of 5% potassium iodide solution. The tubes were washed with 5ml of water each and poured into each conical flask with contents, and 4 drops of phenolphthalein was then added into each conical flask and was titrated with 0.01M thiosulphate until a colour change was obtained.

Calculation:

Peroxide value = (Blank Titre – Sample Titre) * 0.01 * 1000

Weight of sample (g) (2g)

Where: B = blank titre value = 32 cm^3, S = sample titre value = 30.4 cm^3

Molecular weight: the molecular weight of any type of oil can be calculated using the formular:

Mw = 56.1* 1000 * 3

7. Iodine value

0.2 g of oil sample was weighed into a dry 250 mL glass stopper bottle and 10ml of chloroform was added to the oil. 10 mL of Hanus solution was then added and allowed to stand in the dark for 1 hour. 10 mL of 10% Potassium Iodide with 100 mL of water were added and the resulting mixture was then titrated with 0.1N Sodium thiosulphate solution using starch (0.5%) as indicator just. A blank determination was brought out alongside the oil samples.

Iodine value was calculated thus:

Iodine value = (_1−_0)∗_∗1269

Where, V1 = titer value for blank, V0 = titer value for sample and 1269 = Concentration conversion coefficient and W is weight of sample (g).

8. Determination of the Density

The densities of the s were determined by ASTM method D – 129 –12b (2017). The sample was brought to a specified temperature and a test portion was transferred to a hydrometer cylinder that had been brought to approximately the same temperature. The appropriate hydrometer, also at a similar temperature, was lowered into the test portion and allowed to settle. After temperature equilibrium has been reached, the hydrometer scale reading and the temperature of the test portion were taken. The observed hydrometer reading was reduced to the reference temperature by means of a petroleum measurement table. Any hydrometer correction was applied to the observed reading and the corrected hydrometer scale reading recorded to the nearest 0.1kg/m3 as density

Source (f): ASTM-D 129-12b (2017)

RESULTS AND DISCUSSION

This chapter discusses in details the results of rice husks pretreatment, pyrolysis conditions, bio-oil characteristics, physical and chemical properties of biodiesels, fatty acid compositions, biodiesel blending and engine performance. Moreover, a comparison with the existing results in literature has been conducted. In this research, the physical and chemical properties were measured using the equipment mentioned in chapter 3. The engine used in this research were conducted on a 206 kW six-cylinder Honda diesel engine integrated with a Froude hydraulic dynamometer with a maximum power of 455.5 kW. The engine was instrumented with a thermocouple, load cells, a tachometer, a Froude hydraulic dynamometer, and a calibrated tank with an accuracy of 0.5 for measuring the fuel consumption. The fuel consumption was measured, based on volumetric measurement approach, as a measure of flow rate (mass per unit time).

4.2 RICE HUSK PRETREATMENT

The Husk was washed to remove impurities and then air dried in the sun for 72 hrs. The rice husk was subjected to two types of pretreatment. The Dried Rice Husk was then characterized for Proximate and Ultimate Analysis which indicated the values in the table below:

Table 4.1: Proximate, Ultimate and Chemical Analysis of Rice husks

	Component	Value
Proximate Analysis	Volatiles	58.22%
	Fixed Carbon	8.48%
	Ash	24.71%
	Moisture	8.59%
Ultimate Analysis	Carbon	34.9%
	Hydrogen	5.15%
	Oxygen	59%
	Nitrogen	0.31%
	Sulphur	0.64%
Chemical Analysis	Cellulose	37.34%
	Hemicellulose	10.07%
	Lignin	41.08%
	Extractives	11.51%

Ordinary Pretreatment: The rice husk obtained from local Kaduna rice mill was air dried in the sun to a moisture content of 10-15% (w. b). The husk was then fractionated to remove the large (>4 mm) and smaller chips (<2 mm) with the use of vibrating screen separator. After screening, the husk was kept in dry atmosphere for further analysis.

Torrefaction Pretreatment: Torrefaction is a thermo-chemical pretreatment process using biomass within a narrow temperature ranging from 200°C to 350°C. Another portion of the rice husks sample was subjected to this heat treatment. This was done at 350^0C for 4 hours.

Table 4.2: Pyrolysis Yield Temperature

	Pyrolysis Temperature	Yield (%)			Pyrolysis Time (hours)
		Biooil	Biogas	Biochar	
PORH	800^0C	12	18	70	8
PTRH	540^0C	24	27	49	4
PORH+C_T	800^0C	4	26	70	8
PTRH+C_T	650^0C	14	36	50	5

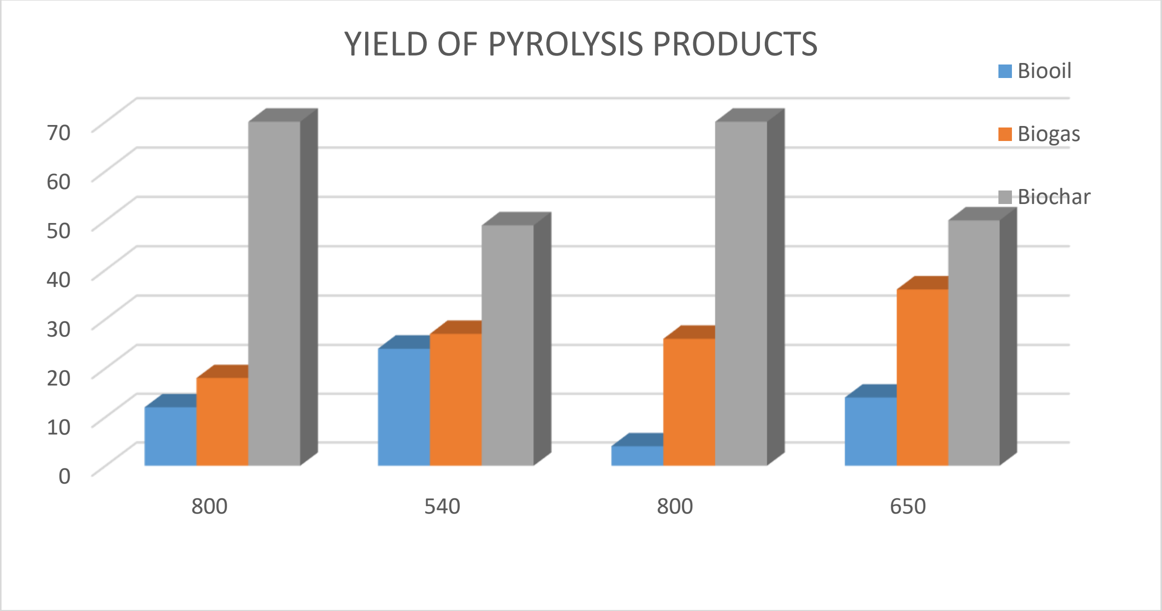

Figure 4.1: Yield Temperature of Bio-oil

Table 4.3: Raw bio-oil and upgraded bio-oil chemical composition analysis by GC-MS with area percentages.

Raw bio-oil	Upgraded bio-oil

Compound name	Area (%)	Compound name	Area (%)
Ethanone,1-(4-hydroxy-3-methoxyphenol)	19.55	1-Butanol	34.12
Phenol,2-methoxy-4-methyl-	10.81	Acetic acid,butyl ester	8.99
Acetic acid	5.1	Propanoicacid,butyl ester	3.04
Phenol,2-methoxy-	4.15	Butanoicacid,octyl ester	2.69
2-Propanone,1-hydroxy	3.63	Phenol,4-methyl	2.59
Phenol,2-methoxy-3-(2-propenyl)-	3.28	Cyclopentanone,2-methyl	2.51
Phenol,2-methoxy-4-propyl-	3.16	Phenol,5-methoxy-2,3-dimethyl	2.06
Phenol,4-ethyl-2-methoxy-	2.61	Benzaldehyde,3,4-dihydroxy	1.99
3,4-Anhydro-d-galactosan	2.1	Hexanoicacid,butyl ester	1.96
Benzeneaceticacid,alpha-hydroxy-	1.96	Pentanoicacid,butyl ester	1.82
Furfural	1.94	3-Undecene,6-methyl-	1.47
Acetic acid,fluoro-,ethyl ester	1.93	Oxalic acid,isobutylnonyl ester	1.36
Hexanoic acid,1-methylhexyl ester	1.85	Cyclohexanone,2-butyl	1.08
2-Cyclopenten-1-one,2-hydroxy-3-methyl	1.84	Ethanol,2-(4-(1,1-dimethylpropyl)))	1.07
Acetic acid,1-methylethyl ester	1.82	Phenol,2-ethyl-6-methyl	1.04
2-Furancarboxaldehyde,5-methyl-	1.78	3-Methyl cyclopentanone	0.89
Eugenol	1.78	2-Heptanone	0.88
Phenol,2-methoxy-4-(1-propenyl)-	1.65	Cyclohexanone,3-dimethyl	0.87
Heptanoic acid	1.42	Cyclopropane,trimethyl methylene	0.86
2-Cyclopenten-1-one,2-hydroxyl-	1.42	Cyclopentane,1,2,3,3,5-pentamethyl	0.86
Vanillin	1.39	Phenol,4-propyl	0.84
1,2-Benzenediol,4-methyl-	1.31	4-(N-Dimethylamino) phenol,acetate	0.83
4-Hydroxy-2-methylacetophenone	1.27	Cyclohexanone,2,3-dimethyl	0.83
3-Methoxy-4-methylaniline		1.25	
Glutaraldehyde		1.16	
Phenol,2-methyl-		1.14	

As shown in this table above the major chemical compounds present in the upgraded bio-oil are esters, ethers, ketones, phenols and alcohols

From the experiment results, it can be concluded that the higher heating value increased from

16.0 to 271.3MJ/kg. The results of gas chromatography-mass spectrometry (GC–MS) and FT-

IR analysis showed that the ester compounds in the upgraded bio-oil increased. It is possible to improve the properties of bio-oil by esterifying the raw bio-oil.

CONCLUSION AND RECOMMENDATIONS

CONCLUSION

Nigeria is the largest producer of rice in sub-Saharan Africa. Rice is a staple food in most homes. With the current intervention by this government administration seen by the rice pyramid unveiling, Nigeria is gradually closing in on being self-sufficient in rice production. Just last year, it produced 9 million metric Tons and about 20% of the totality of the rice crop is rice husks. Rice husk is the outer covering of rice seed, presenting as output of rice milling process. The waste disposal method of this residue is mainly open burning which poses environmental concerns.

In the same manner, fossil fuels which is the major energy source is causing environmental degradation that needs to be mitigated. Most transport fuels are from fossil origin where the GHG emissions and the global warming it causes is a subject of world debate. The need to replace fossil fuels with renewable alternative is on the rise and use of biomass derived fuels a welcome venture.

In this work, rice husk is being valorized to biodiesel to replace fossil/petroleum diesel. Rice husk which is an agricultural waste can be converted into a valuable product through pyrolysis and upgrade through esterification and transesterification. It proved to cut down emissions and protect the ecosystem from further degradation.

Biodiesel has attracted attention as a viable renewable energy source due to its lower greenhouse gas emission and its potential to reduce dependence on imported fossil fuels as well as meet the global energy demand. Use of biomass derived fuel agrees with carbon sequestration principles and carbon neutrality cycle. Carbon like Hydrogen, Oxygen and Nitrogen is a chemical element and the basic building block of biomolecules. It exists on earth in solid, dissolved and gaseous form. However, oxides of carbon pollute the environment in concentrations earmarked. Carbon balance should be neutral or negative for all processes now as the level in the atmosphere is already alarming to ensure a sustainable world today and in the future. The bio-oil and biodiesel has so many industrial and domestic applications thereby taking care of rice husk disposal issues as well as fossil fuels pollution issues.

CONTRIBUTION TO KNOWLEDGE

The potentials of converting rice husk to a biofuel which is infrastructure compatible and environmentally friendly since its emissions are within limits.

RECOMMENDATIONS

Based on the conclusion, the following recommendations can be drawn:

1. Optimization of bio-oil production from several Lignocellulosic biomass sources should be considered in the future studies.
2. Engine emission tests analysis and performance improvement using locally sourced additives to improve engine performance and emission should be considered.
3. Establishment of the limiting factors of commercial biodiesel production cost such as feedstock raw material generation, equipment cost and government policy should be considered by conducting a techno-economic, sensitivity analysis and life cycle assessment (LCA).

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