ENERGY ANALYSIS IN THE PRODUCTION OF ETHANOL FROM SAW DUST

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Abstract - Energy from fossil fuels has played a very important role in our lives, but such an important role has been clouded out due to the environmental hazard caused from fossils emission. This has select to a new dimension in energy utilization known as renewable energy fuels. To fully support this type of energy from biological mass, adequate biomass source must be harness. This work thus was carried out to utilize a local available biomass waste as an alternative source of ethanol which is currently used for spark ignition engine as a renewable energy fuel. It also determined the yield of ethanol from the sawdust used. The materials used for the production of the liquid fuel are sawdust, H_2SO_4 (Sulphuric Acid) and Water and the sawdust that wascollected in a polythene bag from sawmill market, waste dump site at Orita Challenge Ibadan, Oyo State. The sawdust were then weighed on weighing balance to determine the weight of each quantity and were transferred into pretreatment chamber where volume of hydrochloric acid was added and were thoroughly mixed for about 10 minutes before heating was applied in the fermenter chamber after the slurry have been pumped into the fermenter chamber. The heating process took place for different time, and then the steam passing through the condenser was cooled before collection. Afterwards, its mass and volume of the liquid fuel produced were determined. At the end of this study, the Mass of sawdust increase ranges from 0.5kg to 2.0kg sample, volume of water ranges from 3000ml to 18000ml, amount of concentrated H_2SO_4 ranges from 30ml to 120ml, temperature ranges from 51ºC to 82ºC. The energy input of Milling for the processing of ethanol for (D= 1 litre, N= 2 labour, Ta= 30mins) is 52.3MJ, while mixing and liquefaction for gas stove (n= 70%, p=0.25hp, t= 129 mins, N= 2 labours, Ta= 112mins) is 205.11 MJ, and (n= 70%, p=0.25 hp, t= 10.4 hrs, N= 3 labours, Ta= 623 mins) for charcoal stove is 1,166.56 MJ.

Keywords: Energy input, liquefaction, sawdust, ethanol production, charcoal stove, gas.

1. INTRODUCTION

Biomass resources in the country include Agricultural crops, wood, charcoal, grasses and shrubs, residues and wastes (agricultural, forestry, municipal and industrial), and aquatic biomass. Total biomass potential in Nigeria, consisting of animal and agricultural waste, and wood residues, was estimated to be 1.2 PJ in 1990 [4]. In 2005, research revealed that bio-energy reserves potential of Nigeria stood at: Fuel wood 13071,464 hectares, animal waste, 61 million tonnes per year, crop residues, 83 million tonnes [8].

Bio fuels can be broadly defined as solid, liquid or gaseous fuels consisting of or derived from biomass. At the moment potential crops for bio fuel production in the country are cassava, sugar cane, rice and sweet sorghum for Bio ethanol; palm oil, groundnut, and palm kernel for biodiesel because of their high yield and current production output in the country [1]. Nigeria is the largest producer of cassava in the world and has the largest capacity for oil palm plantation which serves as a great source for biodiesel [3.6.12]. It is interesting to mention that Nigeria could also be a major player in the bio fuel industry given the enormous magnitude of various waste/residues (agricultural, forestry, industry and municipal solid) available in the country. Bio fuel may be of special interest in many other developing countries like Nigeria for several reasons [2, 5].

Climate in many of the countries are well suited to growing biomass. Biomass production is inherently rural and labor-intensive, and thus may offer the prospect for new employment in regions where the majority of populations typically resides. [9] classified Nigeria as one of the countries with very high potential for energy crops production.

Fossil resources are still primary energy and chemical sources; around 75% is used for heat and energy production, about 20% as fuel, and just a few percent for the production of chemicals and materials [15]. Natural regeneration of fossil resources through the carbon cycle is significantly slower than their current rate of exploitation. A small number of countries possess the major reserves of fossil fuels, which additionally increases unsustainability of their production. Furthermore, increased greenhouse gas emission arises from fossil fuel combustion and land-use change as a result of human activities, and consequently results in an acceleration of the global warming crisis [13, 16]. In most developed countries, governments stimulate the use of renewable energies and resources with some major goals: to secure access to energy, to mitigate climate changes, to develop/maintain agricultural activities and to ensure food safety. Affordable energy, climate change and social stability, as the three pillars of sustainability,

are directly related to the above mentioned major goals [12].

Current situation of global warming and all fossil-based problems could be successfully altered by replacing fossil with renewable resources, which are more uniformly distributed and cause fewer environmental and social concerns [10,16].

During the last decades of the 20th century, there was an enormous interest in the production and usage of liquid bio fuels (biodiesel or Bio ethanol) as promising substitutes for fossil fuels. Bio fuels manufactured from plant-based biomass represent renewable energy resources. The use of this feedstock would reduce fossil fuel consumption and consequently the negative impact on the environment [7]. Development of bio refinery aims to fulfill the sustainability criteria for bio fuel production.

Bio refinery is an integrative and multifunctional concept that uses biomass for the sustainable production of different intermediates and products as well as the complete possible use of all feedstock components [5]. The concept includes selective transformation of the different molecules available in the biomass into bio fuels, but also into pharmaceuticals, pulp, paper, polymers and other chemicals, as well as food or cattle feed [3]. A wide range of technologies are able to separate biomass resources into their building blocks, like carbohydrates, proteins, fats, etc. The plant that produces lignocelluloses-containing raw materials could be a good example of bio refinery concept where cellulose and hemicelluloses produce simple (fermentable) sugars and lignin produces target compounds (e.g. polymers, resins, pesticides, levulinic acid and other materials). Recently, there have been considerable efforts to improve selectivity and efficiency of lignin depolymerization and upgrading processes for the target compound production. The catalytic hydrodeoxygenation process is the most promising way for target compound production from lignin [17].

In general, the bio refinery process usually comprises the following stages: pretreatment and preparation of biomass, separation of biomass components and subsequent conversion and product purification steps. There are two basic approaches for bio refinery concept implementation: bottom-up and top-down. Bottom-up bio refinery approach is characterized by the spreading of current biomass processing facilities (the production of only one or a few products) into a bio refinery with the aim to obtain an enlarged range of products and/or an increase of usable biomass fractions through the connection to additional technologies. An example of bottom-up bio refinery is the wheat and corn starch bio refinery (Lestrem, France) that starts as a simple starch factory. It gradually expanded the number of products, like starch derivatives and starch modifications, chemicals and fermentation products. A corn starch bio refinery in the USA (Decatur, Illinois) and wood lignocellulosicbiorefineries in Austria (Lenzing) and Norway (Sarpsborg) also use bottom-up approach [9].

The main objective of this project work is;
i. To produce Bio-Ethanol with Sawdust as feedstock using an existing Bio-Fuel Production Plant

ii. To determine energy input in various levels of production

2. GENERAL REVIEW OF LITERATURE

Many environmental problems such as greenhouse gases and pollution of air, water and soil originate from fossil fuels. Fossil fuels release greenhouse gases, like carbon dioxide, that contribute to global warming. Carbon dioxide from fossil fuel combustion accounted for nearly80 percent of global warming in the 1990's [4]. The sawdust is obtained from sawn wood and probably other wood wastes. Sawdust can be wastes/residue from either hardwood or softwood or the mixture of both. Sawdust serves as a cheap substrate for ethanol production, does not distort the human food chain and takes care of the environmental waste. The major difficulty in the hydrolysis of lignocelluloses contents from wood, to obtain fermentable sugars, lies in separating it from lignin that encloses it and makes it difficult to access. Acid hydrolysis is one of the pretreatment methods used for the lignocelluloses contents to make it susceptible to fermentation to obtain cellulosic ethanol [3,7,11].

Pretreatment Techniques

[15] has described pretreatment has procedure required to alter the biomass macroscopic and microscopic size and structure as well as its submicroscopic structural and chemical composition to facilitate rapid and efficient hydrolysis of carbohydrates to fermentable sugars. Lignocellulosic biomass, including forestry residue, agricultural residue, yard waste, wood products, animal and human wastes, etc., is a renewable resource that stores energy from sunlight in its chemical bonds [20,31, 36, 40].

The overall purpose of pretreatment is to break down the shield formed by lignin and hemicelluloses, disrupt the crystalline structure and reduce the degree of polymerization of cellulose [30]. Pretreatment has been viewed as one of the most expensive processing steps within the conversion of biomass to fermentable sugar. With the advancement of pretreatment technologies, the pretreatment is also believed to have great potential for the improvement of efficiency and cost reduction [22, 25, 35].
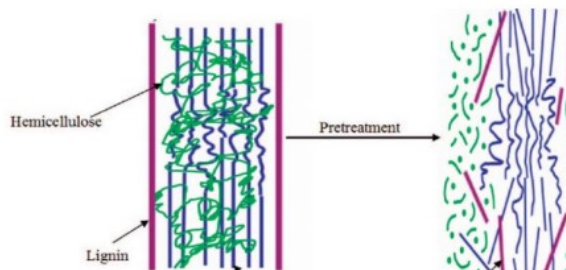

Fig. 1. Pretreatment in the Conversion of Biomass

Pretreatment techniques have been developed for various end uses of biomass feedstocks. The aim of this study emphasizes the biomass pretreatment in preparation for acid hydrolysis for producing of reduced

sugars and microbial fermentation for cellulosic ethanol production [38]. It primarily covers the impact of biomass structural and compositional features on the pretreatment, the action mode of different pretreatment methods, the pretreatment study status, challenges and future research targets [39].

Various pretreatment technologies have been extensively studied to process different biomass for cellulosic ethanol production. However, none of those can be declared a "winner" because each pretreatment has its intrinsic advantages and disadvantages. An effective pretreatment is characterized by several criteria; avoiding size reduction, preserving hemicelluloses fractions, limiting formation of inhibitors due to degradation products, minimizing energy input and being cost effective [25, 29, 35].

Physical Pretreatment

Physical pretreatments are methods without addition of chemicals or micro-organisms. They use external forces to reduce the LCMs into fine particles in order to increase the surface area of the materials. According to the forces used, the physical pretreatment can be further divided into two sub-catalogs; mechanical (dry, wet, vibratory ball milling) [36].and non-mechanical method (steam explosion, irradiation and pyrolysis) [6].

Mechanical Pretreatment

Mechanical pretreatments use shearing force to reduce biomass particle size, change the lignocelluloses structure and reduce degree of polymerization and crystallinity of cellulose [17]. Depending on the final size of the material, the mechanical pretreatment consists of milling, grinding or chipping. Chipping leads to 10 to 30mm particles and milling and grinding lead to 0.2 to 3mm [4, 29]. Milling includes ball milling, two roll milling, hammer milling, compression milling agitation bead milling, pan milling, fluid energy milling and colloid milling [33]. For aspen, vibratory ball milling is reported to be a more effective methods compared to ordinary ball milling [40].

However, according to the research performed by [32], the energy input to reduce the biomass to fine particle is higher than the theoretical energy content held in biomass, which makes the milling not economical for most lignocellulosic biomass, especially for high moisture biomass. Furthermore, these methods are species selective. Improper application of mechanical pretreatment will lead to carbohydrate losses, in which case the final fermentable sugars and ethanol yield will be reduced [8]. Therefore, mechanical pretreatment is considered to be impractical to be applied exclusively. Combination of mechanical pretreatment and chemical size reduction is commonly used to make the pretreatment more cost efficient [10].

Extrusion, which utilizes heating, mixing and shearing to increase accessibility of the materials, is a novel promising pretreatment technology. Both physical and chemical modifications occur as the lignocellulosic biomass passes through the extruder [4]. High efficiency makes this pretreatment method appealing.

Non-Mechanical Method

Irradiation pretreatment can be performed by Gamma rays, microwave, ultrasound, pulse electrical filed, UV and electron beam. Irradiation will cause the disruption of beta-1, 4-glycosidic bonds and cellulose crystalline structures [13]. In addition, the high energy of these radiations will lead to the formation of free radicals, which leads to a further degradation of the lignocellulosic materials. This method is widely used in waste water sludge pretreatment [28]. For the application for lignocellulosic biomass, including rice straw, bagasse, sawdust, chaff, corn stalk, peanut huts and oil palm empty fruit bunch, was studied in pervious experiments by using ultrasonic irradiations [34].

Dramatic enhancements of the enzymatic hydrolysis efficiency were achieved [22]. Unfortunately, irradiation pretreatments are reported to consume high levels of energy and require long process time with expensive high quality equipment [12]. Irradiation pretreatment methods by themselves are currently limited to laboratory scale and not considered as a feasible solution for industrial applications.

Steam explosion is exposing biomass to steam under high pressure and temperature followed bya decompression at the end [20]. Liquid hot water (LHW) pretreatment (co-current, countercurrent and flow through) is a pretreatment similar to steam explosion, except that, in LHW pretreatment, instead of steam, biomass is merged into hot water with certain pressure and temperature. Both these processes are able to cleave the acetyl groups and uronic acid groups from hemicelluloses and consequentially acidify the medium. Furthermore, water at high temperature acts as acid [11]. As a result, acidic condition will cause partially hydrolysis of hemicelluloses and amorphous cellulose to oligosaccharides and to fermentable sugars, also resulting in a more accessible material for the following hydrolysis or fermentation steps [3].

Moreover, for steam explosion, the lignin structure is partially modified which also leads to higher digestibility of the biomass [39]. In addition, the shear forces caused by expansion contribute to the structural modification [5]. Both mechanisms are similar to acid pretreatment. However, the steam explosion is able to offer higher fermentable sugar concentrations due to the lower water content [23]. There are no chemicals added in both methods. In addition, size reduction is not required for lignocellulosic biomass since breakage of particles will occur during pretreatments [33], these methods are more economic feasible in lignocellulosic conversion application. The total reduced sugar yield after hydrolysis is increased over seven times with the pretreatment as compared to non-treated aspen [16].

LHW was applied on yellow poplar wood sawdust with and without pH control [27]. The pretreatment proved to involve the partial conversion of cellulose and hemicelluloses into polysaccharides and monosaccharide's. Nevertheless, during steam explosion and LHW, high temperature is reported to increase the lattice structure of the cellulose and consequentially increase the cellulose crystalline [7]. In addition, higher pretreatment temperature also leads to increased material solubility adding to the pretreatment yield loss [37].

High severities also causes the production of various fermentation inhibitors, includes furfural, 5-Hydroxymethylfurfural (HMF), phenolic compounds and aliphatic acid, making this method not suitable for

pretreatment. Monitoring and controlling the pH is considered to be an efficient improvement for LHW pretreatment. With controlled pH, cellulose solubility and formation of HMF, levulinic and formic acid are minimized.

Biological Pretreatment

Because of the environmental issues, more and more studies turn to biological pretreatment methods, which use fungi, bacteria or their enzymes [9]. Fungi are applied as delignification agent to digest or change the lignin structure and hydrolyze the hemicelluloses [2]. As a result, enzymes used for the hydrolysis process are able to approach polysaccharides such as cellulose and other hemicelluloses much easier. In the present literature, various species of brown rot fungi, white rot fungi and soft rot fungi have been studies [31].

White rot fungi only attacks lignin, but brown rot and soft rot fungi mainly attack cellulose while slightly modifying the lignin structure. Among these species, white rot fungi are more commonly used in pretreatment since they produce lignin-degrading enzymes including laccases and peroxides [1]. Pleurotusostreatusis reported to be able to convert over 35 percent of wheat straw cellulose into reduced sugars in five weeks [14].

Stereumhirsutum was found to be very efficient in pretreated Pinusdensiflora, a type of softwood [18]. Other white rot fungi like Cyathusstercolerus, Phanerochaetechrysosporium, Phanerochaete sordid and Pycnoporuscinarbarinus were also tested on several substrates for their delignification efficiency [37].

Researchers agree that there are significant advantages to the biological pretreatment methods, especially since these procedures are completely environmentally friendly and require low energy input [21]. However, the drawback of these methods outweighs their advantages. Almost all those fungi need more than one week to react with biomass. In addition, lignindegradation of white rot fungi requires a carbon source, mainly cellulose and hemicelluloses, since it is a co-oxidative process. Thus, while reacting with lignin, these fungi will reduce cellulose and hemicelluloses concentration in biomass, thereby decreasing the yield of fermentable sugars [24].

As a result, although enormous experiments have been carried out at lab-scale, none of the biological pretreatments have been applied to industrial-scale production [15, 27]. Thus, these methods still need to be improved before they can be used for large-scale production. Development of genetically modified strains with high lignin degradation capacity and high cellulase activity are necessary [14].

Chemical Pretreatment

Chemical pretreatments have been studied dated back to the early 1900's and several reports have been published since 1980's comparing response of enzymatic hydrolysis after different chemical pretreatment methods [17]. Contradictory to the physical methods, chemical pretreatments are mainly used for modifying the lignin in the biomass, removing hemicelluloses and to change cellulose polymerization as well as cellulose crystalline structure [39]. Acids, alkali, salts, organic solvents as well as oxidizing agents are all considered to be effective pretreatment agents [19].

Bio Ethanol Production Process

Currently, industrial Bio ethanol production is divided into three generations based on the type of feedstock used [28] . The processes involved in all bio fuel generations include: pretreatment, hydrolysis (although not required in the fermentation of sugar cane), and conversion of sugars to Bio ethanol via fermentation. Some feedstocks require pretreatment conditions (i.e., lignocellulosic feedstock and algal biomass) to release fermentable sugars into the media. Without pretreatment, fermentation progress can be slowed due to limited availability of fermentable sugars for metabolism.

Furthermore, genetics of feedstocks can contribute to variations in sugar content and influence fermentation ethanol yield [26]. Currently, fourth-generation Bio ethanol production methods are being investigated, which utilize genetically engineered organisms to enhance fermentation efficiency. However, these approaches are not yet implemented at an industrial scale [30].

3. METHODOLOGY

Materials

The materials were selected based on the various characteristics such as availability, durability, strength, hardness for the modification and testing of complete bio-ethanol production plant. The modification and testing of complete bio-ethanol production plant was at Odo-ona Elewe, Ibadan, Oyo State, Nigeria. The wood shavings (sawdust) used for the evaluation was gotten from Saw Mill New garage Area, Ibadan.

Bills of Engineering Materials

Table 1. Bill of Engineering Materials and Evaluation

S/N	Materials	Quantity	Unit rate (₦)	Total Cost (₦)
1.	¾ union joint	3	300	900
2.	¾ air value	1	300	300
3.	1"adaptor"	2	70	140
4.	¾ 1"bash"	2	50	100
5.	Copper flexible	1	600	600
6.	¾ socket	2	85	170
7.	¾ M and F socket	1	60	60
8.	Small gum	1	800	800
9.	¾ adaptor	1	60	60
10.	Clip	1	100	100
11.	½ tap	3	600	1800
12.	3029 wire	8	220	2000
13.	Capacitor	1	1200	1200
14.	Paper tape	1	300	300
15.	Blue paint			3000
16.	Silver paint			1000
17.	Petroleum (paint)			500
18.	Cassava peel			1500
19.	Grinding of peel			1500
20.	Gum			500
21.	Cylinder			1500
22.	Filling of the cylinder	10		6750
23.	Charcoal	1 bag	4400	4400
24.	Diesel			8500
25.	Plumber workmanship			2000
26.	Welder workmanship			80000
27.	Acid			30000
28.	Transport			20000
29.	Lab test			20000
	Total			**189,680**

Methods

The following are the steps to carry out when evaluating the bio-ethanol production plant.

Step 1: The sample each of agricultural by-product will be locally sourced and pour it into pre-treatment unit.

Step 2: I will measure the volume of water, acid then also pour it into pre-treatment unit and stir all together for some minute until it turn slurry

Step 3: And then transfer it into fermentation unit. Stir and heat until it bring out steam.

Step 4: The steam passes through pipe to the condensation unit and give out water (ethanol).

Step 5: I will record the temperature rate to produce ethanol.

Evaluation Models

These are the parameter for evaluation
a) The mean value of ethanol extracted in kilogram can be gotten by using the formula

$$R_T = \frac{R1 + R2 + R3 + R4 + R5}{N} \quad \ldots\ldots(1)$$

Where

R_T = Mass of ethanol gotten at each replicate

N = Total number of replicates

b) The yield of ethanol extracted can also be calculated by

$$Y = X/M \quad \ldots..(2)$$

Where Y = is the yield of ethanol extracted

X = mean value of ethanol extracted

M = mass of feedstock

Source: (Adelekan, 2014)

c) Energy input for processing of ethanol
    Mixing and liquefaction .

$$E_{ml} = 3.6\,(nPt + 3.6\,(0.075\,N\,Ta)\,MJ \quad \ldots.(3)$$

where n = appliance efficiency; P = rated horse power of appliance, KW; t = hours of operation, h. Conversion of 1Kwh to 3.6 MJ was used.

Distillation

$$E_d = 3.6\,(nPt)\,MJ \quad \ldots…..(4)$$

Total energy input for production of saw dust ethanol ET is the sum of the components involved in each process. Thus the total energy ET becomes:

$$ET = jEml + Ed \quad \ldots…..(5)$$

Sources: (Bamgboye *et al* 2018)

4. RESULTS AND DISCUSSION

Results

Table 2 : Extraction of Biofuel with Gas stove

Mass of saw dust (kg)	Volume of water (ml)	Volume of H_2SO_4 (ml)	Temperature (°c)	Time (mins)	Mass of Biofuel (kg)	Volume of Biofuel (ml)
0.5	3000	30	52	13	0.15	150
1.0	8000	60	51	19	0.15	150
1.5	13000	90	55	23	0.20	200
2.0	18000	120	54	34	0.25	250
2.5	23000	150	56	40	0.25	250

(Source: Field Work, 2022)

Table 3: Extraction of Biofuel with Charcoal Stove

Mass of saw dust(kg)	Volume of water (ml)	Volume of H_2SO_4 (ml)	Temperature (°c)	Time (mins)	Mass of Biofuel (kg)	Volume of Biofuel (ml)
0.5	3000	30	55	68	0.05	50
1.0	8000	60	64	85	0.05	50
1.5	13000	90	69	140	0.11	110
2.0	18000	120	82	150	0.11	110
2.5	23000	150	85	180	0.13	130

(Source: Field Work, 2022)

Calculation for the mean value of Biofuel extracted in kilograms (kg) and the yield of Biofuel (%).

For Gas stove

(a) For 0.5kg of Saw dust
    Mean value = 0.15
    Yield of ethanol extracted = 0.15 / 0.5 x 100 = 30%

(b) For 1.0kg of Saw dust
    Mean value = 0.15
    Yield of ethanol extracted = 0.15/ 1.0 x 100 = 15%

(c) For 1.5kg of Saw dust
    Mean value = 0.20
    Yield of ethanol extracted = 0.20 / 1.5 x 100= 13.3%

(d) For 2.0kg of Saw dust
    Mean value = 0.25
    Yield of ethanol extracted = 0.25 / 2.0 x 100 = 12.5%

(e) For 2.5kg of Sawdust
    Mean value = 0.25
    Yield of ethanol extracted = 0.25/2.5 x 100 = 10%

For charcoal stove

(a) For 0.5kg of Saw dust
    Mean value = 0.05
    Yield of ethanol extracted = 0.05 / 0.5 x 100 = 10%

(b) For 1.0kg of Saw dust
    Mean value = 0.05
    Yield of ethanol extracted = 0.05/ 1.0 x 100 = 5%

(c) For 1.5kg of Saw dust
    Mean value = 0.11
    Yield of ethanol extracted = 0.11 / 1.5 x 100= 7.3%

(d) For 2.0kg of Saw dust
    Mean value = 0.11
    Yield of ethanol extracted = 0.11 / 2.0 x 100 = 5.5%

(e) For 2.5kg of Saw dust
    Mean value = 0.13
    Yield of ethanol extracted = 0.13/ 2.5 x 100 = 5.2%

Table 4. Biofuel Yield Produced with Gas Stove

Mass of saw dust (kg)	Volume of water (ml)	Volume of H_2SO_4 (ml)	Mean Temperature (°c)	Mean Time (mins)	Mean Mass of Biofuel (kg)	Yield of Biofuel Extracted (%)
0.5	3000	30	52	13	0.15	30
1.0	8000	60	51	19	0.15	15
1.5	13000	90	55	23	0.20	13.3
2.0	18000	120	54	34	0.25	12.5
2.5	23000	150	56	40	0.25	10

(Source: Field Work, 2022)

Table 5: Quantity of Biofuel Yield Produced with Charcoal Stove

Mass of saw dust (kg)	Volume of water (ml)	Volume of H₂SO₄ (ml)	Mean Temperature (°c)	Mean Time (mins)	Mean Mass of Biofuel (kg)	Yield of Biofuel extracted (%)
0.5	3000	30	55	68	0.05	10
1.0	8000	60	64	85	0.05	5
1.5	13000	90	69	140	0.11	7.3
2.0	18000	120	82	150	0.11	5.5
2.5	23000	150	85	180	0.13	5.2

(Source: Field Work, 2022)

Table 6: Feedstock Retention Time (Gas Stove)

Saw dust (kg)	Volume of H₂SO₄ (ml)	Time (mins)
0.5	30	13
1.0	60	19
1.5	90	23
2.0	120	34
2.5	150	40

(Source: Field Work, 2022)

Table 7: Feedstock Retention Time (Charcoal Stove)

Saw dust (kg)	Volume of H₂SO₄ (ml)	Time (mins)
0.5	30	68
1.0	60	85
1.5	90	140
2.0	120	150
2.5	150	180

(Source: Field Work, 2022)

Table 8: Cost and Time Comparison between the Heat Sources

Source	Unit (kg)	Cost (₦)	Time (min)
Gas	10	6750	129
Charcoal	50	4400	623

(Source: Field Work, 2022)

Table 9: Laboratory Analysis Report of the Liquid Produced

Parameters	Units	Sample of Biofuel Product
Viscosity	CP	6.80
Acid value	MgKOH/g	7.28
Specific Gravity	g/g	0.8514
Density	g/ml	0.8509
Moisture	%	28.61
Total Glycerine	%	0.059
Free Glycerine	%	0.017
Flash Point	°C	65.30
Carbon Residue	%	0.14
Sulphur	%	0.48
Pour Point	°C	7.50
Cloud Point	°C	9.60

(Source: Field Work, 2022)

Energy input for processing of ethanol Mixing and liquefaction

$$E_{ml} = 3.6 (nPt + 3.6 (0.075 N Ta) MJ$$

a) For gas stove

Where n = 70%;
P = 0.25 horse power (hp), KW;
t = (13+19+23+34 +40) = 129 /60 = 2.15 hrs,
N= 2 labour,
Ta= (13+19+23+34 +40) mins = 129 mins
= 3.6 (70 x 0.25 x 2.15 + 3.6 (0.075 x 2 x 129)
E_{ml} = 205.11 MJ

b) For charcoal stove

Where n = 70%;
P = 0.25 horse power (hp), KW;

t = (68 + 85 + 140+ 150 +180)mins = 623 /60 = 10.4 hrs,
N= 3 labour,
Ta= (68 + 85 + 140 + 150 +180) mins = 623 mins
= 3.6 (70 x 0.25 x 10.4 + 3.6 (0.076 x 3 x 623)
E_{ml} = 1,166.56 MJ

Discussion

Table 1 and 2, x-rayed the mass of feedstock (Sawdust) used in the experiment which ranges from 0.5kg to 2.5kg with water mixture from 3000ml to 23000ml while tetraoxosulphate VI acid (H_2SO_4) OF 30ml to 150ml was added. The result revealed that gas produce biofuel within 13mins to 40mins, while for the charcoal source biofuel was produced within 68mins to 180mins. This simply means that it will be more preferable to use gas as source of heat in biofuel production even through Table 7 has revealed that the cost of gas for production is more higher than that of charcoal (Gas = 6,750 NGN, Charcoal= 4,400 NGN).

In term of the quantity of biofuel obtained from the study, the result shared that the least batched feedstock extraction was 150ml and the highest was 250ml using gas stove. While for the charcoal stove was 50ml and 130ml respectively. This implies that gas stove is more profitable for production of biofuel, compare to charcoal. Table 3 and 4, showed the mass of feedstock (Sawdust) used in the experiment which ranges from 0.5kg to 2.5kg with water mixture from 3000ml to 23000ml while tetraoxosulphate VI acid (H_2SO_4) OF 30ml to 150mlc was added. The result revealed it took gas within 13°C to 40 °C to produce biofuel while for charcoal source, biofuel was produced within 55°C to 85°C, This simply means that it will be more preferable to use gas as source of heat in biofuel production because gas stove is more easier and the temperature to produces biofuel are lower than charcoal stove. In term of the quantity of biofuel obtained from the study, the result shared that the least batched feedstock extraction was 150ml and the highest was 250ml using gas stove. While for the charcoal stove was 50ml and 130ml respectively. This implies that gas stove is more profitable for production of biofuel, compare to charcoal.

Table 5 and 6, show the mass of feedstock (Sawdust) used in the experiment which ranges from 0.5kg to 2.5kg while tetraoxosulphate VI acid (H_2SO_4) of 30ml to 150ml was added. The result revealed it took gas within 13mins to 40mins to produce biofuel while for the charcoal source biofuel was produced within 68mins to 180mins. This implies that gas stove is faster to produce biofuel compare to charcoal stove.

Also table 7 exposed the source of heat (Gas, Charcoal) which the unit quantity used for the source (Gas = 6750 NGN, Charcoal = 4400 NGN) and the time used for biofuel production (Gas = 157mins, Charcoal = 627mins). The result revealed, it took gas source of heat 10kg of gas (#6750) to produce biofuel while charcoal source of heat took 50kg of charcoal (#4400) to produce biofuel time taken too produce biofuel for gas source of heat is lower than charcoal source of heat even through the cost of gas for production is more higher than that of charcoal. In term of the quantity of biofuel obtained Table 4.1and 4.2that the least batched feedstock extraction was 150ml and the highest was 250ml using

gas stove. While for the charcoal stove was 50ml and 130ml respectively. This implies that gas stove is more profitable for production of biofuel, compare to charcoal.

Table 8 show the result of laboratory analysis (parameters and the results) of product getting from the sample which is viscosity (6.80 CP), acid value (7.28mgKOH/g), specific gravity (0.8514 g/g), density (0.8509 g/ml), moisture (28.61%), total glycerine (0.059%), free glycerine (0.017%), flash point (65.30°C), carbon residue (0.14%), sulphur (0.48%) pour point (7.50°C), cloud point (9.60°C).according to Anton et al state that [viscosity (1.3-4.1), specific gravity (0.85), flash point (60.80°C), pour point (-15 to 5°C) igrution quantity (40-45°C) prove that result gotten from Table 4.8 was biofuel.

The laboratory result of the liquid produced as revealed in Table 8 is in accordance with the report of [3]; [4]; [32] and [41] stating standard ethanol properties (Boiling point =78.8, Relative density =0.789ml, vapourization point =78°C, pH =7) viscosity =1.200cmpa, flash point =12.8 °C, specific heat 60 °C, pH =(6.71). This simply means that ethanol was derived as an end product of the experiment.

5. CONCLUSIONS

To address Nigeria's energy problem, a combination of various options and technologies should be integrated, including biomass, biofuel, biogas, solar, wind, hydropower, and other environmentally friendly options. No single solution is the answer. Different nations and regions must consider their resources, technology, workforce, economic, environmental, and political factors when choosing the best options for them. In tropical countries, sawdust, a often overlooked but durable crop, can be used as a sustainable source for producing ethanol fuel for energy. This research has developed a model for energy input in ethanol production, and has also established that ethanol can be produced from sawdust. Using a gas stove to produce ethanol from sawdust reduces stress, time, and increases biofuel production compared to using a charcoal stove.

Furthermore, it is important to note that the integration of different options and technologies from different sectors is critical to achieving sustainable energy solutions for the country. Each option has its own strengths and weaknesses, and no single option can be considered a panacea. Using sawdust as a source of ethanol production is particularly relevant in tropical countries as it is a readily available and sustainable resource. Using gas stoves for ethanol production not only reduces stress and time, but also increases biofuel production compared to using charcoal stoves. The studies presented in this statement provided a model of energy use in ethanol production and demonstrated the feasibility of ethanol production from sawdust.

Recommendations
The following were suggested for the future research work;

a. Alternative feedstocks should be investigated for the production of liquid fuel.

b. Engineers should prioritize the commercialization of ethanol production to address energy concerns both locally and globally.

c. Funding for research in alternative energy production should be provided by governments and multinational organizations.

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