Saudi Journal of Engineering and Technology (SJEAT)
Scholars Middle East Publishers
Dubai, United Arab Emirates
Website: http://scholarsmepub.com/

ISSN 2415-6272 (Print)
ISSN 2415-6264 (Online)

Palm Oil Biomass Waste a Renewable Energy Resource for Power Generation

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Original Research Article

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Article History
Received: 19.11.2018
Accepted: 28.11.2018
Published: 30.12.2018

DOI:
10.21276/sjeat.2018.3.12.2

Abstract: This work evaluated the palm oil biomass waste as a source of renewable energy for electric power generation. Nigeria was once the largest producer of Oil Palm products, but since has been relegated to the back ground by Malaysia and some other countries and needs to revitalize its palm oil industries. Electricity regeneration in Nigeria has also been highly politicized and still at shortfall to its teeming population demand. This situation invariably requires revamping through exploitations of alternative energy sources. This work was carried out at Presco Nigeria Ltd which owns palm plantations from where we obtained our oil palm empty fruit bunches for this research. The result obtained from this work shows that 896 kg of empty fruit bunches produced 1.7 MW of power though lower than that of the same mass of methane, it is proving to be by far more cost effective, easier to maintain and run. The research also reported that oil palm empty fruit bunch has more calorific value than other oil palm biomass resources. Placing this research finding with others in literature indicates that the quantity of the biomass is directly proportional to the amount of energy produced.
Keywords: Palm oil, Empty fruit bunch, Electric Power, Renewable energy, Biomass.

INTRODUCTION

Energy is a social and economic need of any country. The energy use in any country is expected to continue to increase as its population increases [1]. The increase in population i.e. Nigeria population which has increase from 159 million in 2010 to about 187 million in 2016 will demand about 25,000MW of power for home and industries in other to have stable electricity.

This electricity is essential for economic growth and improving the standard of living of the increasing population. Without adequate basic energy supply people will not be able to meet up to their domestics needs such as cooking, light their home and chilled up their perishable goods and other needs that require electricity [2]. Therefore the introductions of biomass like the oil palm biomass will help to solve the problem of electricity.

Palm oil is currently the world largest source of edible oil. Palm oil mill (PMO) in Nigeria produces about 0.94 million tonnes and 1.54% of world total oil production in 2015. It is predicted that the demand of world palm will remain of high increase as followed by population growth, food and chemical industrialized. The more crude palm oil (CPO) produced the more biomass wastes. A PMO wastes are around 13 to 17% fibre, 6 to 10% shell and 25 to 27% empty fruit bunch (EFB) based on its capacity. However, this biomass waste needs to be utilized effectively to overcome its disposal problem. Palm biomass has long been identified and utilized as renewable energy but there is rare energy power plant applied. In the palm oil mill, after oil extraction process there will be large amount of palm solid residues biomass. Especially empty fruit bunch (EFB) which is prevalent in some part of Nigeria like the eastern part and southern part of the country. During the year 2015, an average of 0.94 tonnes of EFB were produced, only about 0.25 tonnes were utilized.

The demand for energy is increasing globally, especially Nigeria which the main source of power generation is hydro, steam and gas turbine. A lot of research activity has been done in Nigeria and some are still on how to find solution to this power problem in the country through finding substitutes to the fossil energy [3].

The palm oil industries generate large quantity of wastes whose disposal is a challenging task. These waste can been converted into energy using incineration or other chemical processes. Some companies in Nigeria such as Presco Nigeria, NIFOR Nigeria are utilizing this empty palm fruit bunch in generating their electricity which has saved them from the problem of power interruption and minimized cost.

Take Indonesia and Malaysia which are the world largest producers of palm oil respectively generate 53.6% and 36.8% of total world palm oil production at about 33.4million tonnes and 19.9million tonnes of crude palm oil. They generate electricity from the waste biomass of the empty palm bunch and also get other product from them. One of the unique aspect of Malaysian renewable energy sources is that the palm oil mill is self-sufficient in energy, using palm press fiber (PPE), empty fruits bunch (EFB) and shell as fuel to generate steam in waste fuel boilers for processing and power generation with steam turbines [4].

Oil palm biomass emerges as a potential major contribution to renewable energy as the government has now shifted from conventional sources such as coal, oil and gas to promoting renewable energy sources in order to increase energy security. Indeed the combustion of fossil fuels as sources of energy for heat, transportation and electricity is known to be the major factor of global warming. The world is moving from the conventional non renewable energy sources to renewable energy sources due to their renewability and environmentally-friendly nature is critical for future generation of power.

The Malaysian government has made several efforts to encourage the use of renewable energy to scale down dependency on fossil fuels and to meet the growing demand for energy. As a result, the fifth–fuel policy was introduced in 2001 to encourage new renewable energy sources such as oil palm, rice husk and wood waste, as compliment to the conventional energy supply. The adoption of this fifth-fuel policy was supported by the implementation of the small renewable energy power (SREP) [5]. Sarawak one of the largest town in Malaysia has the potential to generate a total of 425MW of electricity from biomass sources, where 375MW of the amount is contributed to by palm biomass.

According to history Nigeria was the largest producer of oil palm between 1901 and 1970, even the Malaysia got their seedling from Nigerian. The major challenges that Nigeria encounter was over dependence on crude oil which has caused the decline in oil palm production just the way Malaysia is using to generate electricity to their national grid Nigeria would have been the first to have carry it out. However all hope is not lost the federal government should go back to the round table and utilized this opportunity of this empty balm bunch which is abundance.

In Nigeria most of the electricity generated is from gas fire thermal power plant which used several method in its conversion. One of the methods is to burn the gas in a boiler to produce steam, which is then used by steam turbine to generate electricity. Thus has led to over dependent on the conventional oil which has led to gas flaring which can be converted to more meaningful product instead of wasting the resources.

Palm biomass has to be considered in the search for alternatives source of energy, it has become one of the most commonly used renewable sources of energy in the last two to three decades in some countries. Over dependent on hydro power and steam turbine in Nigeria has make the biomass underutilized. Considerable research and development work is currently on to develop smaller gas fires that would produce electricity on a small scale. Biomass for this moment is used for off grid electricity generation but almost exclusively on a large industrial scale [6].

Lignocelluloses biomass which is produced from the oil palm industries include palm kernel cakes (PKC),palm kernels shell (PKS), empty fruit bunch (EFB), oil palm tusk (OPT), oil palm fronds (OPF),palm press fibers (PPF)and palm oil mill effluent (POME).

Empty Palm bunch (EPB) is the main source of palm biomass that can be used by power plants. It is a resource which has huge potential to be used in for power generation, currently not be utilized effectively. many plantation use a small amount for their own internal use about (10-15%) used but large portion about 85% is put aside either biodegrading into composites or at times burnt to avoid space loss by storage which in turn cause air pollution. The application of the shells for road hardening has no impact on environment, however, current practice is actually wasting potential renewable energy source. Palm oil residues are currently underutilized; therefore maximizing energy recovery from the waste is desirable for both economic and environmental reasons.

This empty palm fruits bunch is abundance in the plantation and it is very cheap with little or no cost in getting it. Oil palm waste is reliable resources because of its availability, continuity and capacity for renewable energy solution. Furthermore in current situation the presence of oil palm waste has created a major disposal problem, thus has a negative effect on the environment. Therefore to avoid this negative effect on the environment this project will address this issue by exploiting this palm biomass in generating electricity.

Some industries has succeeded in using this biomass waste to generate their electricity such as NIFOR(Nigeria institute for oil palm oil research) located in Ovia South East, Presco Palm Oil Industry located in Ikpoba-Okha Local Government in Edo State depend on the empty palm fruit bunch in generating their electricity. Apart from power generation the fresh palm fruits (FPF) will also yield other products which will boost the GDP of the country and create job which will help to reduce unemployment in the society.

Biomass Wastes from Palm Oil Mills

The palm oil industry generates large quantity of waste whose disposal is a challenging task. The empty fruit bunches are left as residues, and the fruit are passed to oil mills. The palm oil fruits are then pressed, and the palm kernels are separated from the press cake (mesocarp fibers). The palm kernels are then crushed and the kernels are then transported and pressed in separate mills. In a typical palm oil plantation, almost 70% of the fresh fruit bunches are turned into biomass wastes in the form of empty fruit bunches, fibers and shells, as well as liquid effluent. This by-product can be converted to value added product or energy to generate additional profit to the palm industry [7]. These biomass wastes include the following.

Palm kernel shells (PKS)

Palm kernel shells (PKS) are the shell fractions left after the nut has been removed after crushing in the palm oil mill. Kernel shells are a fibrous material and can be easily handled in bulk directly from the product line to the end use. Large and small shell fractions are mixed with dust-like fractions and small fibers.

Moisture content in kernel shell is low compared to other biomass residues with different sources suggesting values between 11% and 13%. Palm kernel shells contain residues of palm oil, which accounts for its slightly higher heating value than average lignocelluloses biomass. Compared to other celluloses from the industries, it is a good quality biomass fuel with uniform size distribution, easy handling, easy crushing and limited biological activities due to low moisture content.

Press fiber and shell generated by the palm oil mills are traditionally used as solid fuels for steam boilers. The steam generated is used to run turbines for electricity production. These two solid fuels alone are able to generate more than enough energy to meet the energy demands of palm oil mills [7].

Energy potential of palm kernels shells

Nigeria generates large quantity of biomass waste whose disposal is challenging task. Palm kernels shells (PKS) are shell fractions left after the nut has being removed after crushing in the palm oil mill.

Palm kernel shells contain residues of palm oil, which account for its slightly higher heating value than the average lignocelluloses biomass. Compare to other residues from the industry, it is a good quality biomass fuel with uniform size distribution, easy handling, easy crushing, and limited biological activity due to low moisture content. PKS can be readily co-fired with coal in great fire and fluidized bed boilers as well as cement kilns In order to diversify the fuel mix.

The primary use of palm kernel shells is as a boiler fuel supplements the fiber which is used as primary fuel. In recent year's kernel shell are sold as alternative fuel around the world. Besides selling shell in bulk, there are company that produce fuel briquettes from shells which may include partial carbonization of the material to improve combustion characteristics. As a raw material for fuel briquettes, palm shell are reported to have the same calorific characteristics as coconut shells. The relative smaller size makes it easier to carbonize for mass production, and its resulting palm shell charcoal can be pressed into a heat efficient biomass briquette.

Palm kernel shell has been traditionally used as solid fuels for steam boilers in palm oil mills in Nigeria. The steam generated is used to run turbines for electricity production. These two solid fuels are able to generate more than enough energy to meet the energy demands of a palm oil mill. Most palm oil mill in the region is self-sufficient in terms of energy by making use of kernel shells and mesocarp fiber in cogeneration. Nowadays, cement industries and power producers are increasingly using palm kernels shell to place coal. In grate –fire boiler systems, fluidized- bed boiler system and cement kilns, palm kernel shells are an excellent fuel.

Co-firing of PKS yield added value for power plant and cement, kilns, because the fuel significantly reduces carbon emissions – this in the renewable energy certificate, carbon credits, etc., there is a great scope for introduction high-efficiency cogeneration system in the industry which will result in substantial supply of excess power to the public grid and supply of surplus PKS to other nations. Palm kernel shell is already extensively in demand domestically by local industries for meeting process heating requirement, thus creating supply shortage in the market.

Palm oil mill effluent (POME)

Palm oil processing also gives rise to highly polluting waste-water, known as Palm oil mill effluent (POME), which is often discarded as disposal ponds, resulting in the leaching of contaminants that pollute the ground water and soil, and the release of methane gas into the atmosphere. POME could be used for biogas production through anaerobic digestion. At many palm oil mills this process is already in place to meet water quantity standards for industrial effluent. The gas however is flared off.

In a conventional palm oil mill, 600-700kg of POME is generated for every ton of processed FFB. Anaerobic digestion is widely adopted in the industry as the primary treatment for POME. Liquid effluent from palm oil mills can be anaerobically converted into biogas which in turn can be used to generate power through gas turbines or gas-fired engines [7].

Biogas potential of POME

POME is the effluent from the final stages of palm oil production in the mill. It is colloidal suspension containing 95-96% water, 0.6-0.7% oil and 4-5% total solids including 2-4% suspended solids [4].

POME is always regarded as a highly polluting wastewater generated from palm oil mills. However, reutilization of POME to generate renewable energies in commercial scale has great potential. Anaerobic digestion is widely adopted in the industries as primary treatment for POME. Biogas is produced in the process in the amount of 20m^{3}per ton FFB. This effluent could be used for biogas production through anaerobic digestion. At many palm oil mills this process is already in place to meet water quality standards for industrial effluent. The gas however.

Empty fruit bunches (EFBs)

In a typical palm oil mill, empty fruit bunches are abundantly available as fibrous materials of purely biological origin. EFB contains neither chemical nor mineral additives, and depending on proper handling operations as at the mill, it is free from foreign element such as gravel, nails, wood residues, waste etc. However it is saturated with water due to the biological growth combined with steam sterilization at the mil. Since the moisture content in EFB is around 67%, pre-processing is necessary before EFB can be considered as a good fuel. Empty fruit bunches can be conveniently collected and available for exploitation in all palm oil mills. Since shells and fibers are easy to handle, high quality fuel compared to EFB, it will be advantageous to utilize EFB for onsite energy demands while making shells and fibers available for offsite utilization which may bring more revenges as compare to burning of site[7].

Energy potential of empty fruit bunches

A palm oil plantation yields huge amount of biomass wast**e** in the form of empty fruit bunches (EFB). EFB is a resource which has huge potential to be used for power generation, though not being utilized fully. There is a large potential of transforming EFB into renewable energy resource that could meet the existing energy demand of palm oil mills or other industries. Pre-treatment steps such as shredding/chipping and dewarting (screw pressing or drying) are necessary in other to improve the fuel property of EFB. Pre-processing of EFB will greatly improve its handling properties to reduce the transportation costs to the end user i.e. power plants. Under such scenario, kernel shells and mesocarp fibers which are currently utilized for providing heat for mills can be relived for other uses off site with higher economic returns for palm oil mills.

The fuel could either be prepared by the mills before sale to the power plants, or handled by the end users based on their own requirements. Besides, centralized EFB collection and pre-processing system can be considered as a component in EFB supply chain. It is evident that the mapping of available EFB resources would be useful for EFB resource supply chain improvement. This is particular important as there are many different competitive uses. With proper mapping, assessment of better logistics and EFB resource planning can lead to better cost effectiveness of both supplier and user of the EFB.

MATERIALS AND METHODS

Raw materials

Fresh fruit bunch (FFB): The fresh fruit bunch was obtained from the oil palm plantation of Presco Nigeria Limited located at Obaretin Estate in Ikpoba-Okha local government area of Edo state with a land space of 12560 hectares and other local plantation also visited in Edo state. About hundred and twenty tonnes (120 tonnes) of FFB was used in this research work. The fresh fruit bunch was further processed in other to get the desired raw material which was used to fire the boiler. The figure below shows the plantation and the fresh fruit bunch.

Palm kernel shells (PKS) and Palm press fibre (PPF): These are the fractions left after the crushing was made in the palm oil mill. They are fibrous materials and the moisture content is low compare to other biomass residues. It contains residue of palm oil which gives it a high heating value than any other average lignocelluloses biomass.

Fig-1: Presco Palm Plantation

Fig-2: Fresh Fruit Bunch (FFB)

The palm press fiber and palm kernel shell that was generated in the palm oil mill (POM) were used as a solid fuel for steam boilers. The heat in the steam boilers where used in addition to EFB to run the steam turbine for generating the electricity. The figure below shows the mill and PKS.

Fig-3: Palm Kernel Shells

Fig-4: Palm Press Fiber

Empty fruit bunch (EFB)

This is the main raw material used in this research work. The palm oil mill was Presco Nigeria limited which has a capacity of 60 tonnes fresh fruit bunches/hour. EFB is a solid waste residue generated from palm oil mill (POM) after oil is extracted out. It is done in the process of extracting crude palm oil, through the heating chamber with steam to palm off the EFB easily. The EFB is stripping by a separate machine from the palm fruit bunch. The figure shows empty fruits bunch.

Fig-5: Empty Fruit Bunch

A careful breakdown was carried out in the cause of this research in a well-established palm oil mill like Presco Nigeria. It is expected that each 100 tons of palm fresh fruit bunch (PFFB) processed yields 20-24 tons of crude palm oil,19-21 tons of empty fruits bunch,15tons of oil-rich fibre, 5tons of shells, 3tons of palm kernels, about 16% moisture content and 20%effluent.

Pretreatment of empty palm fruit bunch: Pretreatment of empty palm fruit bunch is very important in order to increase its digestibility and its degree of conversion. The method of pretreatment that was used in this research is the chemical pretreatment, which are dilute acid hydrolysis and alkaline pretreatment. Aqueous ammonia (NH4) and solvent (H_2O_2) were used to increase the digestibility of the EFB. Fast pyrolysis of alkaline (NaOH), Ca $OH)_2$ and addition with H_2O_2 were also used.

It has also be investigated by other researchers that alkaline pretreatment seem to be the best. Umikalsom, Ariff, and Karim [8] autoclaved the milled EFB in the presence of 2% NaOH and 85% hydrolysis yield was obtained. Han and his colleagues investigated NaOH pretreatment of EFB for bioethanol production. The optimal conditions were found to be 127.64°C, 22.08 min, and 2.89 mol/liltre NaOH. The effectiveness of alkali pretreatment might be attributed to its capability in lignin degradation. Mission, Haron, Kamaroddin, and Amin [9] investigated the alkali treatment followed H_2O_2 treatment and found that almost 100% lignin degradation was obtained when EFB was firstly treated with dilute NaOH and subsequently with H_2O_2. This confirmed the lignin degradation by NaOH and its enhancement by the addition of H_2O_2.

Conversion process

The conversion process used for this research work was the thermo-chemical conversion. Thermo-chemical conversion of biomass (EFB) involves heating the biomass materials in the absence of oxygen to produce a mixture of gas, liquid and solid. The products were used as fuels after further conversion or upgrading. Generally, thermo-chemical processes have lower reaction time required (a few seconds or minutes) and the superior ability to destroy most of the organic compounds. These include biomass pyrolysis and biomass gasification and biomass torrefaction

Tools and equipment

The boiler used in this work is Presco Nigeria steam boiler. It has a capacity of 25bar and was used in burning 896kg of EFB per hour which generated 1.7MW of electricity. When compare with the combustion of methane gas, will produce 4.58MW. The boiler produced the require heat energy in generating the electricity. The heat generated with the boiler using 896kg of EFB has a calorific value of 19500 kJ/kg. The chimney was used in order to allow smooth flow of heat generated by the boiler to effectively power the turbine without lost to the surrounding. It is 200m tall with a diameter of 3.3metre.

The steam turbine used in this work was Presco Nigeria limited plant located in Ikpo-Okha Local Government Area of Edo State. It has the capacity of generating up to 1.99MW of electricity.

Generation process

The technology used for this project is the steam turbine. It involves some stages of conversion; it extracts thermal energy (heat) from the fuel (EFB) in the combustion chamber via the steam boiler to raise the steam, converting the heat energy generated into kinetic energy in the steam turbine and finally using a rotary generator to convert the turbine mechanical energy into electrical energy.

The three stages of energy conversion is illustrated in Fig. 6 and expressed as;

$$Heat\ Energy\ (steam\ boiler) \rightarrow Mechanical\ Energy\ (steam\ turbine) \rightarrow Electrical\ Energy\ (generator)$$

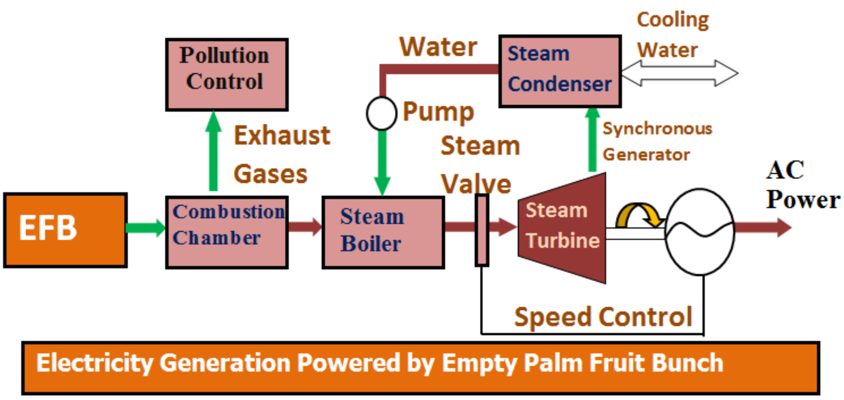

Fig-6: Electricity Generation Plant using EFB

To achieve this successfully, the moisture content of the fuel is totally reduced in order to increase the quality of heat needed to power the steam turbine.

RESULTS AND DISCUSSIONS

The physical and chemical properties of empty fruits bunch (efb)

Empty fruit bunch has its own properties like any other fuel. Table 1 shows various components or constituents of EFB

Table-1: Constituent Properties of EFB

	Value	Unit
Components		
Cellulose	58.3	%(w/t)
Hemicelluloses	23.4	%(w/t)
Lignin	19.2	%(w/t)
Proximity Analysis		
Moisture	9.36	%(w/t)
Volatile	78.59	%(w/t)
Ash	5.31	%(w/t)
Fixed carbon	15.42	%(w/t)
Ultimate Analysis		
Carbon	46.2	%(w/t)
Hydrogen	6.4	%(w/t)
Oxygen	44.39	%(w/t)
Nitrogen	0.66	%(w/t)
Sulphur	0.08	%(w/t)
Other Properties		
Low heating value	13200	kJ/kg
High heating value	19500	kJ/kg
Bulk Density	113.92	kg/m^3

Chemical formula of empty fruit bunch (EFB)

The formula of EFB Fuel sample is $C_eH_yO_rN_vS_m$. If this formula is on a basis of 95kg sample of EFB from the Table 1, then the composition by mass is given as;

$C: 12e = 0.462 \quad hence, \qquad e = 0.462/12 = 0.039$

$H: 1y = 0.064 \quad hence, \qquad y = 0.064$

$O: 16r = 0.4439 \quad hence, \qquad r = 0.4439/16 = 0.028$

$N: 14v = 0.0066 \ hence, \qquad v = 0.0066/14 = 0.00047$
$S: 32m = 0.0008 \ hence, \qquad m = 0.0008/32 = 0.000025$

From the above calculation the formula of the fuel sample is expressed as;
$C_{0.039}H_{0.064}O_{0.028}N_{0.00047}S_{0.000025}$

Amount of heat liberated by the rate of feeding into the combustion chamber through the furnace

The empty palm fruits undergo a shredding process by cutting the EFB into smaller pieces to lose it structure, this help to improve the volume weight ratio and enhance the fuel characteristic.

The combustion ratio is calculated below and the Fig. 7 illustrates the schematic diagram of the steam turbine.

$$Combustion\ Rate\ (CR) = \frac{Total\ mass\ of\ \ burnt\ fuel}{Burning\ Time} \qquad (1)$$
$$= \frac{896}{1\ hour}$$
$$= 896kg/hour$$

The average feeding per hour of operation is 896kg

$$Heat\ released\ Q = Calorific\ Value\ \times Combustion\ rate \qquad (2)$$
$$= 19500 \times 896$$
$$= 17472000kJ$$
$$= 17.47GJ$$

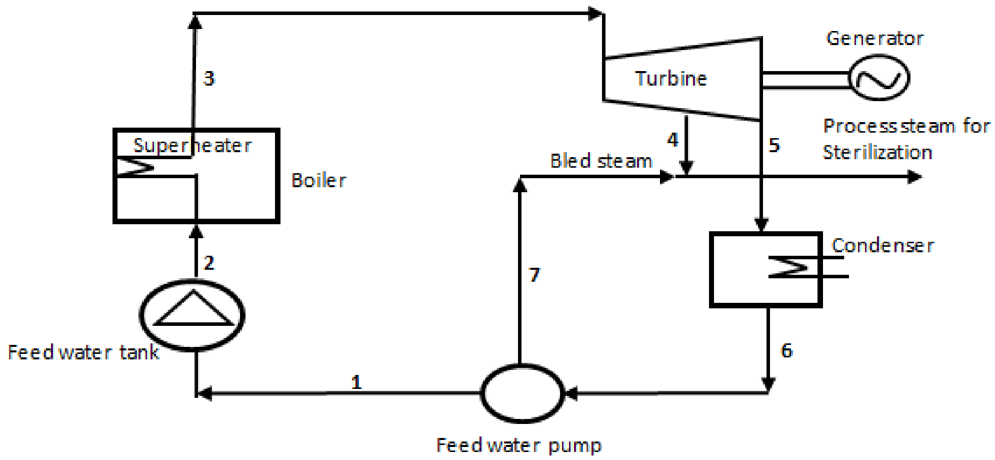

Fig-7: Outlined Scheme of the Steam Boiler

Combustion of empty palm fruit bunch

The combustion of EFB in the boiler take into account the calorific value, its ash content, fuel size and moisture content. A complete combustion of EFB will produce water Vapour (H_20), carbon dioxide ($C0_2$) and other products. The equation below explain the combustion of EFB,

$$C_{0.039}H_{0.064}O_{0.028}N_{0.00047}S_{0.000025} + \beta O_2 + \beta(79/21)N_2 \rightarrow aCO_2 + bH_2O + cSO_2 + dN_2 \qquad (3)$$

$C: 0.039 = a, then, \qquad a = 0.039$
$H: 0.064 = 2b, then, \qquad b = 0.064/2 = 0.032$
$S: 0.000028 = c, then, \qquad c = 0.000028$
$O: 0.028 + 2\beta = 2a + b + 2c, then, imputing\ a, b, c$
$\xrightarrow{yields} 0.028 + 2\beta = 2(0.039) + 0.032 + 2(0.000028), hence, \qquad \beta = 0.041$
$N: 0.00047 + 2\beta\left(\frac{79}{21}\right) = 2d, hence\ computing\ the\ value\ of\ \beta$
$\xrightarrow{\boldsymbol{yields}} 0.00047 + 0.387 = 2d, hence\ d = 0.194$

Therefore the balanced equation is

$$C_{0.039}H_{0.064}O_{0.028}N_{0.00047}S_{0.000025} + 0.041O_2 + 0.041(79/21)N_2 \rightarrow 0.039CO_2 + 0.032H_2O + 0.000028SO_2 + 0.194N_2 + Energy \quad (4)$$

Power generated by the empty fruit bunch

The power produced by burning 896kg of empty fruit bunch is given below by putting the following parameters into consideration

Calorific value (Cv) = 19500KJ/KG
Combustion efficiency (ηcombustion) = 95%
Mass of fuel (EFB) = 896kg
Cycle efficiency (ηcircle) = 45%η
Turbine efficiency (ηturbine) = 90%
Boiler heat transfer efficiency (ηheat transfer) = 90%

$$Power = \frac{\text{m x Cv x ηturbine x ηcombustion xη circl x ηheat transfer}}{3600} \quad (5)$$

$$Power = \frac{896\ x\ 19500\ x\ 0.9\ x\ 0.95\ x\ 0.45\ x\ 0.9}{3600}$$

$$= 1680.588KW$$
$$= 1.7MW$$

Empty fruit bunch power generated compared with the conventional gas fired boiler using methane gas of same mass of fuel

Combustion of Methane gas

$$CH_4 + O_2 \rightarrow CO_2 + H_2O + Energy \quad (6)$$

Heat released by methane gas

$$Heat\ released\ Q = Calorific\ value \times Combustion\ rate \quad (7)$$

Calorific value of methane gas=55178.2kJ/kg
Mass of methane gas =896kg

$$Q = 55178.2 \times 896$$
$$= 49439667.2\ kJ$$
$$= 49.44GJ$$

Power produced from burning 896kg of methane gas is calculated using (1) when the same parameters for EFB are considered.

Calorific value (CV) = 53178.2Kj/KG
Combustion efficiency (ηcombustion) = 95%
Mass of fuel (methane) = 896kg
Cycle efficiency (ηcircle) = 45%
Turbine efficiency (ηturbine) = 90%

Boiler heat transfer efficiency (ηheat transfer) = 90%

$$\text{Power} = \frac{\text{m x Cv x nturbine x ncombustion x η cycle x nheat transfer}}{3600} \quad (8)$$

$$Power = \frac{\text{896 x 53178.2x0.9x0.95x0.45x0.9}}{3600}$$

$$= 4583.109kw$$

$$= 4.58MW$$

Calorific value of fuel from EFB sample

Table 2 below shows the various calorific value of fuel which is used in firing steam boiler from the palm oil mill

Table-2: Calorific Value of Various Palm Oil Biomass Fuels

FUEL	CALORIFIC VALUE(KJ/KG)
Empty fruit bunch	19500
Palm kernel shell	16200
Palm press fiber	11500

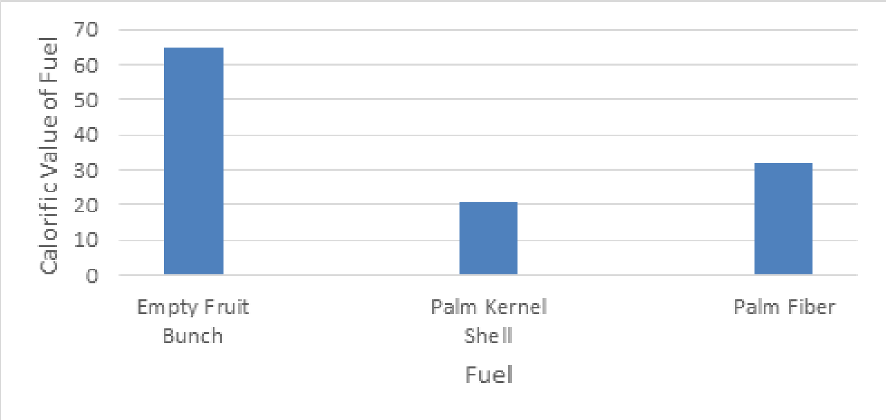

Fig-8: Graph of Calorific Value against Fuel types

Moisture content of the fuel in Table 2 was considered and it was found that empty palm fruit bunch has the highest percentage. To ensure proper heating value it was first dried up and a super heater is incorporated in the boiler in order to increase the heating rate.

$$M_c = \frac{M_1 - M_2}{M_1} \times 100$$

Where, M_c is moisture content, M_1 is initial mass of fuel, M_2 is final mass of fuel after drying

Table-3: Moisture Content of Palm Biomass Fuels

Fuel	Moisture content (%)
Empty fruit bunch	65
Palm fiber	32
Palm kernel shell	21

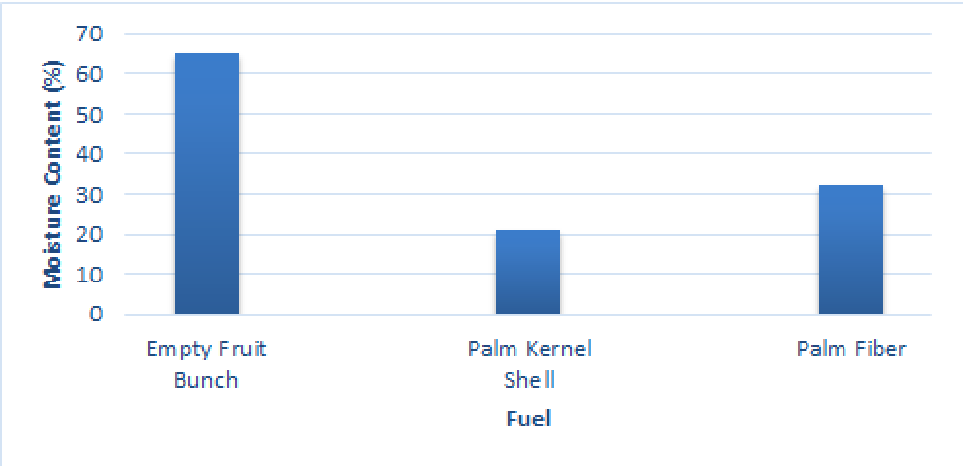

Fig-9: Moisture content of fuel

Table-4: Comparison of Methane and EFB Fuels

Mass of (METHANE)	Power generated (KW)	Mass of (EFB)	Power (KW)
100	511.507	100	187.565
200	1023.015	200	375.13
300	1534.523	300	562.7
400	2046.03	400	750.26
500	2557.54	500	937.83
600	3069.046	600	1125.4
700	3580.6	700	1312.9
800	4092.06	800	1500.52
900	4603.6	900	1688.1

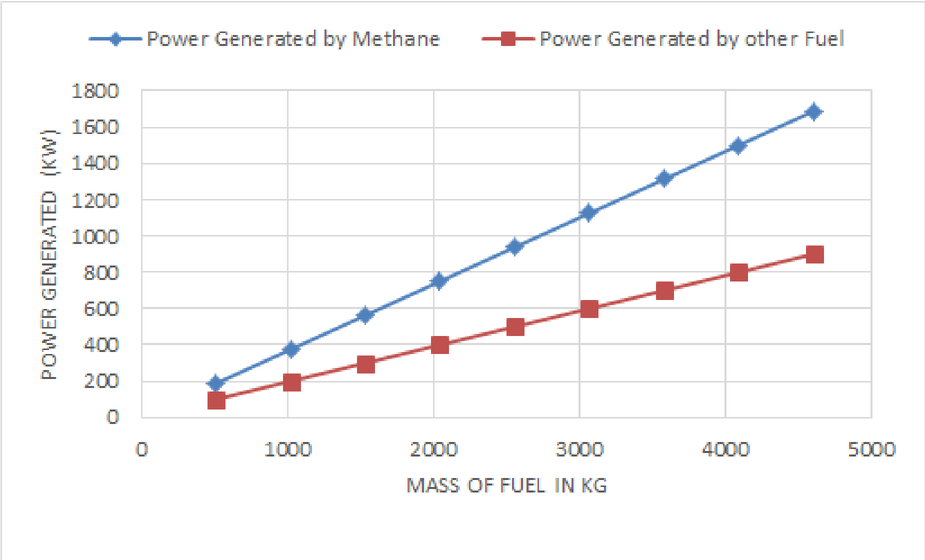

Fig-10: Comparison between Methane and EFB Fuels

DISCUSSION

Equation (1) was used to calculate the combustion rate by burning 896kg of EFB per hour which gives the rate of feeding per hour. Equations (3) and (4) show the complete combustion equations which show that in any complete combustion of EFB; water vapour, carbon dioxide and other product are obtained, if the EFB is completely dry and the moisture content is reduced. Equation (5) expresses how power is generated. A calorific value of 19500 kg/kJ was produced when 896kg of EFB was used in firing the steam boiler to get 1.7MW of electricity.

This value obtained is slightly higher than the results obtained by Olisa and Kontlngo [10].They obtained 1.5MW by using 840kg of EFB in firing a steam boiler. Table 4.6 shows the comparison between the two types of fuel. The results reveal that EFB can produces about 36.6%of what the methane gas can produce giving the same amount of fuel. For the power plant using methane gas it will cost more compare to the plant using EFB that may cost very little due to its availability.

It is shown from Table 4.2, that all the fuel can generate good heat for firing steam boiler but EFB has the highest calorific value therefore it is more favourable for this work.

CONCLUSION

Nigeria is a developing country and one of the sectors that cause rapid development and transformation is power. Currently the country is generating less than 5000MW and the country needs about 25000MW to have stable electricity. However for us to overcome this epileptic power supply alternatives means of power generation should be considered.

The energy supply mix for Nigeria must be diversified through appropriate infrastructure; technology and the utilization of the abundant renewable energy resources present (EFB) which will not only stabilize the electricity but will also improve the energy security of the country. This work gives a clue to the important of utilizing empty fruits bunch in generating electricity using PRESCO Nigeria and Malaysia as a role model.

Finally the government should start looking into providing the necessary infrastructure, technology and expertise for the use of potential power supply from oil mills and other biomasses (like solid wastes) especially as it was unveil in the study. Also the private sector should partner with the government in order to ensure power generated in their local means be distributed to the national grid to boost the power stability in the country.

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