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Empirical Study On Optimizing Energy Recovery From Oil Palm Waste In Nigeria

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Abstract

Nigeria is endowed with abundant supplies of non-renewable energy resources especially oil and gas and they are currently being exploited. There is an urgent need to optimize the use of huge quantity of oil palm biomass waste as an alternative energy source. Against this background this article presents an empirical and quantitative analysis of potential renewable energy from oil palm wastes. In this study, ultimate and proximate analyses were carried out on oil palm wastes, e.g. Empty Fruit Bunch (EFB), Palm Oil Mill Effluent (POME), fibre and shell, to determine the level of fixed carbon, crude fibre, ether extract, percentage hydrogen and heat content. The results obtained showed that EFB had the least percentage dry matter (DM) and ether extract of 72.6 and 2.2 respectively, while fibre had the highest percent DM of 132.6 and ether extract of 2.87. POME recorded the least heat content of 18229 kJ Kg^{-1} while the highest of 35631 kJ Kg^{-1} came from shell. Also, all the waste categories had at least 2.5 molar ratio of hydrogen to carbon. From the result, oil palm waste could be an alternative source of biomass energy and can substantially contribute to sustainable resource management system.

Keywords: Oil palm, Waste, Renewable, Energy, Dry Matter, Heat Content.

1.0 Introduction

Energy resources consist of fossil energy and renewable energy. Fossil energy i.e oil, natural gas and coal are extremely important and play a strategic role. These resources are valuable for national development, functioning as energy resources and industrial raw material as well as foreign exchange earner (Kamaruddin, 2003). Energy resources, which are considered as renewable energy, are biomass, solar energy, geothermal, hydropower, wind energy and ocean energy. The whole potential of biomass energy from the three sectors of forestry, agriculture and estates amounts to the equivalent of about 50,000 MW (Jekayinfa and Omisakin, 2003). Biomass has a significant role to play in solving the world's energy needs. Biomass combustion is carbon neutral. The carbon dioxide released in combustion is recycled by trees and crops and oceans, which may provide fuel for the future. By utilizing biomass as a fuel instead of a non-renewable fossil fuel, the net carbon dioxide released into the atmosphere is unchanged. Biomass utilization can supplement the use of fossil fuels in order to provide heat energy in areas where it is abundantly available. The development of renewable energy utilization especially biomass for rural areas with limited supply of conventional energy, needs to be promoted to balance development. This can be integrated to the regional level to further enhance social and economic well-being of the people. Renewable energy technologies are environmental friendly and contribute effectively towards sustainable development (Yusoff, 2006). The Nigerian government recognizes the importance of energy availability and stability in stimulating economic growth and so introduced the four-fuel strategy namely petroleum, natural gas, hydropower and coal to reduce the over dependence on petroleum and to ensure reliability and security of supply. It is imperative for government to include renewable energy as the fifth fuel and thereby increase the role of renewable energy as an alternative to other sources of energy. Biomass has been identified to be most suitable candidate to contribute towards achieving this goal due to huge amount of oil palm waste in the country (Akinbami *et al.*, 2001).

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2.0 Palm Oil Production and Residues.

The growth of the oil palm industry in Nigeria is not as rapid as the production in Malaysia, with over 2.8 million hectares under production in 2002 (FAO, 2003). Oil palm (*Elaeis guineensis* Jacq) is indigenous to Africa and has been domesticated from the wilderness and transformed to become a plantation-based industry. Today, Nigeria is the second world's largest producer and exporter of palm oil after Malaysia. Production has doubled recently with the establishment of more small-holder plantations in some Southeastern states (Ezedinma and Okolo, 2001) and about 43-45% production output will be mill residues in the form of EFB, POME, shell and fibre; residues will not only accumulate from the mills but also from extensive replanting programmes in plantations in form of oil palm fronds and stems. This article aims to empirically and quantitatively analyze the potential renewable energy (Biomass) from oil palm wastes which may contribute to global sustainable resource management.

3.0 Materials and Methods

Mill residues selected for energy value analyses were Empty fruit bunches (EFB), shell, fibre, palm oil mill effluent (POME) and these were obtained locally. The method used for ultimate analysis was as described in the standard test method for calorimetric analysis by the American Society for Testing Materials (ASTM) D 2016-93 and was carried out at Public Health Laboratory. Owerri. For the ultimate analyses, the following parameters were measured: carbon, hydrogen, sulphur, oxygen and nitrogen content as well as ash content.

Each of the samples was air dried and ground to powder. Samples were divided into four subsamples and were ready for analyses. Carbon and hydrogen contents were determined simultaneously by Leibig-Pregle method and calculated thus:

(a) $$\%\ Carbon = \frac{wt\ of\ CO_2 \times 0.2729 \times 100}{wt\ of\ sample} \quad ...1$$

(b) $$\%\ Carbon = \frac{wt\ of\ H_2O \times 0.1119 \times 100}{wt\ of\ sample} \quad ...2$$

The constants 0.2729 and 0.1119 are from empirical equations derived in Leibig-Pregle methods.

(c) The percentage sulphur content was calculated using Rodriguez *et al.*,(1998) method -equation (3)

$$\%\ Sulphur = \left\{ \frac{(Titre\ value - blank) \times 0.158 \times 100}{wt\ of\ sample} \right\} \quad ...3$$

(d) Nitrogen content followed Dumas-Pregle method as described in AOAC, 1986.

$$\%\ N = \frac{V \times 1.097 \times 100}{g} \quad ...4$$

Where V = volume of nitrogen in the nitrogen flow meter, 1.097= mass of 1 ml of nitrogen at the test conduction, g= weight of sample.

(e) Percentage Ash was determined gravimetrically and thereafter calculated thus.

$$\%\ Ash = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \quad ...5$$

W_1= weight of empty crucible, W_2 = weight of crucible + sample, W_3 = weight of crucible + ash.

(f) Oxygen content : the percentage oxygen content was determined as follows

$$\%\ Oxygen = 100 - (C + H + N + S + ash) \quad ...6$$

where, C= % carbon content in the biomass fuel, H= % hydrogen content in the biomass, N = % nitrogen content in the biomass fuel. S = % sulphur content in the biomass. Ash = % ash content in the biomass.

Proximate composite analyses were also determined as follows.

(g) Percentage dry matter was determined by obtaining the percentage moisture content of samples. This was achieved by heating 2 g of each sample in an oven at 100^{o}C for 16 hrs. percentage moisture content was calculated thus:

$$\%\ Moisture = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad ...7$$

where; W_1= weight of dish and lid, W_2= weight of dish, lid and sample after drying, W_3= weight of dish, lid, and sample after drying, W_2-W_1 = weight of sample prepared for drying.

% Dry matter content = 100-% moisture content.

(h) Ether extract was determined by digesting 2.0 g of sample with conc. HCl and 50 % alcohol and then heated at 80^{o}C for 1 hr. Ten milliliter alcohol was added to the cooled hydrolyzed mixture followed by 35 ml of light petroleum and the fat extracted three times of 25 ml of ether.

(i) Fixed carbon was determined according to AOAC as described in Tochobanoglous et al., 1993, Nelson and Flores (1994).

(j) The approximate energy value (higher heating value) was evaluated using Dulong- Petit formula (Perry and Green, 1997).

Qn = 337C + 1428 (H-O " 8) + 95 S (kJ " kg).
Where, C= % carbon, H= % hydrogen, % oxygen, S= % sulphur.

4.0 Results and Discussion

The result of the ultimate analysis is presented in table 1.0. Shell had the highest % carbon of 20.4 while palm oil mill effluent (POME) had the least of 13.8. Similarly shell had the highest percentage hydrogen of 30.6 and POME recorded the least 17.4 %. Percentage nitrogen is low in all the waste categories, and is between 0.21 % and 0.61 %. All the waste categories recorded significant ($p<0.05$) level of oxygen content and are above 50 %. The sulphur content ranged between 1.26 and 2.68 with fibre recording the highest sulphur content. The results obtained here compared well with results of other authors (Kranzler *et al.*, 1983, Ledward *et al.*, 1983, Jekayinfa and Omisakin, 2005).

Table 1.0 Ultimate composition of oil palm waste.

Waste	n	% H	% N	% O_2	% S	% C
EFB	4	20.4	0.61	110.3	1.46	16.6
Fibre	6	23.4	0.21	93.6	2.68	18.6
Shell	4	30.6	0.31	80.7	2.07	20.4
POME	6	17.4	0.51	60.3	1.26	13.8
P<0.05		ns	**	**	**	**

EFB= empty fruit bunch, POME= palm oil mill effluent. *,**,ns= significant at 5%, 1% and not significant. EFB= empty fruit bunch, POME= palm oil mill effluent.

Dry matter content for all the waste categories were all significant ($p<0.05$) and ranged between 132.6 (fibre) and 72.5 (POME) (Table 2.0). Fixed carbon ranged between 11.5 (POME) and 18.0 (fibre). The waste categories recorded significant ($p<0.05$) level of ether extract and ranged between 2.6 and 3.74, this result is consistent with those of Schaub and Leonard (1996), Brannstein (1981),Kamaruddin (2000) obtained from some agricultural waste. Heat content for the waste examined were highly significant ($p<0.05$) and all remained significant percentage ash content after burning (Table 3.0).

Table 2.0: Proximate composition of oil palm waste

Palm waste	n	Dry matter	% fixed carbon	Ether extract
EFB	4	120.6	17.6	2.60
Fibre	4	132.6	18.0	3.74
Shell	3	120	15.6	2.80
POME	6	72.5	11.5	3.64
P<0.05		**	**	ns

**, ns = significant at 1% and not significant.
EFB= empty fruit bunch, POME= palm oil mill effluent

Table 3.0: Heat value and moisture content of oil palm waste

Palm oil waste	Heat content (KJ kg^{-1})	% ash	% moisture
EFB	20640.2	14.8	65
fibre	23229.8	13.0	41
Shell	35631.4	10.6	35
POME	18229.2	12.8	30

EFB= empty fruit bunch, POME= palm oil mill effluent.

The high moisture content recorded in all the waste categories show that they have to be dried very well to enable proper burning off. The molar ratio of hydrogen to carbon is 6.2, 2.8, 4.2 and 8.7 for EFB, fibre, shell and POME, respectively (Figure 1.0). This value compared well with hydrogen: carbon ratio for methane and iso-octane which are good hydrogen fuels (Enweremadu *et al.*, 2004).

The level of oxygen obtained from the materials tested shows that all the waste materials are good combustible materials. The nitrogen level observed in this study is far below that present in normal combustible fuel e.g. coal has 1.3 and gasoline 0.006. Nitrogen laden combustible materials are source of nitrogen oxides (NOx) to the environment, which cause air pollution (Schaus and Leonard, 1996). Thus, the use of palm oil waste material as energy source is not likely to contribute to air pollution problem.

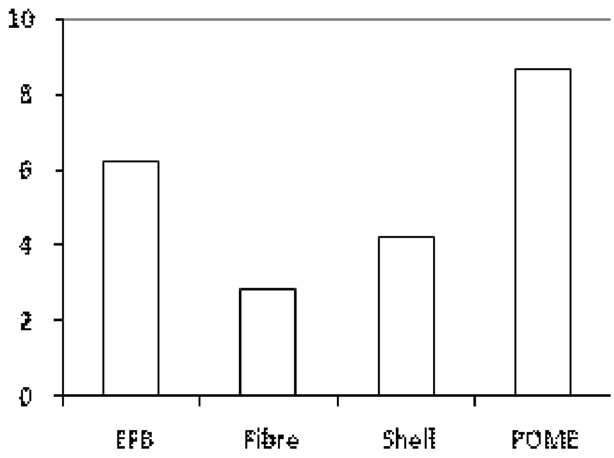

Figure 1.0: Molar ratio of hydrogen to carbon for the palm oil wastes. (EFB= empty fruit bunch. POME= palm oil mill effluent)

5.0 Renewable Energy Programme in a Typical Palm Oil Mill

Crude palm oil mills normally require 15-17 kW per ton FFB or 1020 kW for 60 tons FFB per hour mill (Yusuf, 2006). This energy requirement is met by a non-condensing turbine boiler using steam with a pressure of 20-bar gauge and exhausting at 3-bar gauge (Figure 2). The fuel is produced from oil palm waste e.g shell and fibre with less moisture for effective burning. The power generated is about 1.2 MW. The problems associated with the burning of these solid fuels are the emissions of dark smoke and the carryover of partially carbonized fibrous particulates due to incomplete combustion of the fuels. There are many reasons that contribute to the incomplete combustion of the fuels such as insufficient air and moisture content etc. However, these problems have been overcome in some boilers, through a controlled fuel feeding system and multi-clone dust collectors to trap the particulates. The flue gases from the boiler chimneys are also being used as a heat source for drying of decanter solids. Introduction of advanced cogeneration (combined heat and power) can play major role in combating climate change, as well as introducing significant economic benefits. Cogeneration cuts energy or fuel cost, uses fuels at high conversion efficiencies which results in an overall reduction of emissions of carbon dioxide and other pollutants. Another concept is to produce methane gas from POME, and burning the gas in boilers, gas engines or gas turbines.

6.0 Conclusion:

Palm oil waste has been identified as a good source of biomass energy. It can readily burn with minimal release of NOx –a common air pollutant. Renewable energy (Biomass) initiatives in the development of its technologies require adequate and predictive policies and regulatory framework for effective market development.

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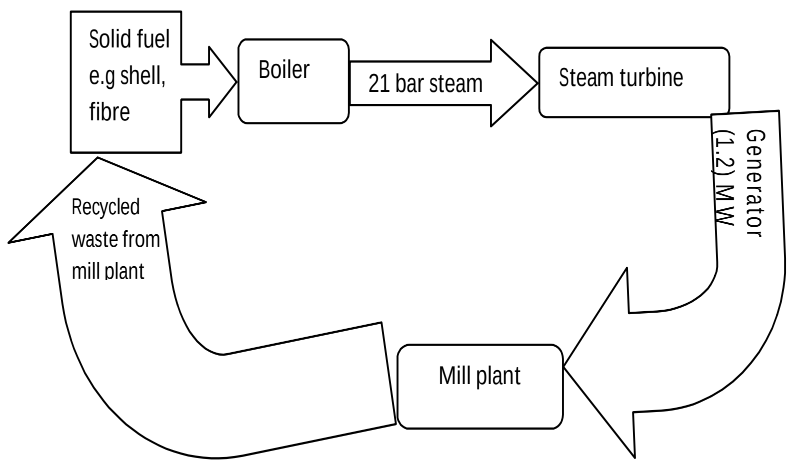

Figure 2.0: Schematic diagram of a biomass energy generation in a mill plant.

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