THE FUEL AND INDUSTRIAL CHEMICAL POTENTIALS OF OIL PALM (*ELEAISGUINEENSISJACQ*) WASTE PRODUCTS

Adeosun, O. J.[1]; Olorunnisola, A. O.[2]; Lucas, E. B.[2]
[1]Department of Agriculture
Engineering Federal University of Agriculture Abeokuta
[2]Department of Agriculture and Environmental
Engineering University of Ibadan
E-mail: adeosunjohnson@gmail.com
Phone No: +234-805-718-8340

Abstract

Oil palm bunch wastes comprising Empty Palm Bunch (EPB), Pericarp Fruit Fibre (PFF) and Palm Kernel Shell (PKS) were obtained from mature palm trees of dura and tenera cultivars.Physico-chemical properties of the feedstock comprising bulk densities, proximate, ultimate and summative analyses,using the standard methods prescribed by ASTM, weredetermined.The heating values of the samples were theoretically evaluated using Dulong-Petit formula. From the result obtained, the moisture, volatile, ash and fixed carbon contentsof air-dried sample feedstock ranges from 5.22 - 4.90, 51.98 – 42.85, 6.19 – 4.57 and 60.76 – 36.93% respectively.The percentage bulk densities ranges from 670.00 – 65.00kg/m^{3}respectively.The carbon, hydrogen, oxygen, nitrogen and sulphur content ranges from 44.40 – 39.77, 11.63 – 8.30, 45.42 – 38.45, 0.41 – 0.13 and 0.54 – 0.19% respectively. Sulphur and nitrogen contents were less than 1% of the samples, indicating minimal environmental degradation if used as fuel. Percentage higher heating values of EPB, PFF and PKS were 22.8, 24.8 and 27.4 MJ/kg respectively; these are higher than 20 MJ/kg, the value for most wood fuels.Ligninand cellulose content of the biomass feedstock ranges from 23.50-45.20% and 34.46-63.58%, both constituents are thermally degradable for conversion to fuels and chemicals.The higher percentage of oxygen content (38.45-45.42%) indicates that the feedstock would be good as chemical feedstock.

Keyword: Physico-chemical properties, Empty Palm Bunch (EPB), Pericarp Fruit Fibre (PFF) and Palm Kernel Shell (PKS), Fuels and chemicals Potentials.

Introduction

Palm oil production is one example of high-level waste generator during processing. Every aspect, from harvesting to the production of crude palm oil, and its eventual refining, results in substantial waste generation, disposal of which is difficult. In Nigeria palm oil mills, landfill is one of the major means of disposal of most of the waste generated from palm oil production. This approach is unsatisfactory, as the biomass accumulation rate far exceeds the rate of decays. The fibre contents in particular being resistant tobio-degradation could be best handle by thermochemical degradation. This creates a nesting area for rodents, and insects. The leachate of fluids formed from the decomposing wastes can permeate through the underlying and surrounding geological strata, thereby mingling with groundwater. In addition, as the residues decompose during anaerobic process, methane, one of the major greenhouse gases, is emitted and this contributes to global warming (Jenner, 2008).

Palm Oil Mills (POMs) could provide one of the best sources for alternative energy and industrial chemical for agriculture in Nigeria, and countries of similar environment, going by the volume of refuse generated annually. It has been reported that Nigeria, produces about 8million tonnes of fresh fruit bunches of palm produce annually (Ugbah and Nwawe, 2008). Mokhtar, (2005), and Poku, (1998) reported that most of which are, EPB, PFF and PKSand they account for over 90 percent of the refuse.Biomassoffers a renewableand sustainablesource of carbon in the form of polymeric (cellulose, starch, lignin,hemicellulose, protein) and monomeric (carbohydrates, oils, amino acids, plantextractives) componentsunlike crude oil which is a wasting asset(Bozell, 2013). These materials could be used to supply both directreplacements for existing petrochemical raw materials and new building blocks forchemical production. .Apart from conventional use of palm oil refuse in production of energy, fiber and palm kernel shell have been successfully used for the production of activated charcoal a substance of many industrial uses (Mohammad,et. al., 2009). Mohammad, et. al., 2009, reported further that EPB is an alternative raw material for cellulosic pulp and that these cellulose derived from oil palm was used in polypropylene composite for the production of biodegradable filler. EPB have been hydrolyzed with acid to produce xylose. Palmsolid refuse are rich in cellulose (25 to 50%), hemicelluloses (20 to 35%) and lignin

These high-volume, low-value waste are better referred to as by-products rather than wastes because they can be put to economically useful purposes such as production of fibre coir, paper or particle board, ceiling board mix, compost as planting medium, among others. Despite all these economically useful purposes for which these by-products may be put to, there are still large left-over, the usage of which can be upgraded by conversion into industrial chemicals or some high-grade fuels through environmental friendly methods. The main objective of the study was to determine fuel and chemical potentials of oil palm waste.

Materials and Methods

Pretreatment of Sample Materials: The three major solid components of oil palm wasteEPB, PFF and PKS.About5kg each of EPB, PFF, and PKS for *dura* and *tenera* cultivars were collected from Palm Oil mill at Ado-Odo, Ogun State, Nigeria.The foreign matters were handpicked from the samples and discarded. Thereafter the samples were sun-dried and packed in waterproof polyethylene bags for further uses.

Determination of Physico-chemical Properties of the EPB, PFF and PKS: The physico-chemical properties of the biomass feedstock such as bulk densities, proximate, ultimate, summative compositions of the samples were determined using the methods prescribed by ASTM D1102 – 84, ASTM D1895B and ASTM D5291 (1995) respectively.

Determination of Heating Value: Dulong-Petit formula was also used to calculate the approximate higher heating values of the biomass feedstock samples based on the result of ultimate analysis of the samples.

$$HHV = 337C + 1428\left(H - \frac{O}{8}\right) + 955\left(\frac{KJ}{Kg}\right) \quad 1$$

Where: C=% of Carbon
H= % of Hydrogen
O=% of Oxygen
S= % of Sulphur

The lower or net heating value (LHV) was determined by:

$$LHV = HHV - 2465Mw \quad 2$$

Where: Mw = Product of the fraction of hydrogen in the waste sample and 9 kg

Results and Discussion

The result of the physico-chemical analyses of the samples arepresented in Table 1. The higherheating values ranges between 22.75, 24.83 and 27.37MJ/Kg for EPB, PFF and PKS respectively. This trend was expected considering the percentage of hydrogen and carbon in the samples (Table 1). The heating values of the samples were comparable with those of other agricultural residues such as groundnut shells, and coconut shells (Jekayinfa and Omisakin, 2005), agricultural and woody biomass (Dupont *et.al*. 2009). The fuels were highly oxygenated; this is evident in the percentages of oxygen content in the fuels that ranged from 39.47 to 45.42%. This gives one of the reasons why the heating values of the samples were comparably lower than those of conventional fuels. These samples would however be good as chemical feedstock (phenol) with their high percentage of lignin and oxygen contents, according to Amen-Chen *et al*. (2001).

The percentages of sulphur and nitrogen contents of the samples were both minimal, (under 1%). This follows the same trend with result reportedas per various studies on agricultural refuse and woody biomass (Calabria *etal*. 2005; Mohammad 2006 andDupont *etal*. 2009). This shows that the fuels produced from these samples would be relatively free of the harmful nitrogen oxides and sulphur compounds, which are known pollutants in petroleum-based fuels. The samples also had minimal ash content (about 6%) Table 1 suggesting that their burning efficiency would be good and thatthey might be suitable for thermal conversion. Ash is also a solid pollutant frequently suspended in the air being in powdered form as particulate.

The volatile contents were 29% and 51.98% (Table 1) for PKS and EPB respectively. This gives an indication of the extent to which biomass feedstock could be pyrolysed (Walker *etal*. 1993; Mohammad, 2006). PKS having the lowest volatile contents might resist degradation during pyrolysis more than PFF and EPB.

Tenera and *dura* EPBs had the highest parentages of cellulose and hemicelluloses (65.74 and 71.61%) respectively followed by *dura* and *tenera* PFFs (59.07 and 64.79%) respectively while the *dura* and *tenera* PKSs had the lowest (48.67 and 52.72%) respectively. Cellulose and hemicelluloses are rich sources of methanol and acetic acid. While *dura* and *tenera* PKSs had the highest percentage of lignin (41.09 and 45.20%)

respectively followed by the *dura* and *tenera* PFFs (30.58% and 36.36%) while *dura* and *tenera* EPBs had the lowest percentage. (23.50 and 28.99%) respectively. Lignin is a rich source of phenolic compounds upon thermal degradation (Amen-Chen *etal*., 2001) suggesting the suitability of the liquid product from pyrolysis of these sample as feedstock for chemical production.

Table 1: Average values of physico-chemical composition of palm bunch solid refuse (%)

	Tb	Ts	Tf	Db	Ds	df
Proximate Analysis						
MC_{db} (wt, %)	4.90	5.22	4.90	4.76	5.04	4.96
VC (wt, %)	51.98	42.85	44.86	50.17	29.90	43.09
Ash (wt, %)	6.19	4.57	6.13	5.22	4.63	5.27
Fixed carbon (wt, %)	36.93	47.36	44.11	39.82	60.76	46.68
Ultimate Analysis						
C(wt, %)	39.77	43.53	41.30	39.84	44.40	41.38
H(wt, %)	8.36	11.55	9.77	8.30	11.63	9.87
O(wt, %)	45.42	39.47	42.94	45.28	38.45	42.89
N(wt, %)	0.13	0.35	0.29	0.16	0.41	0.26
S(wt, %)	0.19	0.47	0.43	0.23	0.54	0.38
HHV (MJ/Kg)	22.77	27.05	24.75	22.75	27.37	24.83
LHV (MJ/Kg)	20.92	24.49	22.58	20.91	24.79	22.64
Physical Analysis						
Bulk density (Kg/m^3)	125.00	505.00	65.00	132.50	670.00	107.50
Energy density(GJ/m^3)	2.85	13.66	1.61	3.01	18.34	2.67
Summative Analysis						
Cellulose (wt, %)	53.48	34.46	51.36	63.58	43.32	47.78
Hemicelluloses (wt, %)	12.26	14.21	13.43	8.03	9.40	11.29
Lignin (wt, %)	28.99	45.20	30.58	23.50	41.09	36.36

Where: T = *Tenera*; D = Dura; b = empty palm bunches; s = palm kernel shells; and f = pericarp fruit fibres C = Carbon; H = Hydrogen; O = Oxygen; N = Nitrogen; S = Sulphur; MC = Moisture Content; VC = Volatile Content; HHV = Higher heating Value; LHV = Lower Heating value.

Transportation is a factor in the selection of biomass for thermal conversion into fuels and chemicals. PKS had a relatively higher energy density (13.66 and 18.34GJ/m^3) for *tenera* and *dura* PKSs respectively followed by EPB (2.85 and 3.01GJ/m^3) for *tenera* and *dura* EPBs respectively while PFF had relatively lowest energy density (1.61 and 2.67GJ/M^3), but PFF can be densified in order to increase their energy density. EPB, however, has lowest transportability advantage because of their low energy density and presence of spikelets that can injure somebody if it is not properly handled thereby prevent ease of densification.

Conclusions

The higher heating values ranged between 22.75, 24.75 and 27.37MJ/Kg for EPB, PFF and PKS respectively. Energy density was higher for PKS with *dura* having the highest value of 18.34 and tenera PKS is 13.46GJ/m^3, while on the other hand, PFF had the lowest energy density of 1.61GJ/m^3, These have energy potentials of 63.10, 66.40 and 34.65GJ/annum for PKS, EPB and PFF respectively. The biomass feedstocks were lingnocellulosic thereby, thermal conversion would be most suitable for their conversion. This is evidence from their high percentage composition of cellulose, Hemicelluloses and lignin.The samples having high percentage of lignin, a rich source of phenolic compounds, andcellulose and hemicelluloses are very rich source of methanol and acetic acid, suggesting their suitability for chemical production.

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