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Full Paper

CHARACTERISATION OF SUN-DRIED PALM FRUIT WASTE BIOMASS MATERIALS

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ABSTRACT

Palm fruit waste biomass, namely: shell, palm fiber and the empty fruit bunch (EFB) were characterized in this study for proper selection as fuel. Fresh fruit bunches (FFB) were processed to obtain the required waste products. These waste products were sun-dried for 11 days. Fuel properties such as the moisture content, bulk density, ash content, volatile matter, fixed carbon content and the calorific value were determined at interval of 3 days. The results indicate that moisture content has a direct effect on other properties. The moisture content was found to exhibit direct variation with the bulk density and the volatile matter, as they decrease with a decrease in the moisture content. The calorific value, fixed carbon content and the ash content exhibit an indirect variation with the moisture content as they increased with decreasing moisture content. After 11 days of drying, the moisture contents of the shell, fiber and EFB decreased from 31.16-6.58, 49.46-3.32 and 57.37-7.71%, respectively; the bulk densities reduced from 0.31-0.28, 0.15-0.08 and 0.31-0.08 g/cm3, respectively; the ash contents increased from 6.55-12.67, 3.46-8.27 and 5.18-16.46%, respectively; the volatile matter decreased from 81.39-73.59, 87.17-77.15 and 84.60-62.80%, respectively; the fixed carbon contents increased from 12.065-13.747, 9.363-14.58 and 10.22-20.74%, respectively; the calorific values increased from 10.87-14.94, 7.57-16.45 and 5.57-13.99, respectively.

Keywords: palm fruit, waste biomass materials, moisture, drying-scheduling, fuel characteristics, energy

1. INTRODUCTION

Palm fruit biomass has the potential to generate energy that can favorably compare with other non-fossil fuel source of heat energy like coal [Chow et al., 2008]. The solid wastes from palm fruit milling operations are: shell, palm fiber and empty fruit bunch (EFB). In large- and medium-scale mills, these waste products are referred to as by-products, because they are plowed back into the milling operation to serve as fuel to generate steam and electricity required in the mill. Although palm fruit by-products can be used for other purposes, research has shown that it is better and more economical to use it to generate energy for the mill [Menon *et al.* 2003]. This practice will not only save the processor the tedious task of waste disposal but also enhance environmental friendliness. This will also reduce the cost of production thereby having a direct economic benefit on the processing operation. This scheme has been in operation in most large scale plants [Hassan *et al.*, 2003].

In most small-scale mills in Nigeria, there are environmental challenges due to ineffective utilization of biomass waste through inappropriate disposal of large amount of it which has constituted environmental hazards and causing serious problems in the cleaning of the environment. It therefore becomes imperative to develop an appropriate technology for the processing of palm fruit at small scale level, to utilize these wastes. This will not only facilitate the recycling of the waste but also ensure higher oil yield at a relatively lower cost.

The palm fruit biomass immediately after extraction contains very high moisture content, usually in the range of 31, 49 and 57% for shell, fiber and EFB, respectively, depending on the method of extraction. This high moisture content reduces their calorific value and consequently limits their potentials as fuel materials. A way to improve on the amount of heat release per kilogram of the fuel material (calorific value), is to dry the biomass. Drying of the biomass will reduce their bulkiness, and enhance better handling of the fuel materials. This drying can be achieved by direct sun-drying; in fact it is the cheapest means of reducing the moisture content of these biomass materials to a level suitable for combustion. This study undertakes the characterization of sun dried palm fruit biomass materials with a view to provide useful data for their utilization

2. MATERIALS AND METHOD

2.1. Waste Preparation

Fresh fruit bunches were obtained from a palm fruit plantation and quartered. The fruits were manually separated from the quartered bunches to obtain the empty fruit bunch. The fruits obtained were then sterilised for 90 minutes and digested for 10 minutes based on an earlier study of Owolarafe et al. [2008]. The digested mash was pressed with a hydraulic screw press to extract the crude oil. The cake was manually pulverised after which the fiber and nuts were separated. The

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EFB, fibre and shell obtained were sun-dried for 11 days. The experiment took place between December and January (dry season) of the years 2008 and 2009, respectively. The average ambient temperature was in the range of 28 - 32 oC and the average relative humidity (obtained from psychometric chart using the wet and dry bulb temperatures) was in the range of 33- 40%.

2.2. Determination of The Properties Of The Biomass

Samples of the biomass were taken to determine some fuel performance parameters such as moisture content, ash content, volatile matter, fixed carbon and specific heating or calorific value at drying interval of 3 days.

2.2.1. Determination of moisture content

The moisture content in the fuel was determined using the standard method prescribed in ASTM D2016-25 [Debdoudi *et al*., 2005]. Each sample was heated in an oven for 1.5 h at 105°C. The moisture content was calculated as given by the equation:

$$\frac{W_i - W_f X100\%}{Wi} \qquad \text{.................} (1)$$

Where:
W_i = initial weight of the material (before drying)
W_f = weight of the material after drying

2.2.2. Determination of Ash content

The ash content was determined by following the procedure of ASTM D-5142 as reported by Debdoudi *et al.* [2005]. About 2 g of the biomass samples were burnt in muffled furnace at 800°C for 5 h and allowed to cool down in a desiccator. The ash content was calculated using the equation below.

$$\%\text{ Ash content } = \left(\frac{\text{final weight* } 100}{\text{Initial weight}}\right) \qquad \text{.........} (2)$$

2.2.3. Determination of volatile matter

The volatile matter was also determined according to ISO 562/1974 as reported by Debdoudi *et al.* [2005]. About 2 g of the samples of the fuel materials were burned in crucible covered with lid placed in a furnace at temperature of 950°C for 5 minutes and allowed to cool down in a desiccator [Lindley, 1989]. The volatile matter content was calculated using the equation below.

$$\%\text{ Volatile Matter } = \left(\frac{(\text{initial weight - final weight})\text{* } 100}{\text{Initial weight}}\right) \qquad \text{.........} (3)$$

2.2.4. Determination of fixed carbon

The fixed carbon of the material was determined as reported by Debdoudi *et al.* [2005] using the relationship below:

FC = 100 - %Ash- %VM. .... (4)

The bulk density was determined by calculating the ratio of the mass to the volume occupied. A container of a known volume was weighed. The container was filled with each sample and reweighed. The difference between the initial weight of the container and the new weight gave the weight of the sample. The bulk density of the sample was calculated as:

$$\left(\frac{Msc - Mc}{Vc}\right) \qquad \text{............} (5)$$

Where:
M_{sc} = weight of sample + container.
M_c = weight of container.
V_c = volume of container.

2.2.5. Determination of calorific value

Also the net calorific value was determined using the relationship below [Bello, 2008].

NCV= 18.7 (1-AC-MC) – (2.5 MC) 6

Where:
NCV = Net (lower) calorific value
AC = ash content, MC = moisture content

All experimental work was carried out in three replications. The data obtained were subjected to statistical analysis [SAS, 2002].

3. RESULTS AND DISCUSSION

3.1. Physical properties of the fresh palm fruit waste

Table 1 shows the properties of the wet wastes. The bulk densities of the shell, fibre and EFB at 0-day of drying were found to be 0.31, 0.15 and 0.31 gcm^{-3}, respectively, while the moisture contents were 31.16, 49.46 and 57.37%, respectively.

Table 1: Properties of wet palm fruit processing waste

	Moisture content (%)	Ash content (%)	Volatile Matter (%)	Fixed carbon (%)	Net calorific value MJkg^{-1}	Bulk density gcm^{-3}
Shell	31.16	6.55	81.39	12.06	10.87	0.31
Fibre	49.46	3.46	87.17	9.36	7.57	0.15
EFB	57.37	5.18	84.60	10.22	5.57	0.31

The ash contents at this moisture content were 6.55, 3.46 and 5.18%, respectively, while the volatile matter ware found to be 81.39, 87.17 and 84.60%, respectively. The fixed carbon contents at the 0-day of drying were 12.07, 9.36 and 10.22%, respectively, and the net calorific values were found to be 10.87, 7.57 and 5.57 MJkg-1, respectively. These values compare well with those obtained by Hussain et al. [2003] on the palm fruit wastes from some Malaysian mills.

3.2. Effect of Drying On Moisture Content of the Palm Wastes

Figure 1 shows the moisture migration pattern of the palm wastes within 0 – 11 days of drying. It was observed that the moisture contents of the shell and fibre dropped rapidly within 0 – 3 days of drying, while the moisture content of the EFB dropped rapidly between 3 – 6 days of drying. The average moisture content of the shell reduced from 31.16% at the 0 day of drying to 6.58% after 11 days of drying, while the average moisture content of the fibre dropped from 49.46-3.32% .The average moisture content of the EFB dropped from 57.37-7.71% after 11 days of drying. Statistical analysis of the effect of drying on moisture contents of the biomass materials indicated that the effect was significant at 99.88% [SAS, 2002]. The moisture content of biomass material is an important parameter that determines their combustibility. The lower the moisture content, the higher the potential of the biomass materials as fuel [Hurstboiler, 2009; Cassidy and Ashton, 2007].

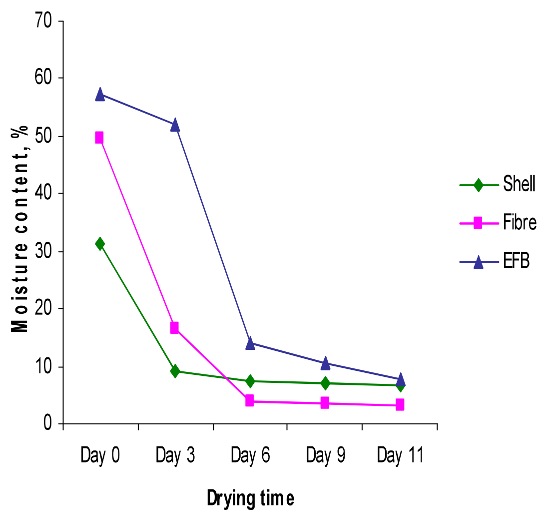

Fig 1: Moisture migration of the palm fruit waste biomass

3.3. Effect of Drying On Bulk Density of the Palm Wastes

Fig 2 shows the effect of drying time (days) on the bulk density of the biomass materials. The average bulk density of the shell reduced from 0.31gcm-3 at the 0 day of drying to 0.28gcm-3 after 11 days drying, while the average bulk density of the fibre dropped from 0.15-0.08 gcm-3. The average bulk density of the EFB dropped from 0.31-0.08 gcm-3 after 11 days of drying. Drying is a way of removing moisture from agricultural materials. The longer the drying time the lower the moisture content. Reduction in moisture content of agricultural products usually brings about reduction in weight particularly with materials with high moisture contents as these biomass materials. This automatically results in reduction in the bulk density especially when appreciable amount of volume doesn't occur. The bulk density therefore reduced as the moisture content reduced (brought about by increasing drying time) as shown in Figures 1 and 2. The effect of drying on bulk densities of the materials was observed to be significant at 99.99% [SAS, 2002]. The data presented here are very useful for the design of the furnace/boiler that will utilise the biomass as fuel materials. In addition low moisture content improves handling of the material and this affects transport cost [Hurstboiler, 2009].

3.4. Effect of Drying On Ash Content of the Palm Wastes

The effect of drying on the ash content of the palm fruit waste is shown in Figure 3. The average ash content of the shell increased from 6.55% at the 0 day of drying to 12.66% after 11 days of drying, while the average ash content of the fibre increased from 3.46-8.27%, the average ash content of the EFB

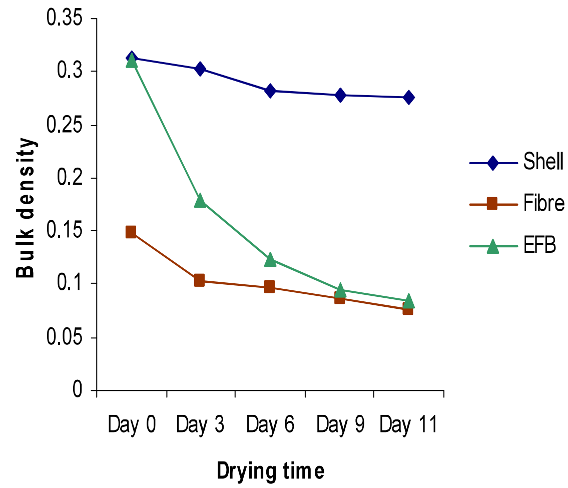

Figure 2: Effect of drying time on the Bulk density of the palm fruit waste biomass

increased from 5.18-16.46% after 11 days of drying. Since increasing drying time brings about reduction in moisture content, the ash contents of the materials increased with increased in drying time. Figures 1 and 3 showed that the ash contents of the fuel materials increased with decrease in moisture content. Drying was observed to significantly affect the ash content of the materials ($p<0.0001$). The result of the ash content of the wet fuel materials obtained compared favourably with the findings of Chow *et al.* [2008]. The ash content of pinewood has also been reported to have increased with reduction in moisture content [Szemmelveisz *et al.* 2009].

3.5. Effect of Drying On the Volatile Matter of the Palm Wastes

The volatile matter of the fuel materials reduced with increasing days of drying as shown in Figure 4. This implies that volatile matter is directly proportional to the moisture content. The average volatile matter of the shell reduced from 81.39% at the 0 day of drying to 73.59% after 11 days of drying, while the average volatile matter of the fibre dropped from 87.17-77.15%, the average volatile matter of the EFB dropped from 84.60-62.80% after 11 days of drying. The effect of drying was observed to significantly ($p < 0.0001$) affect the volatile matter of the palm fruit wastes. This result is also found to be in agreement with the findings of Chow et al. [2008] and Szemmelveisz et al. [2009] on palm fruit wastes and pinewood, respectively.

3.6. Effect of Drying On the Fixed Carbon Content of The Palm Wastes

The average fixed carbon of the shell increased from 12.07% at the 0 day of drying to 13.75% after 11 days of drying, while the fixed carbon content of the fibre increased from 9.36-14.58%, the average fixed carbon content of the EFB increased from 10.22-20.74% after 11 days of drying as shown in Figure 5.

Statistical analysis of the effect of drying on the fixed carbon content of the materials indicated that drying significantly affected the property at 95%. The findings of Chow *et al.* [2008] and Szemmelveisz *et al.* [2009] on palm fruit wastes and pinewood, respectively, corroborate the current results on effect of drying time on the fixed carbon contents. In the current study an optimum fixed carbon content was however observed for a particular drying time.

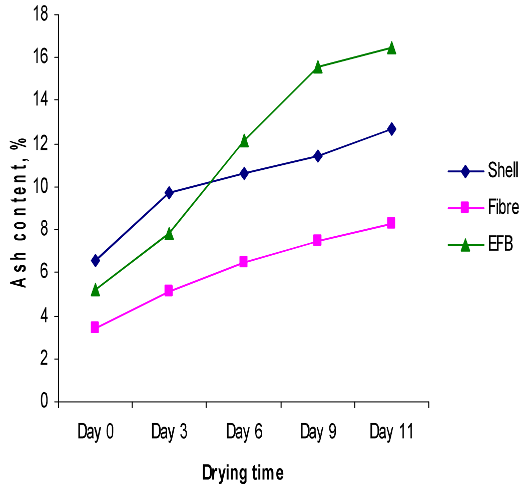

Fig 3: Effect of drying time on the Ash content of the palm fruit waste biomass

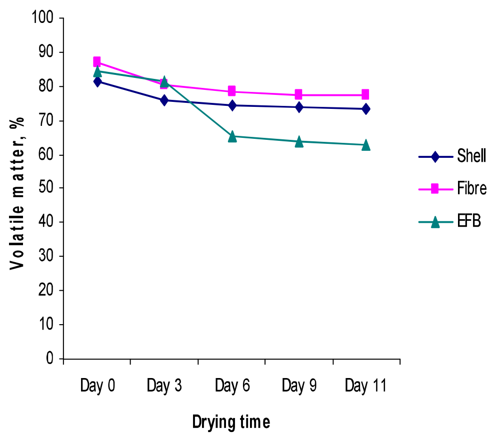

Figure 4: Effect of drying time on the Volatile matter of the palm fruit waste biomass

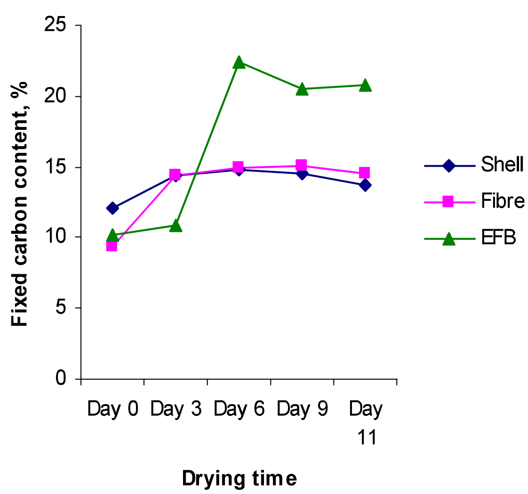

Figure 5: Effect of drying time on the fixed carbon content of the palm fruit waste biomass

3.7. Effect of Drying On the Calorific Value of the Palm Fruit Wastes

The net calorific value of shell at 0-day of drying was 10.87 MJkg-1 and increased to 14.94 MJkg-1 after 11 days of drying, while the net calorific value of fibre and EFB increased from 7.57 and 5.57 to 16.45 MJkg-1 and 13.99 MJkg-1, respectively (Figure 6). Drying significantly affected the calorific value at 99.99%. The increase in the calorific value is as a result of decrease in the moisture content of the fuel materials (Figure 1). This is in agreement with findings of Cassidy and Ashton [2007] on wood. Hussain et al. [2003] also reported that palm fruit wastes with high moisture content with some Malaysian mills has low calorific values Calorific value of the biomass materials is very important in the numerical simulations of thermal conversion system for the biomass materials [Changdong and Azevedo, 2005]. The calorific value of biomass material influences the choice of energy conversion system for the material.

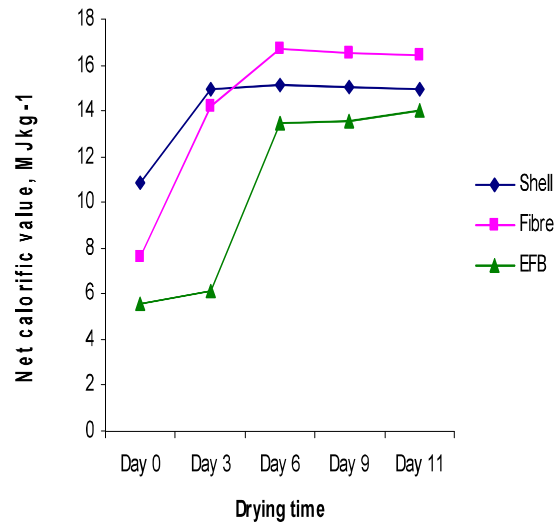

Figure 6: Effect of drying time on the Net calorific value of the palm fruit waste biomass

4. CONCLUSIONS

Ineffective utilization of biomass residues from the oil mill constitutes environmental hazard and pollution, and also emits strong irritating smell due to microbial decomposition activities at dump sites. This calls for an efficient utilisation of these readily available by-products as fuel for this industry by reducing the moisture content to improve its calorific value, which can be achieved by direct sun drying. This study has shown that the calorific value of shell, fibre and EFB after the 6th day of sun drying increases from 10.87-15.08 MJkg^{-1}, 7.57-16.45 MJkg^{-1} and 5.57-13.99 MJkg^{-1}, respectively, during the dry season. This implies that a sun drying scheme can be planned for the utilisation of biomass residues as fuel in palm oil processing industry. This will prevent the processor from over relying on other conventional sources of energy and hence save considerably cost of energy. The data generated is also useful in the design of the furnace/boiler that will utilise the waste materials. These measures will go a long way in improving the oil extraction efficiency and economics of the small and medium scale processors in the Nigerian palm oil industry.

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