Journal of the Nigerian Association of Mathematical Physics
Volume 31, (July, *2015*), pp 61 – 70

An Alternative Solid Waste Management System in Nigeria: A Case for Local Production of Solid Waste Derived Fuel (SWDF)

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Abstract

The problem of waste management is continuously on the increase on a daily basis in Nigeria. Despite the huge clamour for and the importance of proper waste management, the local government authorities and waste managers appear to be unequal to the task of waste management evidenced from the increasing quantity of solid waste constantly decorating street corners, road sides and road medians in the country. Will there ever be a solution to the menace of waste management in Nigeria? This study attempts to profer an alternative approach to waste management in Nigeria through the production and utilization of Solid Waste Derived Fuel (SWDF). It was discovered that about 51.74% of the solid waste stream in Nigeria can be processed to produce SWDF, thereby reducing drastically the volume of solid waste left to be disposed. With an experimentally determined calorific value of 16.81MJ/kg, the produced SWDF can be used as supplementary fuel for cement industries and power generation companies in Nigeria.

Keywords: Solid waste management, Solid Waste Derived Fuel, Calorific Value, Moisture Content.

NOMENCLATURE

C Heat capacity of the bomb calorimeter = 15kJ/℃
ΔT Change in temperature = $T_c - T_a - r_1 (b - a) - r_2 (c - a)$
a time of firing of bomb
b time when the temperature reaches 60% of total change
c time of maximum temperature
T_c maximum temperature
T_a temperature at time of firing
r_1 rate of temperature change during stirring = $(T_a - T_i)/(a - i)$
r_2 rate of temperature change after time c = $(T_f - T_c)/(f - c)$
i initial time of measurement
f final time of measurement
T_i temperature at initial time of measurement
T_f temperature at final time of measurement
e_1 correction of heat of formation of nitric acid (however, flushing the bomb with oxygen prior to firing displaces all nitrogen, thereby preventing nitric acid formation, hence e1 =0)
e_2 correction of heat of formation of sulphuric acid (% of sulphur in sample × mass of sulphur (g) × 57.54J/g
e_3 correction of heat of formation of fuse wire (length of fuse wire consumed in cm × 9.66J/cm)

1.0 Introduction

Solid wastes could be a blessing or a menace depending on how they are managed. Developed countries (like Sweden, USA and Germany, etc.) have been able to effectively managed their solid waste over the years by developing technologies and facilities to harness the potentials (both energy and materials) inherent in solid wastes. Solid wastes management is so advanced in these countries that solid waste is considered as resources rather than as useless substances to be discarded.

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Through effective and efficient solid waste management, these countries have not only been able to collect, store, transport and dispose solid waste with little or no effect on the environment, but have been able to recycle solid wastes into new products, extract heat and electrical energy from solid wastes, as well as obtain environmentally friendly fuels from solid wastes, and thereby creating clean and healthy environment for their citizens to live in.

Despite the huge gains made hitherto from sound solid waste management by developed countries, many developing countries are still huffing and puffing in their attempt to manage solid waste. According to Chattopadhyaya et al [1], in Kolkata, India there is no segregation of solid waste at source, limited house-to-house waste collection and the use of very old vehicles for waste collection. Al-Khatib et al [2], reported that in Pakistan, although Municipal Solid Waste collection was available for 98% of the residents, there is no proper treatment or landfill procedure for the collected waste in most of the area. Instead, waste burning in open dumpsites was the most common practice due to the inefficient collection of waste disposal fees from residents. Municipalities often suspended the collection service due to reduction in its labour force.

In Nigeria, the perpetual population growth and rapid urbanization have been accompanied by increase in solid waste generation in her cities, thereby increasing the complexity of solid waste management in the country. The rate of solid waste collection and evacuation always lag behind the rate of generation resulting in heaps of solid waste defacing most parts of the country and constituting a major source of environmental nuisance in her cities. Most of the local authorities in Nigeria practice dumping as the only option for solid waste disposal. The waste collectors struggle daily to grapple with the increasing quantity of solid waste being generated, hence considerable percentage of the generated and collected solid waste are either deposited in shallow pits in the ground, along the roadside, unapproved dumpsites, low-lying marshland, water ways and water body. This uncontrolled dumping of solid waste poses huge risks to public health and the environment, such as, air pollution, health problems, blocked drains, flooding, erosion, traffic congestion, soil pollution, unaesthetic dumpsites, loss of community pride among others.

The poor state of solid waste management in Nigeria is due to inadequate facilities, poor funding of waste managers, poor implementation of policies and wrong attitude of waste generators among others. According to Egunjobi [3], the problems of effective solid waste management had to do with poor social services delivery efforts which cause unnecessary delays in solid waste clearance. It is either broken down machinery, non-maintenance of dumpers, poorly maintained urban streets and roads and irregularities in the designation of sanitary dump sites. Hence, solid waste management in Nigeria is characterized by inefficient collection methods, insufficient coverage of the collection systems and improper disposal as observed by Ogwueleka [4].

It is saddening to note that in the 21st century, Nigeria is still struggling to manage her solid waste. Uncoordinated institutional functions, low political will, low capacity to discharge duties and poor data for planning [5] are among the contributing factors to the challenge of solid waste management in the country. Babayemi and Dauda [6] decried the complete lack of efficient and modern technology for the management of solid waste. The Federal Government had tried to tackle the problems of solid waste management over the years by rolling out several legislation and regulations on waste management, which include:

i. The Harmful Waste Act, 1998;
ii. Environmental Impact Assessment Act, 1992;
iii. The National Environmental Standards and Regulations Enforcement Agency Act, 2007;
iv. National Environmental Regulations, 2009;
v. The National Environmental Protection Regulations.

These legislations and regulations have had little impact on waste management in the country as evidenced by the way solid wastes are still being disposed indiscriminately. Despite the problems of waste management in Nigeria, there is perpetual increase in demand for good waste management practice for public health and environmental protection. It is against this backdrop that it becomes pertinent to seek and adopt alternative systems of waste management among which is the reduction and reuse of solid waste by converting them into fuels known as solid waste derived fuels (SWDF).

The Integrated Solid Waste Management (ISWM) hierarchy, shown in Figure.1, stipulates that source reduction and reuse are the most desirable solid waste management practice since they are the most effective way to reduce the quantity of waste and resource consumption, followed by recycling/composting. However, after waste is reduced, reused and recycled, waste is still leftover and must be managed further. Here combustion with energy recovery becomes necessary. Combustion can reduce the quantity of waste landfilled and hence saves landfill space. In this regard, SWDF is one form of waste reduction as well as reuse via energy recovery. Therefore, it encompasses both the first and third ranks of the Integrated Solid Waste Management hierarchy.

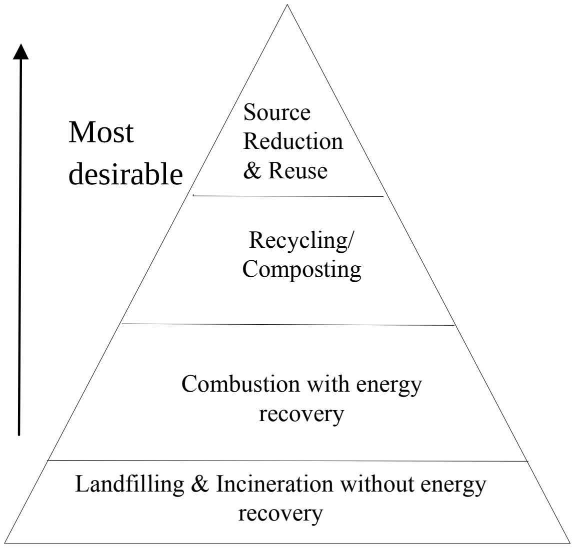

Figure.1: Integrated SWM hierarchy

According to Gendebien et al. [7], SWDF production and utilization have been well developed in Europe; the growth has been tremendously fast from 1.4million tonnes per annum (Mtpa) in 2000 to 12.4Mtpa in 2005. Several European countries have seen production and utilization of SWDF as an alternative waste management system as several legislations (including landfill directive 1999/31/EC) have demanded the diversion of biodegradable wastes prior to landfill. Besides contributing to keeping the environment clean, SWDF can serve as supplementary fuel for electrical power generation plants and cement kilns in cement industries. Due to its higher calorific value and more homogeneity in quality, SWDF is preferable to raw municipal solid waste as supplementary fuel [8].

Several researches have been done on Solid waste management in Nigeria, particularly on material and energy recovery from solid waste [4, 9, 10, 11, 12, 13, 14], however the production of solid waste derived fuel (SWDF) from MSW have not been reported based on available literatures. Presently, there is no known SWDF production facility in Nigeria due to lack of information for decision makers and investors to introduce such plant in the country. Therefore this paper will investigate the potential and process of producing SWDF from solid waste generated in Nigeria, with Benin Metropolis as case study and also experimentally determine some important physical and chemical properties of the produced SWDF. This properties will provide fuel characteristics data for preliminary design of SWDF plant in Nigeria.

1.1 Definition of and why SWDF

Solid Waste Derived Fuel (SWDF) is the combustible high calorific value recovered from municipal solid waste [15]. It can also be referred to as Refused Derived Fuel (RDF), however for the purpose of this paper SWDF and RDF will be used interchangeably for fuel derived from Municipal Solid Waste (MSW). According to ASTM [16], SWDF is a shredded fuel derived from MSW when metal, glass and other inorganic materials have been removed.

Caputo and Pelagagge [17] revealed that MSW composition varies from different sources, seasons and living behaviour. Raw MSW has high moisture content, low calorific value, wide range of particle size distribution and high ash content. Hence using raw MSW as fuel is difficult and unattractive. They also reported that SWDF presents several advantages as a fuel over raw MSW, such as higher calorific value, more uniformity of physical and chemical composition, ease of storage, handling and transportation, lower pollutant emissions and reduction of excess air requirement during combustion.

1.2 Classification of SWDF

According to ASTM [16] standards, SWDF can be classified in seven categories as follows:

i. RDF-1: wastes used in as discarded form;
ii. RDF-2: wastes processed to coarse particle size with or without ferrous metal separation such that 95% by wt passes through a 6-inch square mesh screen, namely coarse RDF;
iii. RDF-3: wastes processed to separate glass, metal and inorganic materials, shredded such that 95% by wt passes through 2-inch square mesh screen, namely fluff RDF;
iv. RDF-4: combustibles wastes processed into powder form, 95% by wt passes through a 10-inch mesh screen (0.035 square), namely powder RDF;
v. RDF-5: combustible wastes densified into the form of pellets, slugs, or briquettes, namely densify RDF;
vi. RDF-6: combustible wastes processed into liquid fuels, namely RDF slurry;
vii. RDF-7: combustible wastes processed into gaseous fuels, namely RDF syngas.

1.3 RDF Standards

Assurance of quality in the production of RDF requires that RDF should have high calorific value and low concentration of toxic chemicals especially for heavy metals and chlorine. Quality aspect influences the economic success or failure of RDF and is led by three participating groups: RDF producers, potential RDF consumers and the respective authorities. Due to their different point of view, suggested RDF quality varies from one group to another [8]. Although there is no RDF quality regulation in Nigeria right now, we can follow the European standard as a guideline and develop our standard according to Nigerian situation later on. The results of a survey of quality standards for RDF in Europe based on concentration of toxic chemicals were reported by [8].
There is also another RDF standard according to calorific value, moisture and ash contents as shown in Table 1.

Table 1: Quality Standard for RDF (Gendebien et al, 2003)

Parameters	Finland	Italy	United Kingdom
Calorific value (MJ/kg)	13 – 16	15	18.7
Moisture content %wt	25 – 35	25	7- 28
Ash content %wt	5 -10	20	12
Sulphur %wt	0.1 – 0.2	0.6	0.1 – 0.5
Chlorine %wt	0.3 – 1.0	0.9	0.3 – 1.2

Calorific value can be determined by using laboratory bomb calorimeter or by calculation if the elemental compositions (C, H, N, O, & S) of the substance are known. The formula used for calculating calorific value is the Dulong formula [18] modified as

$$CV\ (MJ/kg) = 337C + 1419\ (H_2 - 0.125O_2) + 93S + 23N \quad (1)$$

Where, C, H_2, O_2, S & N are given in percentage by weight.

1.4 SWDF Production Process

According to UNEP [15], RDF production process has two subsystems called the front end and back end. Front end or pre-processing subsystem is to receive the MSW and separate them into combustible and non-combustible fractions in order to produce feedstock for back end system. Back end system refers to the conversion process which can either be thermal or biological system.
Caputo and Pelagagge [17], describe RDF production line as consisting of several unit operations in series in order to separate unwanted components and condition the combustible matter to obtain the required RDF characteristics. General unit operations include: screening, shredding, size reduction, classification separation, drying and densification. These unit operations can be arranged in diff1erent sequences depending on the received MSW and required RDF quality. The unit operations in RDF production process are describe as follows:

i. Manual separation
Here bulky items such as appliances, furniture, etc and hazardous wastes are removed manually before mechanical processing. Equipment involved in manual separation usually includes a sorting or table. Sorters are stationed on one or both sides of the belt or table to pick out the recyclable materials.

ii. Size reduction
Size reduction is an essential unit operation in mechanical processing of mixed wastes since it gives a certain degree of size uniformity. Shredding of mixed wastes to the size of about 10cm is common in many waste processing facilities. Though, sometimes secondary or tertiary shredding to sizes below 10cm is required for RDF production. Hammer mills and shear shredders are some shredding equipment used for size reduction in RDF production.

iii. Screening
The purpose of screening is size reduction. It divides the feedstock into at least two streams called oversize (retained on the screen) and undersize (passed through the screen) fractions.

iv. Air classification
Air classification is a separation process by the differences in aerodynamic characteristics of waste. The process consists of the interaction between moving stream of air, shredded wastes and gravitational force. The fraction which is suspended in the air stream is referred to the light fraction and the settled materials are referred to heavy fraction. In air classification of shredded mixed MSW, paper and plastic materials tend to be concentrated in the light fraction and metals, glasses are the main components of the heavy fractions.

v. Magnetic separation
Magnetic separation is used to segregate ferrous metals from mixed MSW. There are three configurations of magnetic separators namely; magnetic head pulley, drum and magnetic belt. In terms of yield, the magnetic metal recovery per unit weight of total magnetic metal in mixed MSW is about 80% for single stage of magnets. Higher rate of recovery can be achieved by using multiple stages of magnetic separation. The percentage of recovery will be

higher up to 85-90% when magnetic separator is used after air classification. This is due to the fact that light contaminants such as paper and plastic which will interfere with the magnetic separation process have been removed during air classification.

vi. Drying and densification

Drying and densification are used in specific purposes such as RDF production and volume reduction of waste prior to landfill. The purpose of drying is to improve the quality of the RDF. Densification is used for production of densified RDF by the way of briquetting, pelletizing or cube formation.

1.5 SWDF Application

According to Rotter et al [8] target RDF users are energy-intensive industries such as Cement industries and power generation either mono-combustion or co-combustion.

2.0 Materials and Method

1.1. Waste collection

Plastic waste bags were supplied to ten residential quarters inside the University of Benin main Campus, Ugbowo. Each residential quarter was supplied with two plastic waste bags, one bag for combustibles wastes and the other bag for non-combustibles wastes. They were educated on what constitute combustible and non-combustible wastes to enhance proper sorting and collection. Both plastic bags were retrieved after five days according to the work plan, with replacement bags for the next collection. The retrieved waste bags were taken to University of Benin Mechanical Engineering laboratory for weighing, sorting and analysis. This was done for 15days and the family size for each residential quarter was taken.

1.2. Weighing and analysis

The collected wastes were weighed in pre-weighed bins using an electronic precision scale with a sensitivity of 0.1kg. The weight of the waste alone was obtained by difference. For sorting, the wastes were spread on clean plastic sheets and the sorting was done by hand. The target sort categories included the following: food waste; paper; plastics/rubber; wood residue; nylon; textile; metals; glass and disposable food packs. The waste separates were further sorted into combustible and non-combustible fraction and then weighed accordingly.

1.3. SWDF Production

Since there is no SWDF plant and equipment available in Nigeria for SWDF production, manual processes as well as improvised equipment were used in the production of the SWDF. The combustible fraction of the wastes was sun dried for 7 hours to reduce the moisture. A pair of scissors was used to reduce the size of the waste components. The average size of the solid waste after this initial size reduction was 2.52cm. A further size reduction was done also with the aid of scissors to an average size of 1.14cm. The reduced waste components were mixed together and bounded together using aqueous cassava starch to from fluff SWDF. This process was carried out in a plastic bucket and stirred with a wooden spatula to obtain a homogeneous mixture. The fluff SWDF was loaded into cylindrical plastic hair rollers which serve as the mould. The fluff SWDF was well compacted inside the rollers in order to produce densified SWDF. The compacted SWDF were taken out of the mould and sun dried for 3 days to remove moisture from them. Figure 2 shows the final product of the processed MSW after drying.

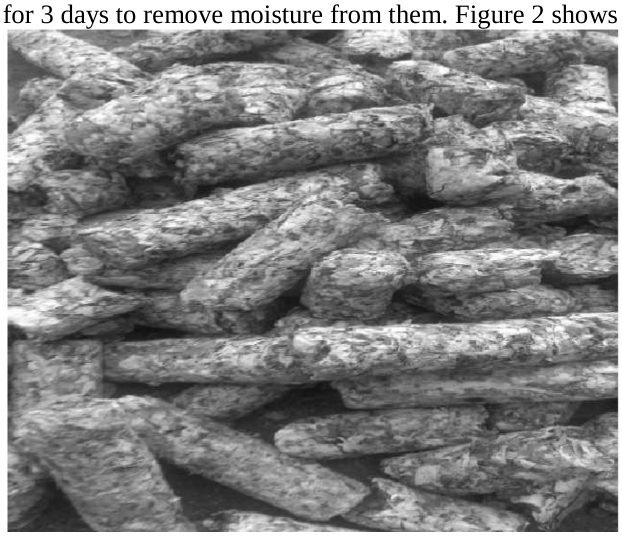

Figure 2: Final SWDF product

1.4. SWDF Moisture Content (MC) determination

10g of the produced SWDF were weighed out and oven dried at 110℃ to a constant weight for 4 hours. The sample was allowed to cool, weighed again and recorded as the dry weight of sample. The percentage Moisture Content (MC) of the sample was calculated using equation (2).

$$\%MC = \frac{\text{weight of wet sample} - \text{weight of dry sample}}{\text{weight of dry sample}} \times 100 \text{ ---------------------- (2)}$$

Source: [19]

1.5. SWDF calorific value determination

A digital oxygen bomb calorimeter was used to determine the calorific value of the produced SWDF. Approximately 1.0g of the SWDF was weighed out and carefully placed in the sample cup of the calorimeter using tweezers. Approximately 10cm of Nickel fuse wire, of known weight, was measured out and attached to the electrodes. The sample cup was placed in the cup holder and the fuse wire was positioned in such way that it almost touches the surface of the sample. To absorb the combustion of sulphur and nitrogen, 1.0ml of water was pipette and pour into the bomb. The bomb was then carefully charged with oxygen gas to a pressure of about 30atm. The charged bomb was carefully placed in the bucket of the calorimeter and the bucket was filled with 2.0l of water. A thermometer sensor probe was inserted into the calorimeter top so that the end of the sensor touches the water in the bucket. The stirrer was started and allowed to run for some time to reach equilibrium after making the necessary electrical connections. The timer was started and the temperature of water in the bucket was recorded at one-minute interval until the thermometer indicates a steady temperature.The bomb was fired afterward and the temperature readings were recorded after 30seconds interval until maximum temperature is attained, i.e. the difference between successive readings was zero or becomes negative.

Then, all the electrical connections were turned off, the ignition wire was removed from the bomb and the bomb was lifted out of the bucket. The valve of the bomb was opened to release the pressure inside of it and its contents were weighed and measured carefully for further analysis. Finally the interior of the bomb was examined was for soot.

The calorific value (CV) of the sample SWDF was calculated afterwards using equation (3).

$$CV = \frac{C\Delta T - (e1 + e2 + e3)}{m} \text{ ………………………. (3)}$$

Source: [20] - All terms already defined in nomenclature

3.0 Results and Discussion

3.1 Daily waste generation and waste characterization

According to Cointreau [21], the entire concept of waste is subject to the value judgment of the primary owner or potential consumer. Broadly, waste can exist in solid, liquid and gaseous forms or in all of the three intermingled. However, solid waste can exist in either solid or semi-solid (i.e. sludge) forms. This report addresses only solid waste in the solid form. These wastes come from everyday activities in residential areas and commercial centres.

The waste collection exercise envisaged a scope covering 10 households. However, only 7 households were actually surveyed. Collection from the other 3 households was not consistent (due to lack of cooperation of the residents) and so was disregarded. The seven households surveyed involved 40 persons. For the entire period, a total of 330kg of solid waste were collected. This translates to a daily per capita rate of 0.55kg for the entire. This figure falls within the range of daily per capita waste generation across cities in Nigeria (0.44-0.66kg) [4]. Results of the characterization of the collected solid waste gave an average of 16.23% of paper, 14.04% of plastic/rubber, 42.11% of food waste, 5.00% of metal, 1.15% of glass, 5.26% of wood residue, 1.32% of disposable food pack, 13.7% of nylon and 1.19% of textile, as shown in Table 2.

Table 2: Average percentage of the components of MSW collected from residential quarters in University of Benin.

Components of solid waste	%weight
Paper	16.23
Plastic/rubber	14.04
Food	42.11
Metal	5.00
Glass	1.15
Wood residue	5.26
Disposable food pack	1.32
Nylon	13.7
Textile	1.19
Total solid waste	100

From the definition of SWDF, it is the combustible fraction that is used for the production of SWDF. From Table 2, the combustible components are 16.23% of paper, 14.04% of plastic/rubber, 5.26% of wood residue, 1.32% of disposable food pack, 13.7% of nylon and 1.19% of textile. Hence the combustible fraction used in the production of SWDF amounts to 51.74% of the total solid waste collected. This shows that converting MSW into SWDF would not only reduce the volume of waste to be managed for disposal but also takes care of MSW components which are non-biodegradable. The non-biodegradable components such as paper, plastics/rubber, disposable food pack, nylon and textiles deface the environment and pose public health hazards to both humans and animals.

3.2 Experimental result of the moisture content and calorific value determination

3.2.1 Moisture content determination

The percentage moisture content of the produced was calculated from the experiment carried out with an oven using the formula in equation (2).

Weight of wet sample = 10g

Weight of dry sample = 8.7g

$\therefore \%MC = \frac{10-8.7}{8.7} \times 100 = 14.94\%$

3.2.2 Calorific Value Determination

The calorific value of the produced SWDF was calculated from the experiment carried out with the bomb calorimeter using the formula in equation (3).

Mass of sample before combustion = 1.0g

Volume of water in bucket of calorimeter = 2.0L

Initial length of nickel fuse wire = 10cm

Final length of nickel fuse wire = 0.5cm

Length of fuse wire consumed = 9.5cm

The rate of temperature change during stirring and change after temperature becomes maximum is calculated using equations (4) and (5)

Rate of temperature change during stirring, $r_1 = (T_a - T_i)/(a-i)$…………….(4)

Rate of temperature change after time, $r_2 = (T_f - T_c)/(f - c)$………………...(5)

Table 3: Temperature readings recorded at 30 seconds interval after firing the bomb.

Time (min)	Temperature (℃)
00	29.796
0.5	29.954
1.0	30.153
1.5	30.254
2.0	30.315
2.5	30.352
3.0	30.378
3.5	30.393
4.0	30.409
4.5	30.419
5.0	30.429
5.5	30.435
6.0	30.440
6.5	30.445
7.0	30.448
7.5	30.450
8.0	30.453
8.5	30.454
9.0	30.456
9.5	30.458
10.0	30.458
10.5	30.458
11.0	30.457

From Table 3;
$r_1 = (29.954 - 29.796)/ (0.5 - 0) = 0.316$
$r_2 = (30.457 - 30.458)/ (11 - 9.5) = -0.000667$
T_a + 60% rise in temperature = 29.954 + [0.6 (30.458 – 29.796)] = 30.3512℃
Hence, by interpolation from Table 3, b = 2.49min.
Therefore,
$\Delta T = [(30.458 - 29.954) + 0.316 (2.49 - 0.5) - 0.000667 (9.5 - 2.49)] = 1.1282$℃
According to Igoni et al [22] percentage of sulphur in MSW is 0.4%
$\Rightarrow e_2 = 0.4 \times 1.0 \times 57.54 = 23.016J = 0.023016KJ$
and, $e_3 = 9.5cm \times 9.66J/cm = 91.77J = 0.09177KJ$
Thus, substituting in equation (3) gives
$CV = [15 \times 1.1282 - (0.023016 + 0.09177)]/ 0.001 = 16.81MJ/kg.$
Results from the experimental determination of the properties of the produced SWDF are summarized in Table 4.

Table 4: Summary of the properties of produced SWDF.

Properties	Value
Calorific value (MJ/kg)	16.81
Moisture content %wt	14.94
Ash content %wt	9
Sulphur %wt	0.4

The utilization of SWDF further enhances the attraction of this approach of solid waste management. SWDF can be used as fuel or supplementary fuel for heat and energy generation in cement kilns and power generation boilers. However, such potential of SWDF depends on its quality which can be determined by the value of its calorific value, moisture content, ash content, sulphur content and chlorine content. The values of calorific value, moisture content, ash content and sulphur content of the produced SWDF are summarized in Table 4. Chlorine content of the produced SWDF could not be determined due to lack of equipment for its determination. Comparison of the values in table 4 and table 1indicates that the produced SWDF is of good enough quality to be used as a fuel. Using SWDF as fuel or supplementary fuel for power generation in Nigeria would go a long way to address the problems of availability of fuel for power generation in the country. The electricity thus generated would greatly complement the current epileptic electricity supply and boost economic activities in Nigeria. It would also contribute to achieving the goals of Nigeria's Renewable Energy Master Plan (REMP), which is to generate 50MW of electrical power in 2015 and 400MW in 2025 from biomass-based fuels [23].

4.0 Conclusion

Solid Waste Derived Fuels (SWDF) also known as Refuse Derived Fuel (RDF) are range of products resulting from the refining or processing of MSW. They have numerous advantages as a fuel over raw or unprocessed MSW namely ease of storing, handling and transportation, lower pollutant emissions, reduced air requirement during combustion, homogenous composition and high calorific value. In a nutshell, SWDF production encapsulates waste reduction, reuse, recycling and energy recovery of an Integrated Solid Waste Management system.
This paper proposed SWDF production from MSW generated as an alternative Solid Waste Management system that can be integrated into Nigeria's current waste management practice. A local production of the fuel was demonstrated with solid waste generated from Benin City. Examination of the produced SWDF pellets was done. With experimentations and formulae from literatures, some important physical and chemical properties were determined. The calorific value of the SWDF was obtained as 16.81MJ/kg which compares with values reported in literatures.
The production of SWDF from MSW is a viable solid waste management alternative that is gaining attention and has been fully adopted and integrated into solid waste management strategies of nations across the globe. It is the view of this study that such a solid waste management option, which promotes recycling and recovery, should be adopted in Nigeria for an effective and efficient integrated waste management systems by local government authorities and solid waste managers.

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