Empirical Analysis of the Energy Potentials in Co-Substrates from Cassava Peels, Cow Dung and Saw Dust

Olawale O.E., Ajibola, Ebun E., Oguntibeju, and Oluwaseyi J. Balogun, *Member, IAENG*

***Abstract*—Nigeria's energy supply is at present almost entirely dependent on crude oil. The decline in fossil fuel production due to many local and international factors coupled with environmental hazards from unchecked exploration activities, and the increase in demand for energy as a result of population explosion, makes it imperative to develop alternative, renewable and locally sustainable forms of energy. Biomass, especially those of cow dung (CD), cassava peels (CP) and saw dust (SD) have been discovered to contain high Carbon to Nitrogen (C:N) ratios. To this end, efforts towards achieving self-sufficiency in energy production have led to the co-digestion of CD, CP and SD under anaerobic conditions. When done in right ratios, it produces biogas and reduces environmental and health hazards associated with inadequate waste management systems. In this project, cow dung, sawdust and cassava peels were mixed in ratio 1:0:1:4, 1:1:0:4 and 1:0:0:2 respectively. The slurries obtained were digested anaerobically under mesophilic condition. A retention period of 20 days was set for gas production. And comparative study of the biogas yields was conducted to determine the most ideal waste combination for energy production. The overall result shows that a blend of saw dust and cow dung is the most viable waste combination for biogas production.**

***Index Terms*—** anaerobic digestion, saw dust, Cow dung, Cassava peels.

I. Introduction

ENERGY is one of the most fundamental inputs for the achievement of many millennium development goals. Energy exist in various forms such as potential, kinetic, solar, thermal, electrical, chemical, nuclear energy. Based on the law of conservation of energy can neither be created nor destroyed, but can only transformed from one form to another [1].

Manuscript received March 6, 2017; revised April 8, 2017. Empirical analysis of energy potentials in co-substrates from Cassava Peels, Cow Dung and Saw Dust.

Olawale Olaniyi Emmanuel Ajibola is with the University of Lagos, Akoka, Yaba, Lagos 23401 Nigeria (phone: +234-802-302-5053; e-mail: waleisiro@yahoo.com).

Ebun E. Oguntibeju is with the University of Lagos, Akoka, Yaba, Lagos 23401 Nigeria (e-mail: ebunoguntibeju@yahoo.com).

Oluwaseyi Jessy Balogun is with the College of Medicine of the University of Lagos, Akoka, Yaba, Lagos 23401 Nigeria (e-mail: seyi8030@yahoo.com).

Burning gasoline in car engines converts (chemical energy) stored in the atomic bonds of the constituent atoms of gasoline into heat energy that then drives a piston which moves the automobile. [2].The wide range of energy use can be broadly divided into three main economic sectors, Residential use (heating and cooling homes, lighting office buildings), Transportation (driving automobiles and moving machines) and Commercial use. The sources of energy can be broadly classified into two categories: the nonrenewable and the renewable forms of energy [3]. The use of biomass as one of the renewable resources to generate energy and power has positive environmental implications and creates a great potential to contributing considerably more to the renewable energy sector, particularly when converted to modern energy carriers such as electricity, liquid and gaseous fuels [4]. Biomass is available in a variety of forms and is generally classified according to its source (animal or plant) or according to its phase (solid, liquid or gaseous) [4, 5]. In order to generate electricity, biomass can be combusted, gasified, biologically digested or fermented, or converted to liquid fuels propelling a generator [6]. Several research institutions and international agencies, such as the National Centre for Energy Research and Development (NCERD), and the Energy Sector Management Assistance Program (ESMAP) administered by the World Bank both rated biomass as one of the cheapest available renewable energy resource for power generation [7].

The use of biomass has two main advantages: first is its nearly unlimited availability and second is the fact that it can be used without essential damage to the environment. In addition, biomass is a storable resource, inexpensive and has favorable energy efficiency. Biomass resources that are available in the country include: agricultural crops, agricultural crop residues, fuel wood and forestry residues, waste paper, sawdust and wood shavings, residues from food industries, energy crops, animal dung/poultry droppings and industrial effluent/municipal solid waste [8, 9, 10, 11].

This study highlights the energy potential of selected organic wastes with the ultimate aim of attracting research interests towards the use of biomass from agricultural produce and other readily available organic wastes to produce methane as is a cost-effective and ecofriendly alternative energy. The work proposes the utility of sawdust and cassava peels, co-digested with cow dung to generate biogas as a means of generating biogas, and as an ecofriendly method of disposing of organic wastes.

A. *Saw Dust*

ISBN: 978-988-14047-4-9
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Sawdust is a by-product of wood generated from the milling activities at wood based industries as wood is converted and used for different purposes. Sawdust is often treated as a waste product of wood operations. However, the use of sawdust as a co-substrate to cow dung to produce biogas as carried out in this work is one of the ways to control and utilize sawdust as a veritable source of renewable energy. The saw dust was obtained from local saw mills, and were pre-treated by soaking in water, before usage.

B. Cassava Peels

Cassava (Manihot esculenta) is a very important crop grown for food and industrial purposes in several parts of the tropics. The major limitation in the use of cassava for feeding livestock is its low protein content. The flour for example contains about 3.0% protein and the peels about 1.66% proteins. The tubers constitute about 20 to 25% starch but very limited quantities of protein, fats, vitamins and minerals. Because of the low protein and high cyanide content of cassava peels their use in animal feeding requires treatment for reduction of the cyanide content and a subsequent protein supplementation. Drying is the most popular practice used to reduce cyanide content of cassava and according to Ravindran (1991), sun-drying alone can eliminate almost 90% of initial cyanide content in cassava [12]. Soaking of cassava roots preceding cooking and fermentation can enable heightened extraction of soluble cyanide by removing approximately 20% of free cyanide in the fresh root after 4 hours [13]. The cassava peels were therefore soaked in water for about 72hours. The water was later drained off, while the cassava peels were sun dried before being grinded to increase the surface area in order to aid decomposition.

C. Cow Dung

Fresh Cow dung was obtained from abattoirs where cows are slaughtered for human consumption. It was evacuated from the intestine of slaughtered cattle. Basically, cow dung are of two kinds: the intestinal dung and the excrement (excreted) dung. The intestinal dung is the type removed from the intestine of cows slaughtered in the abattoirs for human consumption. It consists of undigested residues of consumed matters which is very fresh and contains the normal microbial floral as found in the rumen of cow. Excreted dung is the solid excrement by cow species. It consists of digested residues of consumed matter which has passed through the cow's gastrointestinal system [14]. For the purpose of this study, fresh intestinal cow dung were obtained from the Semi Mechanised Abbatoir, Bariga and the Oko-Oba Farm, Agege both in Lagos State, Nigeria.

II. ANAEROBIC CO-DIGESTION OF WASTES

Co-digestion is the simultaneous digestion of a homogenous mixture of two or more organic waste feedstock [15]. The positive interaction of the elements of the co-substrates more than often escalates the biogas yields of the anaerobic process because the complementary substrates supply the missing nutrients in individual substrate [6, 16]. The process of anaerobic co-digestion of waste products for the production of biogas can be divided into four major stages, namely: hydrolysis, acidogenesis, acetogenesis and methanogenesis. The digestion process begins with bacterial hydrolysis of the input materials that breaks down the insoluble organic polymers notable amongst which is carbohydrates and make them available for further digestion processes [17]. The detailed explanation is as summarized in Figure 1 below:

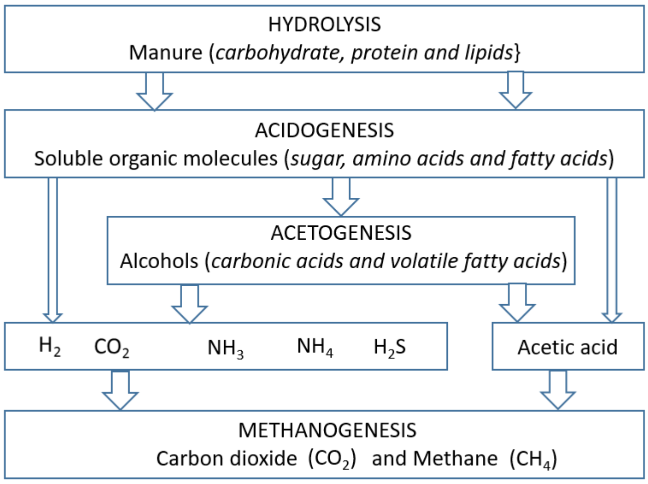
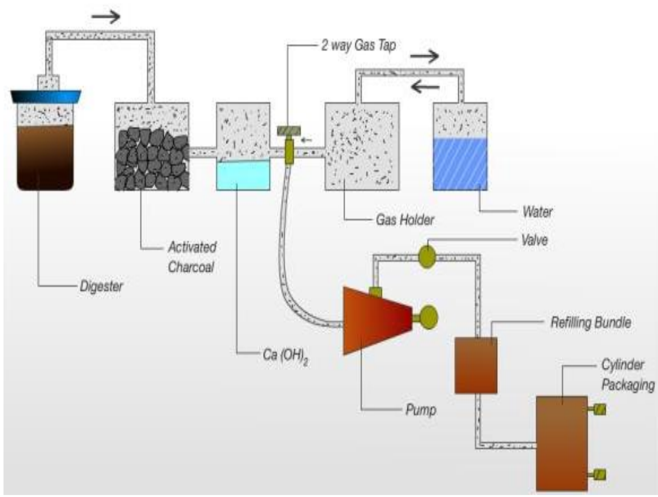


Fig 1: Stages of anaerobic co-digestion of organic wastes

III. METHODOLOGY AND MATERIALS

A. Materials

The materials used in setting up the digester are: activated charcoal, calcium hydroxide Ca(OH), gas holder tubes; water, adhesives (Abro 2000 Silicon Sealant, Epoxy Hardener and Super Glue), 50kg Portable Weighing Scale, 3 units of 20 litre white kegs, 3 units of 250mL laboratory beaker, 3 units each of 16-inch tri-cycle tubes, 6 units of 8mm industrial gas tap, 3 units of 8mm T- connector, 42 feet rubber hose, digital thermometer, PH meter, Bunsen burner and tripod stand. The above listed materials were connected as shown in Figure 2. All perforations were properly sealed and the whole system was air tight.



Source: Ajibola and Eniola, 2012

Fig 2: Schematic of the anaerobic digestion process

ISBN: 978-988-14047-4-9
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

A. Methodology

In this project, the methodology adopted is purely empirical. The slurry obtained from Cow Dung (CD), Saw dust (SD), Cassava Peels (CP), and water (W) were anaerobically digested in batch digesters A, B and C under mesophilic conditions in ratio 1:0:1:4, 1:1:0:4 and 1:0:0:2 respectively. The results obtained were analyzed to determine the slurry with the highest biogas yield. Biogas production was monitored daily by water displacement method. Figure 3 shows the initial setup of the experiment.

Loading of Digesters

The different substrates were weighed and mixed thoroughly in a water container. The mixtures were loaded into the 25-litres fabricated batch digesters. Each slurry was loaded to ¾ of the digester volume, leaving ¼ head space for gas collection. The digesters were properly sealed with the tightening lid locked to exclude air.

Determination of Quantity of Biogas Produced

The quantity of biogas produced daily in millilitres was obtained by downward displacement of water by the biogas on daily basis using a 25ml laboratory beaker. The amount of water displaced into the beaker corresponds to the volume of gas produced. The process was carried out for retention period of 20days. The experimental procedure enumerating the stages of the anaerobic digestion is as shown in Figure 3 below:

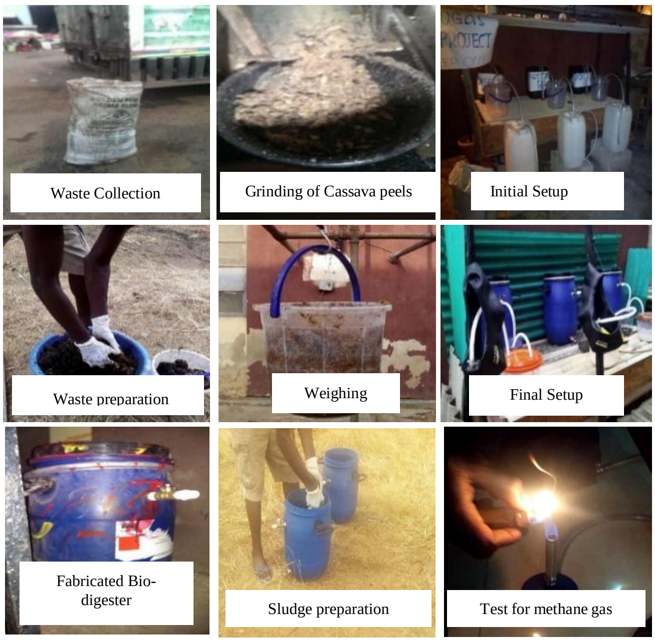


Fig 3: Stages of anaerobic digestion process

Combustion of Biogas

The combustibility of the biogas produced was determined using the Bunsen burner. The Bunsen burner was connected to the digester's valve (tap); with a hose, the valve was then opened to allow the flow of gas through the hose to the gas burner, after which it was ignited.

IV. Results And Discussion

The summary of the composites in Digester A, Digester B and Digester C were weighed. The total weight of the respective slurry formed, the days of commencement of biogas production by each composite and the total volume of biogas produced from each slurry in the various digesters are as contained in Table 1 below. And Table 2 is the comprehensive appraisal of the quantitative parameters of the experiment, namely: the retention period for the entire experiment, the average daily temperature of the immediate environment of the experimental setup, the daily volume of biogas from Digester A, Digester B and Digester C in millilitres, and the cumulative volume of the biogas produced by each of the aforementioned digesters.

TABLE 1
MIX RATIO OF ORGANIC WASTE IN DIGESTERS A, B AND C

Digester	A	B	C
Mix Ratio (CD:SD: CP:W)	2:0:1:6	1:1:0:4	1:0:0:2
(Waste: Water)	1:2	1:2	1:2
Cow Dung (kg)	4	3	6
Saw Dust	0	3	0
Cassava Peels	2	0	0
Water	12	12	12
Total weight of slurry	18	18	18
Gas Production (days)	4	2	2
Gas Volume in 20 days (mL)	60842	80238	77712

The study revealed a dramatic overturn in the production of biogas as the cumulative biogas production of Digester B containing the slurry of cow dung and saw dust as co-substrates surpassed that of Digester C containing cow dung as the sole substrate. This took place after the 13th day of the experiment even though daily production of the gas from Digester B had surpassed that of Digester C by the 6th day of the experiment. Biogas production from the composite of Digester A consisting of cassava peel and cow dung has been on the low ebb except on the 6th day of the experiment when its production level surpassed that of cow-dung/saw-dust slurry sparingly as shown in Figure 6.

TABLE 2
CUMULATIVE VOLUME OF GAS IN DIGESTERS A, B AND C

Average Daily Temp (°C)	Average Daily Temp (°C)	Cumulative volume in Digester (mL)		
		A	B	C
1	26.3	0	0	0
2	28.2	0	0	0
3	28.7	0	55	115
4	30.4	85	179	442
5	31.2	277	474	874
6	32.8	697	881	1468
7	28.2	1105	1526	1893
8	28.4	1557	2119	2333
9	33.5	2087	2789	2923
10	31.7	2593	3456	3537
11	30.6	3108	4096	4194
12	29.1	3598	4721	4802
13	33.7	4140	5486	5427
14	28.7	4593	6136	6041
15	26.5	5101	6739	6576
16	27.9	5623	7245	6930
17	29.5	6075	7813	7255
18	28.7	6423	8353	7470
19	28.2	6728	8838	7656
20	27.1	7052	9332	7776
		60842	80238	77712

ISBN: 978-988-14047-4-9
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Figure 4 compares energy potential in cassava peels/cow-dung as co-substrate (digester B) with that of the slurry of cow dung (digester C). The graphical plot shows a steep slope with an early production of biogas production in digester C containing the slurry of cow dung. This could be attributed to the microbial population and the surface area of cow dung which provides a medium for maximum activities of the extracellular enzymes and mass transfer of the anaerobes within the digester [18].

Digester C started producing biogas from the 2nd day, and it attained a local maximum on the 6th day before experiencing a sharp decline. This could be attributed to the temperature drop between the 6th and 7th day. According to Figure 6, digester B (saw-dust and cow dung) however, started producing biogas on the 3rd day and attained a local maximum on the 6th day. It maintained a steady rise before reaching a global maximum on the 13th day, while in digester C reached its local maximum on the 11th day (Figures 5 and 7). The downward slope after the 14th day in digester C indicates a sharp decline in the daily amount of biogas produced. Figure 5 and Figure 6 showed that digester A only experienced a gradual decline in biogas yield after the 16th day. There exist what seems as global minimum gas yield for the cassava peels/cow dung slurry of digester A that indicated that gas production may begin to rise in volume. The added cow dung (animal manure) lowered the C:N ratio of the cassava peels to value between 20/1 and 30/1 which makes the co-substrate ideal for anaerobic digestion [19, 20].

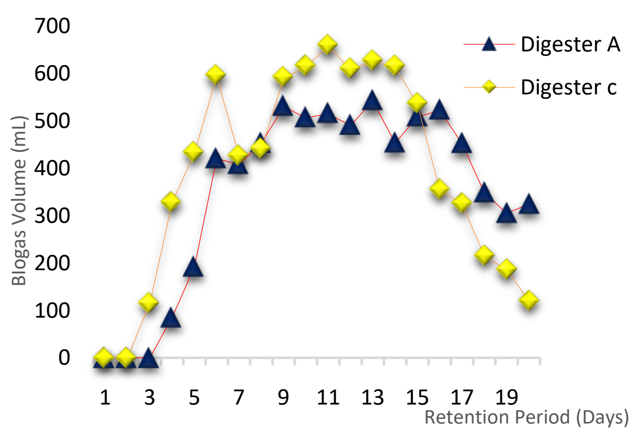


Fig 4: Comparative analysis of biogas production in Digesters A and C

The gradual decline in digester B compared with the sharp decline in digester C, can be attributed to the decrease in the microbial population in the cow dung. Digester B containing saw dust shows a potential rise between the 19th and 20th day due to unused energy still present in the saw dust. This implies that over a longer retention time, saw dust and cow dung might be more reliable for energy production and supply. The cow-dung was co-digested with saw dust to increase biogas-production by lowering the Carbon Nitrogen ratio. This is necessary since saw dust alone gives very poor results due to its lignocellulosic properties (high value of organic carbon and very low value of total nitrogen [21].

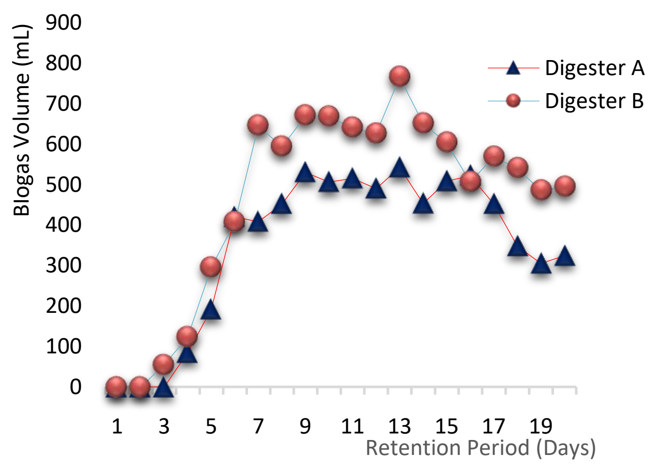


Fig 5: Comparing biogas production in Digesters A and B

Result obtained from figure 6 which compares biogas yield between digester B (CD: SD) and digester C (cow dung only). Both digesters started producing gas on the 2nd day, however, digester C (cow dung only), recorded a higher initial yield with 155ml of gas on the 2nd day compared with 55ml from digester B. This could be attributed to the less microbial population and high fat and fibre content of saw dust [18, 22], therefore degradation of the waste takes longer time.

Figure 6, compares digester A (CD:CP) with B (CD:SD). Digester B (cow dung only) started producing biogas from the 2nd day, and it attained a local maximum on the 7th day. Digester A containing cassava peels and cow dung didn't start producing biogas until the 4th day and reached a local maximum on the 6th day. It maintained a steady rise before reaching a global maximum on the 13th day, while digester B attained a local maximum production level on the 7th day.

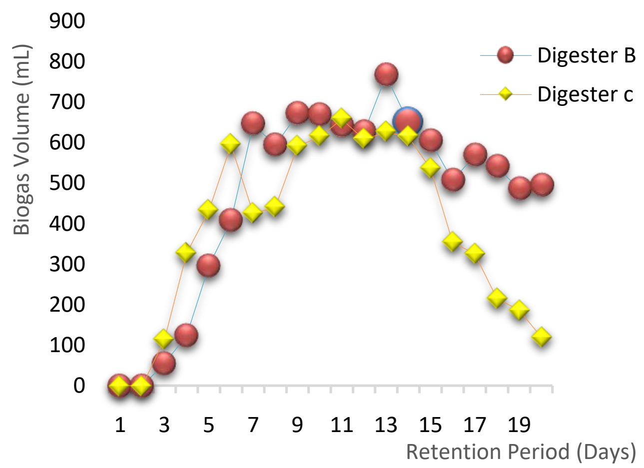


Fig 6: Comparative analysis of biogas production in Digesters B and C

Digest A which contained cassava peels and cow dung recorded the lowest yield. This could be due to traces of cyanide in the cassava peels, which underscores the unreliability of the soaking method in reducing the acidic content of cassava. The mixing ratio of 1:1 was used because it was noticed that biogas production decreased with increasing mixing ratio. The reason for this is that the higher quantity of peels in the mixture, the higher the cyanide content and the lower the volume of biogas produced due to the reduction in digestion activities.

Digester B containing saw dust and cow dung, therefore is a better mixing ratio for biogas production if there is no urgent need for biogas utilization. However, digester C containing only cow dung would be preferred if the biogas is required urgently.

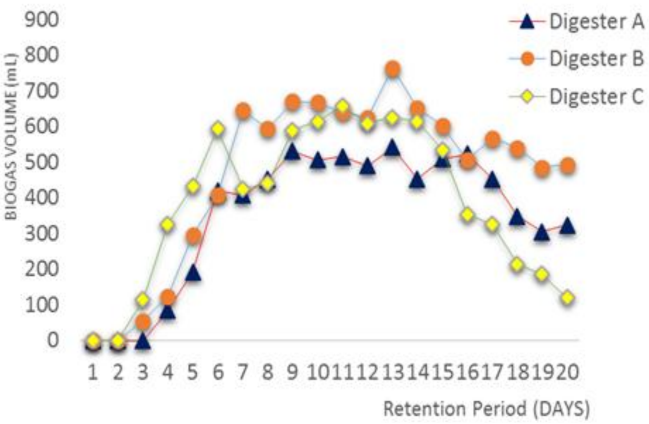


Fig 7: Comparing biogas production in Digesters A, B and C

According to Figure 7, it is clear that the co-substrate of cow-dung and saw-dust as contained in digester B has a better prospect of all the three asides its flourishing production level within the retention period. The slurry of cow-dung in digester C flourish over and above the content of digester B only for the first six days and that of A for fifteen days. However, the slurries in digesters A and B both show upward trend after nineteen days revealing rewarding prospect for future biogas production. To this end, it becomes imperative to expend resources more on the composites of cow dung rather than the monolithic slurry of cow dung. This research is in agreement with the work of Ajibola and Eniola (2012) and other such studies [3, 6, 17].

V. Conclusion

In this work, we have charted a course along which a dependable solution to the incessant power supply could be proffered and provided a sure springboard for researchers in the field of renewable energy upon which a veritable knowledge base could be built. From the result obtained in this project work, cow dung, saw dust and cassava peel have been established as excellent co-substrates. However, ratio 1:1 of CD:SD has been shown by empirical evidence to be the best mixing ratio if there is no urgent need for biogas. The equal quantity of the cow dung and saw dust in the digester, provided just sufficient bacteria that aided digestion of the wastes. The time lag and the cumulative biogas yield shows that the saw dust and cow dung is a better substrate mixture over cassava peels and cow dung on one hand, and cow dung on the other. Since the raw materials are available in abundance within the country, Saw-dust/Cow-dung mix could as well solve the energy for rural communities. Based on the enormous amount of saw dust being produced daily at sawmills, and with over 1,500 cattle slaughtered on daily basis in Lagos metropolitan alone, the availability of raw material is assured. While the degraded waste can also be used as biofertilizers. It is our hope that if results from this research effort is implemented, problems associated with power supply is solvable.

References

[1]. H.D. Young, R.A. Freedman and A. L. Ford 2012. Sears and Zemansky's University Physics. Addison-Wesley. San Francisco.

[2] G. B. Benedik and F. M. H. Villars 1973. Physics with Illustrative Examples from Medicine and Biology. Volume 1 Mechanics, Addison-Wesley, Reading. p. C-2.

[3] O. O. E. Ajibola and E. O. Suley, 2012. Cow dung – Water hyacinth sludge: a veritable source of renewable energy. *Journal of Sustainable Development and Environmental Protection*, 2(1), pp. 49-5

[4] IBEP, (2006), Introducing the International Bioenergy Platform, Food and Agriculture Organization of The United Nations, Rome, On line: http://esa.un.org/unenergy/pdf/FAO%20Bioenergy%20platform.pdf.

[5] U. P Onochie and S. A. Aliu 2016. Economic analysis on power generation from oil palm residues:a case study of NIFOR. *Int. J. Renew. Energ & Environ*. Vol.2, pp 202-210.

[6] J. Mata-Alvarez, S. Maclle, and P., L. 2000. Anaerobic Digestion of Organic Solid Waste. Review paper. An overview of research achievements and perspectives. *Bioresour. Technol.* 74: 3-16.

[7] E. B. Agbro and N. A. Ogie, 2012. A comprehensive review of biomass resources and biofuel production potential in Nigeria. *Research Journal in Engineering and Applied Sciences*. 1(3) 149-155.

[8] C. J. Nyachaka, D. S. Yawas and G. Y. Pam 2013. Production and performance evaluation of bioethanol fuel from groundnuts shell waste. *American Journal of Engineering Research*. 2(12), pp-303-312.

[9] A. S. Sambo (2008). Matching electricity supply with demand in Nigeria. International Association of Energy Economics; p. 32–6.

[10] Y. U. Ngiki, J. U. Igwebuike, S. M. Moruppa, (2014): Utilisation of cassava products for poultry feeding: a review. *Int. J. Sci. Tech*, pp. 48–59.

[11] M. Helmy, 2015. Promoting anaerobic digestion of municipal solid waste in Indonesia. International Solid Waste Association (ISWA'15) World Congress. Flanders, Belgium.

[12] V. Ravindran, 1991. Preparation of cassava leaf products and their use as animal feeds. Roots, Tubers, plantain and bananas in animal feeding, vol. 95, Food and Agriculture Organisation, Rome, Italy, pp. 111–125.

[13] O. O. Tewe, 1991. Detoxification of cassava products and effects of residual toxins on consuming animals D. Machin, S. Nyold (Eds.), Feeding Proceedings, the FAO expert consultation held in CIAT, Cal Columbia p. 621-625.

[14] K. C. Teo, and S. M. Tech, 2011. Preliminary biological screening of microbes isolated from cow dung in Kamper. *African Journal of Biotechnology*. **10** (9): 1640-1645

[15] E. M. Z. Canas, 2010. Technical Feasibility of Anaerobic Co-digestion of Dairy Manure with Chicken Litter and Other Wastes. Tennessee Research and Creative Exchange. Master Thesis.

[16] C. Steinwig, 2011. Interventions for successful recycling of nutrients and energy from food waste: How can Swedish municipalities overcome barriers for a sustainable food waste management system? M.Sc. Thesis. Lund University. Sweden.

[17] O. O. E. Ajibola, T. T. Fagbamila and O. J. Balogun 2016. Experimental investigation of energy potentials of kitchen organic waste. *Journal of Engineering Research*. Vol. 21, No. 1, pp.133 – 140.

[18] C. U. Ukonu, 2011: Optimization of Biogas production using combinations of saw dust and cow dung in a batch anaerobic digestion bioreactor, pp.

[19] B. A. Adelekan and A. I. Bamgboye, 2009. Comparison of biogas productivity of cassava peels mixed in selected ratios with major livestock waste types using selected mixing ratios of slurry, Afr. J. Agric. Res. Vol.4 (7); pp.571-577.

[20] B. A. Adelekan, 2012. Potentials of Selected Tropical Crops and Manure as Sources of biofuels. Dr. Sunil Kumar (Ed.), ISSBN: 978-953-51-0204.

[21] B. Deepanraj, V. Sivasubramanian, and S. Jayaraj. 2014. Biogas generation through anaerobic digestion process research. A Review. *Journal of Chemistry and Environment*, 18(5), pp. 80 – 93.

[22] E. E. Oguntibeju, 2016. Comparative analysis of the energy potentials in co-substrates from cassava peels, cow dung and saw dust. M.Sc. Thesis. Universityof Lagos, Nigeria.