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Non-Isothermal Devolatilization of Industrial and Chewing Sugarcane Bagasses

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ABSTRACT

The devolatilization is the first step of thermochemical processes and requires an in-depth understanding. In this paper, the devolatilization of industrial and chewing sugarcane bagasses has been investigated using thermogravimetric analyser (TGA). The devolatilization of industrial sugarcane bagasse (ISB) and chewing sugarcane bagasse (CSB) were related to its lignocellulose content (cellulose, hemicelluloses and lignin). The component compounds of bagasse exhibit three major mass loss peaks which decompose independently. The first and second mass-losses were associated with hemicellulose and cellulose degradation and are responsible for the appearance of the first peak and second peak with the temperature range of 180–254 °C and 250–317 °C respectively. Lignin degradation was observed to occur at a much higher temperature of 317–900 °C as denoted by the third peak. A comparative evaluation of the bagasse obtained from the two varieties of sugarcane shows that there was an overlap of TG-CSB over TG-ISB during hemicellulose decomposition which later separated with the emergence of cellulose decomposition. The thermal stability of bagasse decomposition was observed to increase in the following order: hemicellulose < cellulose < lignin. The result of TGA indicated that CSB has higher thermal stability than the ISB. The difference in the lignocellulose fraction provides an explanation for these differences. The percentage of cellulose and lignin content in CSB is greater than that of ISB with lignin content constituting a larger percentage of the difference. These experimental results help explain and predict the behaviour of bagasses in practical applications.

Keywords: Chewing Sugarcane; Industrial Sugarcane, Bagasse, TGA/DTG; lignocellulose

1. INTRODUCTION

Holistic utilization of agricultural produce and its resulting by-products in industrial transformation process has been widely acknowledged as a vital aspect of sustaining the environment and conserving the much needed economic resources (Dormo *et al.*, 2004). Sugarcane bagasse is an abundant agricultural waste produced as a by-product of sugarcane processing from sugar industries. In Nigeria, there are two main types of sugarcane; the industrial and chewing sugarcane. The chewing sugarcane is mainly consumed in its natural form for its sweetness in all communities in Nigeria (Ojehomon *et al.*, 1996). It is characterized with a purple colour and is known to be robust with less sucrose and much water. It is often softer than the industrial type with high ability to withstand drought (Ojehomon *et al.*, 1996). In Nigeria, the

chewing sugarcane accounts for 60% of cane production because of its domestic economic viability when compared to industrial cane (Gana, 2011). Chewing cane is in high demand due to high rate of public consumption which has led to the generation of enormous quantities of sugarcane fibre wastes that littered the major streets of most Nigerian cities. In addition to domestic consumption of this sugarcane in its natural form, it is processed into local brown sugar cakes referred to in Hausa language “Alewa and Mazarkwaila” (Gana *et al.*, 2009).

The industrial sugarcane is a major feedstock in sugar mills (Naidu, 1987). It is mainly used for the production of sugar and alcohol (Sun *et al.*, 2004). The stems of the crop are cut and transported from the field to sugarcane mills where they are crushed to produce sugarcane juice and sugarcane bagasse. The juice is subjected to evaporation until it is concentrated into sugar. The increase in the



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importation of raw sugar from Brazil with poor field practice and the need to conserve the nation foreign exchange have stimulated the Nigeria Government interest towards making concerted efforts to foster sugar production (Nzeka *et al.*, 2013). Privatization of sugar estates, improved field practices, out growers programme, and efficiencies of the factory and its boilers have generated large amount of bagasse. The continuous accumulation of these bagasse and its non-utilization by the industry presents an agricultural waste problem (Ouensanga, 1988). Sugarcane bagasse is a lignocellulosic plant's cell wall. It is mainly constituted of hemicellulose, cellulose and lignin, which act as a structural support (Idi *et al.*, 2011). The fraction of lignocellulose bagasse is dependent on the sugarcane variety, maturation, soil type or condition, amount of fertilizer applied and the condition harvesting (Lamb *et al.*, 1977). Generally, about 280 g of bagasse is generated from 1 tonne of sugarcane (Sun *et al.*, 2004). Sugarcane corresponds to approximately 40 wt% of the total stem mass (Sun *et al.*, 2004).

A number of possible biotechnological processing routes are available for the production of bio-products from agricultural waste (biomass). Among all products biofuel have been of great interest (Demo *et al.*, 2004). These technological schemes used to convert biomass to an alternative energy source include physical, biochemical, thermal and chemical technique (Abdullah, 2010). Thermochemical processes constitute alternative route for biomass utilization (Garba *et al.*, 2006; Abdullah, 2010 and Garba *et al.*, 2012). Because of its large potentials, it has the ability to become the main energy source in the closest future. Co-firing coal with biomass is a short time opportunity reaps from biomass advantages (Garba *et al.*, 2013). Gasification is a benign and efficient alternative for producing upgraded fuel from biomass (Prins *et al.*, 2003). Pyrolysis is all-round process for recovering fuel and chemical (Biagini *et al.*, 2006). Torrefaction is a fuel

upgrading process where raw biomass is heated in the temperatures of 200–300 °C under an inert atmosphere (Garba *et al.*, 2014).

Thermogravimetry Analysis (TGA) is an important means of obtaining key information about the vital characteristics such as reaction mechanism, thermal stability, phase transformation and essential data on specific temperature of the heterogeneous reactions taking place during pyrolysis (Abdullah, 2010). TGA comprise of main two components - Thermogravimetry (TG) and differential thermogravimetric (DTG) analyses. In TG, a continuous graph of mass change against temperature or time can be monitor while DTG is an approach performed by detecting the rate of mass loss.

Many researchers have studied thermal characteristics of different biomass materials (Munir *et al.* 2009). For instance Abdullah *et al.* (2010) carried out TGA study of rice husk and oil palm shell while Ouensanga (1988) investigated the thermal degradation of sugar cane bagasse and its components (cellulose and lignin) between room temperature and 700 °C under atmospheric condition (nitrogen, dry air, oxygen) using thermogravimetric analysis. Recently, Vanita *et al.* (2011) reported their findings on thermal decomposition of bagasse from different locations using thermogravimetry analysis.

The quantum of sugarcane bagasse generated in Nigeria call for a concerted research effort towards its proper evacuation by converting these waste to energy. As far as the author's knowledge could go there are no documented literatures on the thermal behaviour of sugarcane bagasse originating from Nigeria so as to establish its potential for energy generation. This paper focuss on the study of thermal behaviour of sugarcane bagasse originating from Nigeria. In this work, thermal characteristics of industrial and chewing sugarcane bagasses was studied in an inert atmospheres, leading to a comparative evaluation of the



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thermal behaviour in order to explore their energy potential.

2. METHODOLOGY

2.1. Materials

Two sugarcane bagasse from two different varieties of sugarcane namely; Chewing Sugarcane and Industrial Sugarcane were employed in this work. Chewing sugarcane bagasse (CSB) was collected from Wuya Kpansanako Community of Bida, Niger State. Industrial sugarcane bagasse (ISB) was collected from sugar mills located in Bacita, Kwara State, Nigeria. Figure 1 shows the pictorial view of the samples. The samples were not washed to remove the residual sugars because in an industrial setting the sample will be used as received. These samples were then crushed to obtain a particle size less than 250 μm and were kept in air tight bins prior to analysis.



Figure 1. Bagasse Sample (a) CSB (b) ISB

2.2. Determination of Lignocellulose Fraction

Following Van Soest's Fibre method (van Soet *et al.*, 1963), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were measured. The NDF was determined by refluxing bagasse ash for 1h in a neutral buffered detergent solution. The residue corrected ash which is also the total cell (NDF = hemicelluloses + cellulose + lignin) is the NDF. ADF (ADF% = lignin + cellulose) was determined by refluxing the NDF sample in a solution of cetyl ammonium bromide (CTAB) in 2M sulphuric acid. Hemicelluloses dissolves and was removed by filtration. ADL was measure by further treating ADF

sample with strong acid (72% sulphuric acid) to dissolve the cellulose in order to determined the lignin. The hemicellulose content was derived by subtracting NDF values from ADF values while cellulose content was derived by the difference between ADF and ADL.

2.3. Thermogravimetry Analysis

A TG / DTG non-isothermal test was carried out using Perkin Elmer thermogravimetric analyser (TGA-4000) for the two samples of bagasse: ISB and CSB. The TGA equipment was purged with oxygen gas to simulate conventional combustion with flow rate of 20 ml/min and heating rate of 10 $^{\circ}\text{C}$ /min, the analysis was performed using a temperature scan range 30 to 900 $^{\circ}\text{C}$. The weight of empty crucible was zero and latter load with sample to be analysed.

2.4 Fourier Transform Infrared Spectroscopy Analysis

The FTIR spectra of bagasse samples were obtained using SHIMADZU Series FTIR Spectrophotometer, 400 mg samples of potassium bromide containing about 5 mg of bagasse powder were prepared and subjected to analysis.

3. RESULTS AND DISCUSSIONS

The decomposition profiles as shown by thermograms from TGA reflects characteristic parameters essential for the understanding of the thermal behaviours of a fuel (Munir *et al.*, 2009). Different region can be distinguished from the thermograms. These regions represent the beginning and the ending of the derivative of thermogravimetric curve (DTG) which shows the breakdown of organic matter in the samples under inert atmosphere and therefore it is a reflection of the combustion of the release volatiles during partially decomposition organic materials (Idi *et al.*, 2011).



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Figure 2 and 2 shows the weight loss curve (TG) and derivative thermogravimetric (DTG) evolution profiles of ISC and CSB samples as a function of temperature using heating rate of 10 °C/min. Table 1 shows the proximate and thermal properties of the ISC and CSB samples. The thermal degradation can be divided into three stages; moisture drying, main devolatilisation and continuous slight devolatilisation (Munir *et al.*, 2009). The Stage I is often attributed to dehydration of water (Idris, 2010). The TG and DTG curves in Figure 2 show that ISB dehydration begins at room temperature up to approximately 180 °C which corresponds to the first peak in the DTG evolution with a mass loss of about 10%. Figure 3 shows CSB dehydration begins at slight higher temperature approximately 186 °C with corresponding lower mass loss of approximately 8 %. These values were also indicated in Table 1. The mass loss observed in ISB sample shows quantitative agreement with 10 % for central Pakistan but greater than 6.5 % of South African bagasse sample as reported by Munir *et al.* (2009) and Akinwale *et al.* (2011) respectively. In Stage II, between temperature ranges of 180-250 °C (for ISB in Figure 2) and 186-255 °C (for CSB in Figure 3), a negligible weight loss were observed. This stage is followed by the start of devolatilization which is characterized by the sudden weight loss. The negligible weight loss before the start of devolatilization can be attributed to the removal of bound moisture and the start of polysaccharide hydrolysis (Roque-Diaz, 1985, Mansaray 1999). In the third stage, there is no obvious weight loss observed beyond temperature of 500 °C. Nevertheless, the ISB and CSB samples continue to decompose until beyond temperature of 900 °C with maximum decomposition at temperature of approximately 906 °C.

Table 1: Characteristics of the thermogravimetric experiment under N₂ conditions.

Sample	MC (%)	VM (%)	AC (%)	T _p	T _o	Degradation Temperature range (°C)
CSB	7.6	12.1	4.92	228	210	186 - 254
		2		297	254	254 - 317
		14.6		351	341	317 - 472
ISB	10.2	7.30	3.42	235	213	180 - 250
		10.5		283	283	251 - 318
		14.7		353	344	318 - 460

The elemental analysis of raw biomass is the starting point in establishing the suitability of a given solid fuel to be burned in a furnace from the thermal behaviour point of view (Garba *et al.*, 2012). The high mineral content in bagasse would have a measurable effect on the thermal degradation rate. Both samples of ISB and CSB were subjected to XRF analysis and the results are shown in Table 2. The CaO and Fe₂O₃ content may be particularly important. CaO(s) is refractory in character and it will raise the thermal stability (Mansaray *et al.*, 1999). Consequently CSB with higher Ca content (80% CaO compared with 76% CaO for ISB) show higher stability than the ISC.

Table 2: Chemical analysis of bagasse samples.

Oxide (%)	ISB	CSB
SiO ₂	14.22	12.21
Al ₂ O ₃	2.51	1.72
TiO ₂	0.48	0.40
MgO	0.34	0.3
MnO	0.20	0.19
CaO	76.11	80.01
Na ₂ O	1.02	0.98
K ₂ O	2.2	2.31
Fe ₂ O ₃	3.0	1.71



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P ₂ O ₅	0.012	0.11
BaO	0.01	-

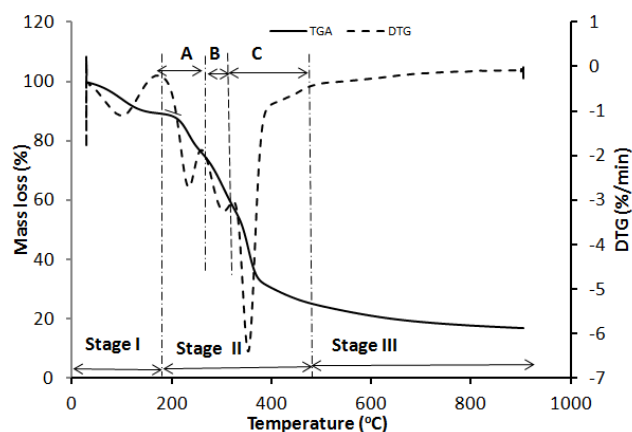


Figure 2. Thermal property of industrial sugarcane bagasse (ISB)

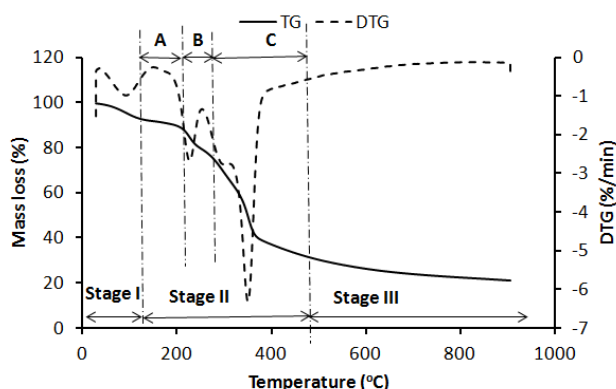


Figure 3. Thermal property of chewing sugarcane bagasse.

Lignocelluloses biomass are majorly composed of hemicelluloses, cellulose and lignin (Shafizadeh, 1982). The Stage II of weight loss exhibits three distinctive regions A, B, and C as depicted Figures 2 and 3. Region A, ranging from a temperature of 180-254 °C and region B from a temperature of 250-317°C were found to be similar to the curves of decomposition of hemicelluloses (Wang *et al.*, 2011; Nola *et al.*, 2010) and cellulose (Wang *et al.*, 2011; Nola *et al.*, 2010), whereas region C which is the decomposition at higher temperature is thought to be

due to decomposition of the complex and/or aromatic structures such as lignin (Idris *et al.*, 2010).

The small peak in A shown in Figures 2 and 3 are indication of lower stability of this hemicellulose when compared with the B (cellulose). The component C (lignin) shows the main peak at temperature range of 317-900 °C. Lignin degradation occurs gradually over a wide temperature range due to its cross link and aromatic nature resulting in broader peak (Fahmi *et al.*, 2007).

Onset (T_o) and peak temperatures (T_p) are important tools in knowing thermal stability of the fuel (Daniela *et al.*, 2011 and Bao-Guo *et al.*, 2006). The former refers to the temperature when weight loss just begins, while the latter to the temperature of the maximum rate of decomposition.

Figure 2 shows the onset and peak temperatures for degradation of the sample. The onset temperatures for hemicelluloses (T_{o1}), cellulose (T_{o2}) and lignin (T_{o3}) are 213, 283 and 345 °C respectively. Low onset temperature means the component is easier to degrade. Hemicellulose is easily susceptible to heat and less resistance to degradation (Bridgeman *et al.*, 2008). Whereas lignin degradation is more resistance and therefore large amount of heat is required. Figure 4. TG and DTG curves of industrial sugarcane bagasse (ISB) and chewing sugarcane bagasse (CSB).

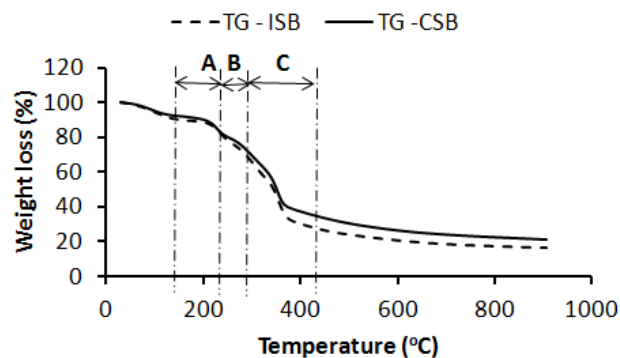


Table 2. Lignocellulose fraction of bagasse



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Bagasse	Cellulose	Hemicellulose	Lignin
ISB	38.8	29.4	21.7
CCB	39.2	26.1	24.1

Figure 4 gives a comparison of the TG-DTG profiles for ISB and CSB. It is seen that the TG-CSB lapped over TG-ISB during hemicelluloses decomposition but separated at the emergence of cellulose (B) decomposition and the difference become more apparent during lignin decomposition. This indicated that the thermal stability increase in the order: hemicellulose < cellulose < lignin. The reason for this relatively higher thermal stability of the lignin is probably due to the substantial percentage of lignin in CSB. The difference in the lignocelluloses fraction (Table 2) provides an explanation for these differences. The percentage of cellulose and lignin content of CSB is greater than that of ISB with lignin content constituting larger percentage of the difference.

FTIR spectroscopic investigations provide information on the natural polymer functional group. FTIR spectrum of ISB and CSB were displayed in Figure 3 (a) and (b) respectively. There is a broad band at 3385 cm^{-1} , which is characteristic for the OH-stretching of cellulose and this band gives good information about the hydrogen bonds formation. There is also side - band at 2923 cm^{-1} which represents the C-H stretching of cellulose. The peak at 1634 cm^{-1} , 1040 cm^{-1} and 407 cm^{-1} assign to C=C stretching of aromatic ring in lignin, C-H deformation of lignin and -COO vibration of acetyl groups in hemicelluloses, respectively. In FTIR spectra, lignin appears in between cellulose and hemicelluloses. This revelation is corroborated by the ample evidence in literature of numerous investigators (Idi *et al.* 2011; Uma *et al.*, 2012) that lignin is embedded in the

hemicellulose and cellulose structure to strengthen the cell wall of plant. ISB exhibit similar wavelength pattern to CCB except at wavelength between $500 - 400\text{ cm}^{-1}$ it shows narrower band. CSB exhibited higher % transmittance.

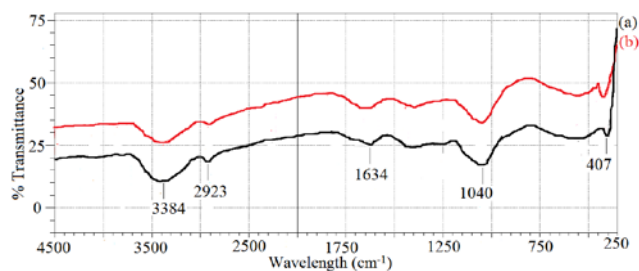


Figure 4. FT-IR Spectra of (a) ISB and (b) CSB.

4. CONCLUSION

Devolatilization of industrial and chewing sugarcane bagasses using TGA have been presented. The devolatilization of bagasse were related to it cellulose, hemicelluloses and lignin which pyrolyse independently. The first, second and third mass-loses were associated with hemicelluloses, cellulose and lignin degradation and thermal stability of bagasse decomposition was observed to increase in the following order: hemicellulose < cellulose < lignin. A comparative evaluation of the bagasse obtained from the two varieties of sugarcane shows that chewing sugarcane bagasse is more thermally stable than industrial sugarcane bagasse.

REFERENCE

- Abdullahi, S. S., Yusuf, S. N., Ahmad, M. M., Ramli, A. and Ismail H. (2010) "Thermogravimetry study on pyrolysis of various lignocellulosic Biomass for potential Hydrogen production, *International Journal of chemical and Biological Engineering* Vol. 3 No. 3, pp. 137 – 141.
- Biagini, E., Fantei, A., Tognotti, L., (2006) "Effect of the heating rate on the devolatilization of biomass residues" *d. Eng. Chem. Res.* Vol.45, No.13, pp.4486 - 449.
- Bridgeman, T. G., Jones, Shield, J. M., I, Williams, P.T. (2008) "Torrefaction of reed canary grass, wheat straw and willow to



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- enhance solid fuel qualities and combustion properties”, *Fuel* 87 pp. 844 – 856.
- Dormo, N., Belati-Bako, K., Bartha, L., Elorestein, U, and Gubiczaan, h., (2004) “Manufacturals of an environment – safe biolubricant from fuel iol by enzymatic esterification in solvent free system”, *Biochemical Engineering Journal*, Vol. 21, pp. 229 – 234.
- Gana, K. A., Shebayan, J. A. Y., Ogunlela, V. B., Odion, E. C., Imolehin, E. D., (2009) “Path coefficient analysis on growth parameters of chewing sugarcane as affected by fertility rates and weed control treatments at Badeggi, Nigeria”, *Agricultural tropica et subtropica*, Vol.42, pp.1.
- Gana, A. K., (2011a) “Appropriate method for organic manure application for higher sugarcane yield in Nigeria”, *Journal of Agricultural Technology*, Vol.7, No.6, pp. 1549-1559
- Garba, M., U., Alhassan, M., Kovo, A. S., (2006) “A Review of Advances and Quality Assessment of Biofuels” *Leonardo Journal of Sciences*, pp.167 - 178.
- Garba, M., U., Ingham, D., B., Ma, L., Porter, R., T., J., Pourkashnian, M., Tan, M., H., Z. and Alan Williams, (2012) “ Prediction of Potassium Chloride Sulphation and Its Effect on Deposition of Biomass-Fired Boilers” *Energy & Fuels*, Vol.26 No.11, pp.6501 - 8.
- Garba, M., U., Oloruntoba, J. M., Isah, A. G., Alhassan, M., (2015) “Production of Solid Fuel From Rice Straw Through Torrefaction Process”, *International Journal of Science and Engineering Investigations* Vol.4 No.37, pp.1 – 6.
- Idris , S. S., Abd Rahman, N., Ismail, K., Alias, A. B., Abd Rashid, Z., (2010) “Investigation on thermochemical behaviour of low rank Malaysian coal,oil palm biomass and their blends during pyrolysis via thermogravimetric”, *Bioresource Technology*, Vol.101, pp. 4584 – 4592.
- Lamb, B., W., Bilger, R., W.,(1977) “Combustion of bagasse: literature review” *Sugar Technol.* Vol.4, pp.89 – 130.
- Mansaray, K .G., Ghaly, A. E., (1999) “Determination of kinetic parameters of rice husksin oxygen using thermogravimetric analysis”, *Biomass and Bioenergy* Vol.17 pp.19 – 31.
- Ma., B., Li., X., Xu, L., Wang, K., Wang, X. G., (2006) “Investigation on catalyzed combustion of high ash coal by thermogravimetric analysis”, *Thermochimica Acta* Vol.445, pp.19 – 22.
- Munir, S., Daood , S. S., Nimmo, Cunliffe , W., A. M., Gibbs, B.M. (2009) “Thermal analysis and devolatilization kinetics of cotton stalk, sugar cane bagasse and shea meal under nitrogen and air atmospheres”, *Bioresource Technology* 100, pp. 1413 – 1418.
- Naidu, K. M. (1987) “Potential yield in sugar cane and its realization through variety improvement” sugarcane varietal improvement. Sugarcane Breeding Institut, Coimbatore, India, pp. 1 – 17.
- Nola, G. D., Jong, W. D., Spliethoff, H., (2010) “TG–FTIR characterization of coal and biomass single fuels and blends under slow heating rate conditions: partitioning of the fuel-bound nitrogen”, *Fuel Process Technol.* Vol.91, pp.103 – 15.
- Nzeka, U.,Olaito, P., (2013) Annual Sugar Report for Nigeria 2013, *Sugar Annual*, pp. 2 – 4.
- Ojehomon, V. E. T., Busari, L. D., Ndarubu, A. A., Gana, A. K and Amosun, A., (1996) “Production practices and costs/returns analysis of traditional chewing cane production in Nigeria”, *WAFSRN Journal* Vol.6, No.2, pp.14 - 22.
- Prins, M., J., Ptasinski, K., J., Janssen F., J., J. G., (2003). “From coal to biomass gasification: comparison of thermodynamic efficiency” In: Houbak, N., Elmegaard, B., Qvale, B., Moran, M., J., editors. Proceedings of 16th Int. Conf. on Efficiency, Costs, Uma M. C., Obi, K., Muzenda, E., Guduri, B. R., & Varada R. A. (2012) “Extraction and characterization of cellulose microfibrils from agricultural residue – Cocos nucifera L”. *Biomass and Bioenergy*, Vol.46, pp. 555 - 563.
- Roque-Diaz, P., University, C., Villas, L.C.V., Shemet, V.A., Lavrenko, V.A., (1985) “Studies on thermal decomposition and combustion mechanism of bagasse under non-isothermal conditions”, *Thermochimica Acta* Vol.93 pp. 349 – 352.
- Shafizadeh, F. (1982) “Introduction to pyrolysis of biomass”, *Journal of Analytical and Applied Pyrolysis*, No. 3, pp. 283 – 305.
- Sun, J. F., Sun, R. C. and Su Y. Q., (2004) “Fractional extraction and structural characterization of sugarcane bagasse hemicelluloses”, *Carbohydrate polymers* Vol.56: pp. 195 – 204.
- Van Soest, P. J., (1963) “The use of detergent in the analysis of fibrous feed II: A rapid method for the determination of fibre and lignin”, *J. Assoc off Agri Chem*, Vol.46, pp. 829 - 835.
- Vanita, R. M., William, O. S., Doherty, Ray L. F., and Pyam M., (2011) “Thermal Decomposition of Bagasse: Effect of Different Sugar Cane Cultivars” *Ind. Eng. Chem. Res.* Vol.50, pp.791 – 798.
- Wang, C., Wu, Y., Liu, Q., Yang, H., Yin, F., (2011) “Analysis of the behavior of pollutant gas emissions during wheat straw/coal cofiring by TG–FTIR”, *Fuel Process Technol.* Vol.92, pp.1037 – 41.