An Overview of Lignocellulose in Twenty (20) Local Government Areas of Bauchi State

[1]Mustapha D. Ibrahim and [2]Ahmad Abdurrazzaq
[1]Department of Chemical Engineering,
Abubakar Tafawa Balewa University,
Bauchi, Bauchi State, Nigeria
[2]Department of Chemical Engineering Technology,
Federal Polytechnic Mubi,
Mubi, Adamawa State, Nigeria
[1]E-mail: amibrahim2007@gmail.com, [2]E-mail: areizzunni@gmail.com

ABSTRACT
In the past few decades, there has been an increasing research interest in the value of lignocellulosic material. Lignocellulose biomass abundant holds remarkable high potentials that will go a long way in solving environmental, domestic and industrial problems if harnessed. The overview looked into only six (6) types of lignocellulose which comprised of sugar cane bagasse, corn stover, groundnut shell, sorghum residue, millet residue, and rice straw in Bauchi State. Research method adopted was by analysis of variance and percentile. The quantity of lignocelluloses studied i.e. Sugarcane bagasse, corn stover, groundnut shell, millet residue, sorghum residue and rice straw were found to be (936.7; 539,079.9; 144,352.0; 784,419.5; 905,370.6; and 73,335.5) tones/annum respectively. However, lignocellulose as a source of bioenergy in form of ethanol, the findings further revealed the estimated quantity of ethanol from sugarcane bagasse, corn stover, rice straw, sorghum, groundnut shell and millet to be at 142,462.7; 78,317,527.9; 9,339,055.9; 147,973,770.9; 18,022,347.2; and 62,322,129.3 liters/annum respectively.

Keywords: lignocellulose; production capacity; energy; biomass; Bauchi

INTRODUCTION
Bauchi State; a state located between latitudes 9° 3´ and 12° 3´ north and longitudes 8° 50´ and 11° 0´ in the north-eastern part of Nigeria has a total land area of 49,119 km^2 representing about 5.3% of the country's total land mass and extents two distinct vegetation zones, namely the Sudan savannah and the Sahel savannah. The Sudan savannah type of vegetation covers the southern part of the state with the vegetation getting richer and richer towards the South. The Sahel type of savannah becomes manifest from the mid of the state as one moves from south to northern part of the State. The characteristics of this type of vegetation comprise of isolated stands of thorny shrubs. On the other hand, the southern part of the state is mountainous as a result of the continuation of the Jos-Plateau, while the northern part is generally sandy. The rainfall in Bauchi State ranges between 1300mm per annum in the south and 700mm per annum in the extreme North. Moreover, In addition to the rains, the state is watered by a number of rivers and dams which include Gongola and Jama'are rivers, Gubi and Tilden Fulani Dams respectively. All these provide necessary conditions that support agriculture. However, there are twenty (20) Local Government Areas in Bauchi State, namely: Alkaleri, Bauchi, Bogoro, Dambam, Dambam, Darazo, Dass, Gamawa, Ganjuwa, Giade, Itas/Gadau, Jamaáre, Katagum, Kirfi, Misau, Ningi, Shira, Tafawa Balewa, Toro, Warji and Zaki. (bauchistate.gov.ng)

Bauchi state Local Government Areas agricultural production is characterized by large number of scattered small scale producers employing traditional manual tools based on rain-fed crops but providing the major food needs of their locality. Farming systems vary with the ecological zones of the State. However, the study acknowledged that the agricultural produce were meant mainly for human consumption, hence only the residues were considered for this finding.

Agricultural residues are organic materials produce as byproduct during the harvesting and processing of agricultural crops. Agricultural residues which are produced at the time of harvest are primary or field based residues while those produced along with the product during processing are secondary or processed based residues. Agricultural residues are heterogeneous, varying in bulk density, moisture content, particle size and distribution depending on the mode of handling. They are usually fibrous, low in nitrogen and vary with geographical location, (Simonyan and Fasina, 2013). Some of the field residues are used as fertilizer, for erosion control and as feed for livestock. Close to 45% of the residue are however burnt on the farm site before the start of the next growing season.

LIGNOCELLULOSE

Lignocellulosic material is mainly composed of plant cell walls, with the structural carbohydrates cellulose and hemicellulose and heterogeneous phenolic polymer lignin as its primary components. However, their content varies substantially, depending on the species, variety, climate, soil fertility and fertilization practice. (Irshad et al., 2013)
Table 1 shows the typical chemical compositions of all these three components in various agricultural residues (such as corn Stover, sugarcane bagasse and rice straw lignocellulose materials) that vary in composition due to the genetic variability among different sources.

Table 1: Percent composition of lignocellulose components in various lignocellulose materials

Lignocellulose Material	Lignin	Hemicellulose	Cellulose
		X	***Y***
	(%)	(%)	(%)
Sugarcane bagasse	20	25	42
Corn Stover	19	26	38
Rice straw	18	24	32.1
Sorghum	21	27	45
Groundnut shell	30-40	25-30	25-30
Millet	10-30	25-50	25-40

(Tanzila et al, 2014)

Cellulose is the principle component of lignocellulose biomass; it is a homopolysaccharide compose of repeating β-D-glucopyranose units responsible for mechanical strength and chemical stability to plants with its concentration ranges from 40 to 50% of dry weight. Hemicellulose is less complex, it is a heteropoly saccharide composed of pentoses (D-xylose and D-arabinose), hexoses (Dmannose, D-glucose and D-galactose) and sugar acids with concentration in lignocellulosic biomass is 25 to 35% and it is easily hydrolysable to fermentable sugars. Lignin is the third major component of lignocellulosic biomass, it is a complex polymer of phenyl propane (*p*-coumaryl, coniferyl and sinapyl alcohol), it acts as cementing agent and an impermeable barrier for enzymatic attack and its concentration ranges for 20 to 35%. (Bishnu et al., 2011)

The distinctive feature of plant cell walls is their two-part structure, as illustrated in Fig. 1. A primary cell wall is developed with cell division, and enlarged during cell growth to a fiberglass-like structure, with crystalline cellulose micro fibrils embedded in a matrix of polysaccharides such as hemicelluloses. (Xin-Qing et al., 2011)

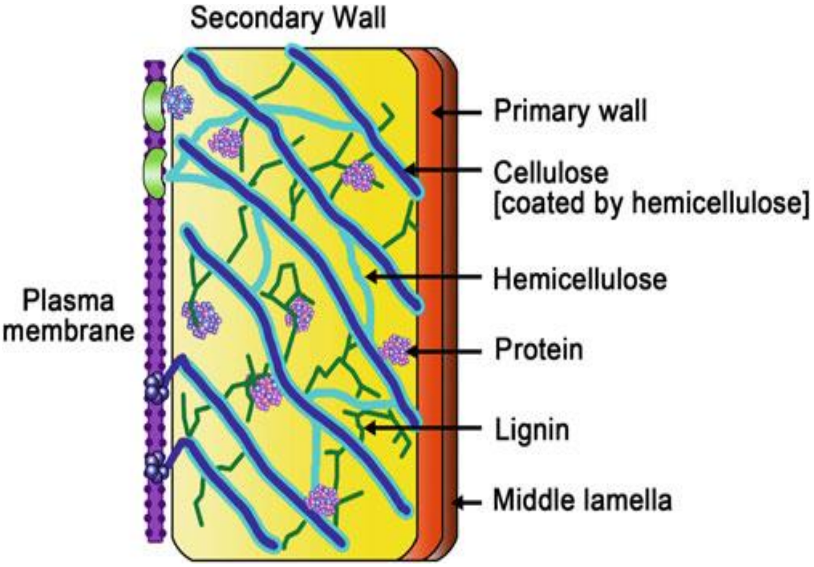


Figure 1: Schematic diagram of plant cell walls (Xin-Qing et al., 2011)

CLASSIFICATION OF LIGNOCELLULOSIC MATERIAL

In other to acknowledge lignocellulose materials it is important to classify lignocelluloses which are of different sources, hence, are as follows. (Maha, 2004)

- Woody Biomass
  - Forest residues
  - Wood waste
- Non-Woody Biomass
  - Agricultural residues
    - Straws (wheat, barley, rice)
    - Bagasse (sugarcane, sweet sorghum)
    - Stover (corn, milo)
- Organic Waste
  - Animal waste
  - Sawage sludge

IMPORTANCE OF LIGNOCELLULOSE AS BIOMASS

In Pulp and Paper Industry

Generally, lignocellulose biomass serves as the feedstock for pulp and paper industries. (Wikipedia.org)

As Biofuel

Large magnitudes of lignocellulose biomass resources are available as potential candidate that are convert-able into high value bio-products like bio-ethanol/bio-fuels. The detailed step by step information on the conversion of lignocellulosic biomass into fuel ethanol is illustrated in Figure 2.

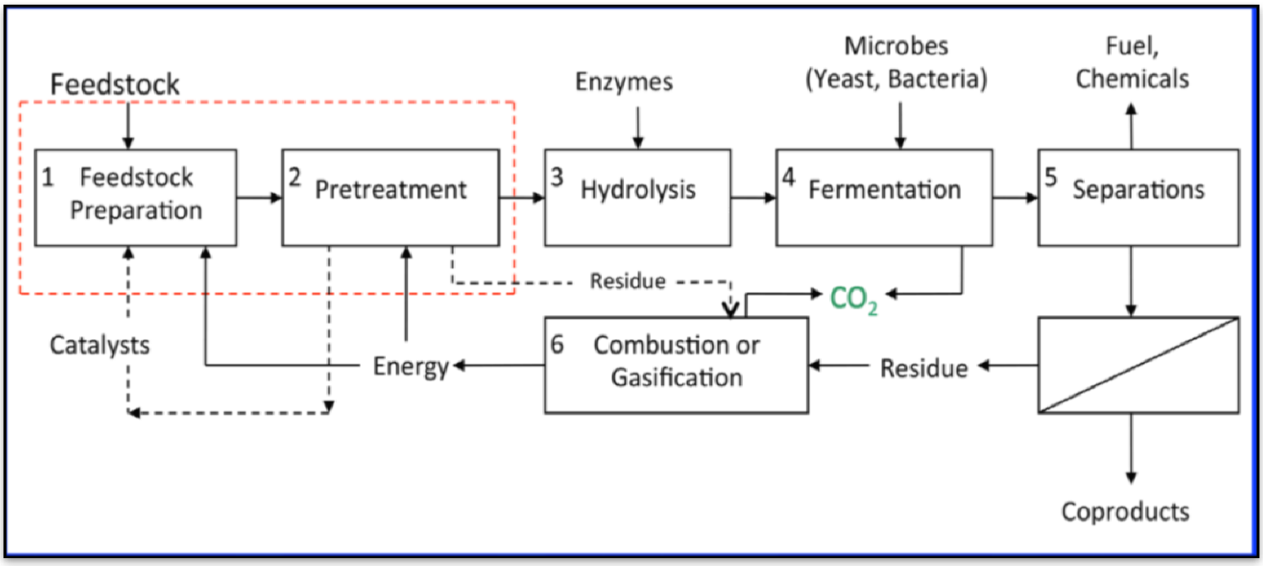


Figure 2: Flow Chart Conversion of Lignocellulosic material to Fuel (U.S. DOE, 2015)

The basic unit operations in a bio-refinery are (1) feedstock preparation, (2) pretreatment, (3) hydrolysis, (4) fermentation, and (5) separations (e.g., distillation or membrane separation and concentration of unfermented components by evaporation). Lignin is recovered either before or after fermentation and then gasified or combusted (6), making the process energy self-sufficient. Steps (3) and (4) are combined in processes where cellulose hydrolysis and fermentation occur simultaneously. Dilute acid, liquid hot water, and steam explosion pretreatments (2) result in process flows depicted by solid lines. Pulping processes and alkaline pretreatments extract a significant amount of lignin before the hydrolysis and fermentation steps [dotted line from step (2)], with pretreatment catalysts recycled to the beginning of the process (1). Lignin in excess of what is required for energy generation may be further processed into chemicals and drop-in biofuels. (U.S. DOE, 2015)
The ever increasing costs of fossil fuels and their greenhouse effects are a major concern about global warming. Therefore, all these issues are creating a core demand to explore alternative cheaper and eco-friendly energy resources. Hamelinck et al (2005) and Lin et al (2006)

METHOD

In view of the study, findings were carried out on six specific but not the least lignocellulose biomass around the twenty (20) LGA of the State. The specified lignocelluloses include:

- Millet residue
- Sugar cane bagasse
- Cone Stover
- Rice straw
- Grondnut shell
- Sorghum residue

Field survey was conducted under 2014 annual rainy season harvest (excluding irrigation activities) of the 20 local government areas in Bauchi State. During the field experiment average farm land of three hectares was considered at two different locations within the countryside of each LGA for each lignocellulose sample.

Data collected for the findings were quantity (capacity production) and farm size (total area of production). The data retrieved was subjected to variance, percentile and energy content analysis. Majors and minors were further used for means separation.

RESULTS

Table 2: Production Capacity of Lignocelluloses per Local Government Area, 2014 Season.

	LOCAL GOVERNMENT AREA	Alkaleri	Bauchi	Bogoro	Dambam	Darazo	Dass	Gamawa	Ganjuwa	Giade	Itas/Gadau	Jamaáre	Katagum	Kirfi	Misau	Ningi	Shira	Tafawa Balewa	Toro	Warji	Zaki
Type of Lignocellulose	Sugarcane bagasse	117.3	0.5	8.9	0.1	0.4	9.8	0.4	0.6	0.1	0.1	0.4	0.1	48.9	0.1	0.6	0.1	22.4	136.9	0.03	0.1
	Corn Stover	475.3	295.5	72.8	95.2	49.1	42.8	266.4	81.8	6.1	12.6	4.3	12.9	188.4	10.8	74.6	11.7	201.3	556.7	10.2	13.4
	Rice straw	50	33.9	8.4	0.2	1.9	4.9	0.5	3.3	0.1	0.3	0.1	0.3	21.6	0.2	3.1	0.2	23.1	63.4	0.4	6.3
	Sorghum residue	141.2	87.8	21.6	54.3	150.4	12.7	145.5	251.5	34.5	69	24.7	71.5	55.9	61.6	231.8	66.6	59.8	164.1	32.1	73.9
	Groundnut shell	8	5	1.3	7.1	52.8	0.7	18.9	7.4	4.2	9	3.2	9.2	3.2	8	108	8.7	3.5	9.5	11.1	9.6
	Millet residue	13.5	8.4	2.1	74.8	35	1.2	200.5	59.1	47.6	95.2	33.9	98.6	5.3	84.9	54	91.8	5.7	156.6	7.3	101.9

Production Capacity (tones/Ann)

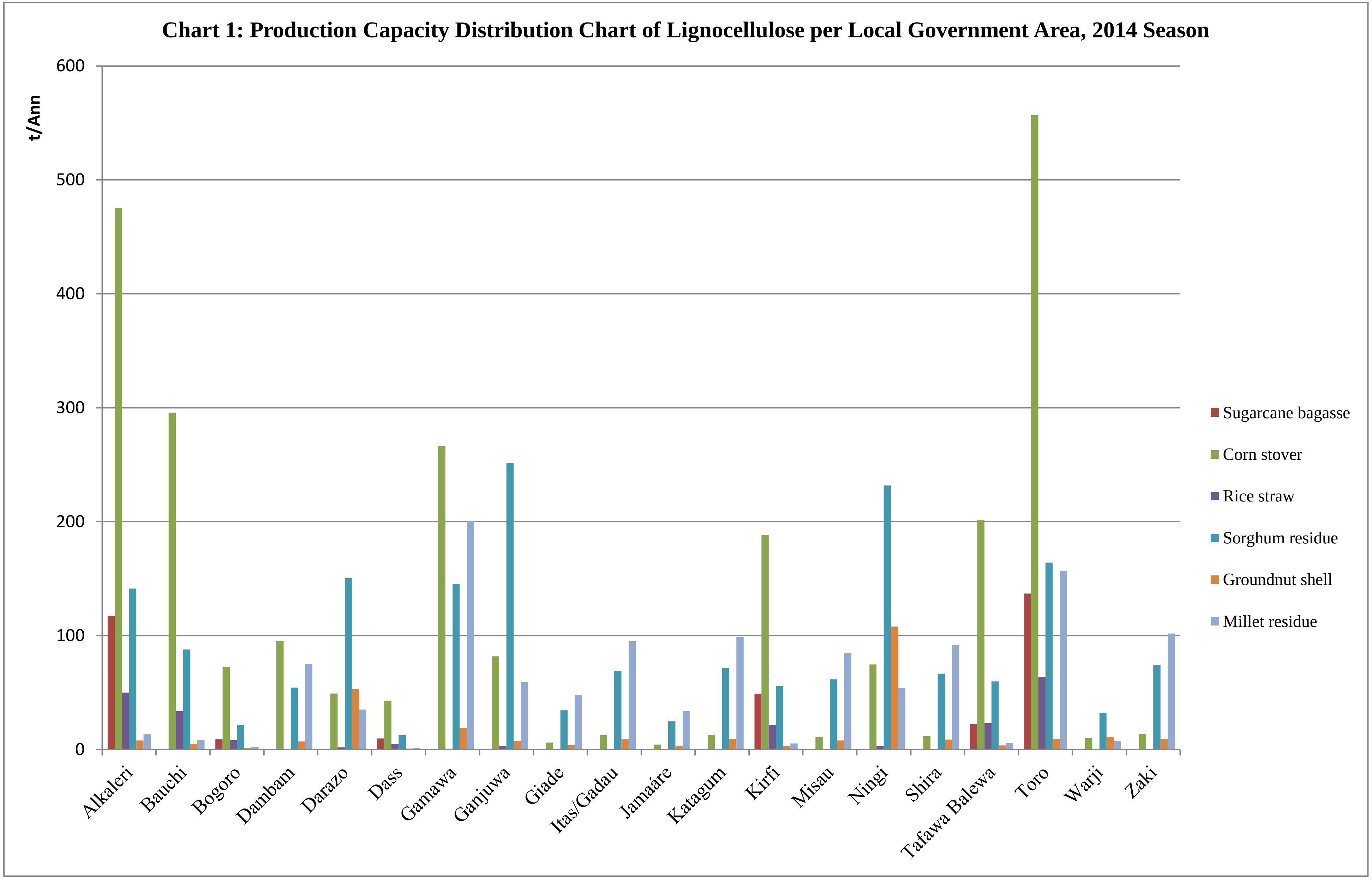


Chart 1: Production Capacity Distribution Chart of Lignocellulose per Local Government Area, 2014 Season
t/Ann
600
500
400
300
200
100
0
Alkaleri
Bauchi
Bogoro
Dambam
Darazo
Dass
Gamawa
Ganjuwa
Giade
Itas/Gadau
Jamaáre
Katagum
Kirfi
Misau
Ningi
Shira
Tafawa Balewa
Toro
Warji
Zaki
Sugarcane bagasse
Corn stover
Rice straw
Sorghum residue
Groundnut shell
Millet residue

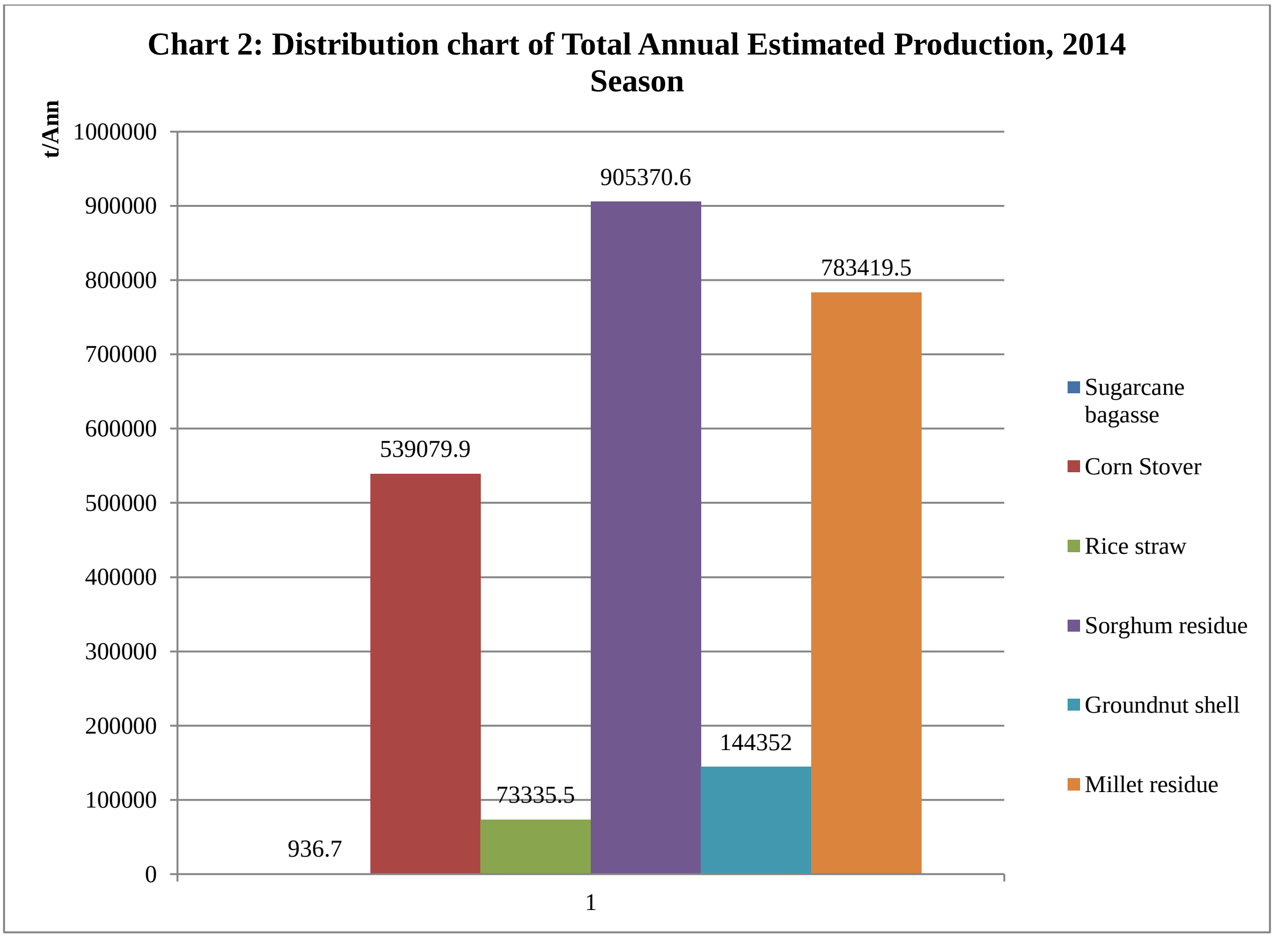
Table 3: Percent production of Lignocellulose studied under year (2014) reviewed.

LOCAL GOVERNMENT AREA		Alkaleri	Bauchi	Bogoro	Dambam	Darazo	Dass	Gamawa	Ganjuwa	Giade	Itas/Gadau	Jamaáre	Katagum	Kirfi	Misau	Ningi	Shira	Tafawa Balewa	Toro	Warji	Zaki
Type of Lignocellulose	Sugarcane bagasse	33.72	0.14	2.56	0.03	0.11	2.82	0.11	0.17	0.03	0.03	0.11	0.03	14.06	0.03	0.17	0.03	6.44	39.36	0.01	0.03
	Corn Stover	19.15	11.91	2.93	3.84	1.98	1.72	10.73	3.30	0.25	0.51	0.17	0.52	7.59	0.44	3.01	0.47	8.11	22.43	0.41	0.54
	Rice straw	23.13	15.68	3.89	0.09	0.88	2.27	0.23	1.53	0.05	0.14	0.05	0.14	9.99	0.09	1.43	0.09	10.68	29.32	0.19	0.14
	Sorghum	7.80	4.85	1.19	3.00	8.31	0.70	8.04	13.89	1.91	3.81	1.36	3.95	3.09	3.40	12.80	3.68	3.30	9.06	1.77	4.08
	Groundnut shell	2.77	1.73	0.45	2.46	18.31	0.24	6.55	2.57	1.46	3.12	1.11	3.19	1.11	2.77	37.45	3.02	1.21	3.29	3.85	3.33
	Millet	1.15	0.71	0.18	6.35	2.97	0.10	17.03	5.02	4.04	8.09	2.88	8.37	0.45	7.21	4.59	7.80	0.48	13.30	0.62	8.65

Percent Production (%)

Table 4: Estimated Total Lignocellulose Production under year (2014) reviewed

Lignocellulose	Production *U* (tones/Ann)	Area (hectares)
Sugarcane bagasse	936.7	2309.5
Corn Stover	539079.9	265085
Rice straw	73335.5	378925.5
Sorghum residue	905370.6	593613.8
Groundnut shell	144352	401453
Millet residue	783419.5	428089.5
Reference		BSADP (2014)



Determination of Quantity of Energy (biofuel or ethanol) in a given Lignocellulose

Process residues offer high potential as energy source. Chemical composition of a crop residue plays a vital role in determination of how much energy it can generate. This varies depending on factors such as variety, age of residue or stage of harvest, physical composition including length of storage and harvesting practices, (Simonyan and Fasina, 2013). However, quantity of energy in a given lignocellulose material sampled was determined by the following relation;

$$Z = Uv\left(\frac{x+y}{100}\right)$$

Where;

x = Amount by percentage of Hemicellulose in a lignocellulose

y = Amount by percentage of Cellulose in a lignocellulose

Z = Estimated quantity of ethanol in (liters) per annum from a type of lignocellulose (e.g. corn stover).

v = Quantity of ethanol in volume/tone of Cellulose-hemicellulose. It was found to be a constant value in liters/tone.

U = Total amount of a type of lignocellulose (e.g. corn stover) per annum.

For values of x and y see Table 1.

For values of U see Table 4

For value of v see Table 5

Table 5: Estimated quantity of Biofuel (Ethanol) per Lignocellulose

Lignocellulose	**Amount of Cellulose-Hemicellulose** (Tones)	**Amount of Ethanol Per Tone of Cellulose-Hemicellulose** ***V*** (Liter/ton)	**Estimated Amount of Biofuel (ethanol)/annum in a type of lignocellulose** ***Z*** (Liter/Ann)
Sugarcane bagasse	627.6	227.0	142462.7
Corn stover	345011.1	227.0	78317527.9
Rice straw	41141.2	227.0	9339055.9
Sorghum residue	651866.8	227.0	147973770.9
Groundnut shell	76393.6	227.0	18022347.2
Millet residue	549093.7	227.0	124644258.6
Reference		Bruce et al. (2006)	

DISCUSSION

Bauchi State is an agricultural land that produced a large magnitude of lignocellulose wastes.

Table 2 and 3 confirmed the effective production distribution of the Lignocelluloses sampled. This was carried out base on 2014 rainy season production.

Ganjuwa has the highest production capacity of Sorghum residue at about 13.89% with 251.5t/Ann, while Dass the least producer of Sorghum residue, with 0.70% by proportion of production at 12.7t/Ann.

In terms of Millet residue, Gamawa produced the largest quantity of the lignocellulose biomass, with 17.03% by proportion of the total production with 200.5t/Ann, while Dass was the least producer of Millet residue, with 13.30% by proportion of production and 1.2t/Ann respectively.

Table 2 and 3 placed Ningi as the highest producer of groundnut shell with quantity at 108t/Ann; and 37.45% by percentile, while Dass was least at 0.7t/Ann; and 0.24% respectively.

With respect to Sugarcane bagasse, Toro produced 39.36% with 136.9t/Ann as the major producer, whereas Warji, the least, only gave 0.03% with 0.03t/Ann.

Corn Stover, Toro produced the highest with 22.43% and 556.7t/Ann, however Jamaáre gave the least with 0.17% and 4.3t/Ann production.

Moreover, rice straw lignocellulose production was also analyzed. The analysis put Toro as the highest producer with 29.32% and 63.4t/Ann, while Giade was the least with 0.05% and 0.1t/Ann.

As agriculture base State it was established how the Lignocelluloses were distributed according to the geography and climate characteristics of the State. However this finding let the study to categorically divide the state into three zones which include central, north and south.

The Central zone, this includes Darazo, Ganjuwa, Warji and Ningi. Due to the climatic condition of the area, agricultural activities produce mostly lignocellulose of legumes, hence, produced the largest amount of groundnut shell biomass, (Table 2 and 3).

The Northern zone (comprising of; Katagum, Zaki, Gamawa, Itas-Gadau, Jamaáre, Shira, Giade, Dambam, and Misau) produces the largest percent by proportion of Sorghum residue and Millet residue lignocellulose biomass, as shown in Table 3.

Like the other two zones, the Southern zone is also very active in agricultural activities. The zone engulf the following local government areas; Bauchi, Toro, Dass, Tafawa-Balewa, Bogoro, Alkaleri and Kirfi. Their majors were production of rice straw, corn stover, and sugarcane bagasse. The climatic condition of the area gave support to high activities and production of the above mention lignocelluloses. The region is characterized of relatively high level of rain fall compare to the two other zones, this boost agricultural activity of high level production of rice, maize and sugarcane in turn produces large quantities of their lignocellulose waste with respect to the state.

Furthermore, deduced from Table 5, with respect to total quantity produced per annum by the State at large, sorghum and millet produced 905,370.6t/Ann and 784,419.5t/Ann of their residual lignocellulose material (i.e. sorghum and millet residues) respectively. However, sugarcane, corn, rice and groundnut produced 936.7t/Ann; 539,079.9t/Ann; 73,335.5t/Ann; and 144,352.0t/Ann of their residual lignocelluloses (i.e. sugarcane bagasse, corn stover, rice straw, and groundnut shell) respectively under year studied.

Greatness in lignocellulose from several years ago shows an increasing demand for industrial important enzymes. In such scenario, cellulase is being used in many of the industrial applications mainly but not limited in the field of cotton processing, paper recycling, and agriculture and in the field of research and development (Tanzila, 2014). Besides all those applications, the production of fuel ethanol from lignocellulose biomass through cellulase hydrolysis is a promising tool of the modern world. The most promising technology for the conversion of the lignocellulosic biomass to fuel ethanol is based on the enzymatic breakdown of cellulose using cellulase enzymes (Prassad, 2007). However, such wastes can be utilized for the production of domestic and industrial uses like energy, etc. Table 5 depicts that the lignocellulose biomass lying fallow as a result of agricultural activities in the state were full of massive potential reservoir of energy that can be harnessed.

Hence, the findings on these lignocelluloses shows that; sorghum residue, sugarcane bagasse, corn stover, rice straw, groundnut shell and millet residue produced 651,866.8t/Ann, 627.6t/Ann, 345011.1t/Ann, 41141.2t/Ann, 76393.6t/Ann and 549,093.7t/Ann of cellulose-hemicellulose respectively, as indicated in Table 5. Furthermore, according to the energy analysis presented in Table 6, the cellulose-hemicellulose content of the lignocelluloses (i.e. sorghum residue, sugarcane bagasse, corn stover, rice straw, groundnut shell and millet residue) produced 147,973,770.9 liters, 142462.7liters, 78317527.9liters, 9339055.9liters, 18022347.2liters and 124,644,258.6liters of ethanol per annum respectively.

Therefore, lignocellulose material can no longer be looked at as a waste, rather a potential material that can be harnessed and turned into useful material e.g. livestock feed, energy, production of enzymes, etc.

CONCLUSION

Due to ever increasing interest to transform and make the environment a safer place. Research and Development has been carried out and still on going in recycling, extraction and turning most of the materials perceived as harmful, waste and pollutant into useful materials. Ever since, lignocellulose biomass was not left out.

However, this finding prompted into promoting potentials of lignocellulose biomass. With comprehensive analytical process, quantity of lignocellulose biomass of sugarcane bagasse, corn stover, rice straw, sorghum residue, groundnut shell and millet residue were identified within the 20 Local Government Areas of Bauchi State. Energy potential analyzed with respect to standard. However, great opportunities exist in Lignocellulose biomass for exploitation given the large availability of the resources in the State.

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APPENDIX 1

DETAILED CONVERSION FACTORS

Table 6: Conversion factors of Lignocelluloses overviewed

CONVERSION FACTOR				Reference
GENERAL	1 t	< >	1000 kg	
Corn – Stover	1 kg	:	1 kg	Vagts (2005)
Sugarcane - Bagasse	10 t	:	3 t	Rainey (2014)
Paddy - Rice straw	4.3 kg	:	1 kg	Bioenergy Consult (2015)
Groundnut – Shell	74 wt.%	:	26 wt.%	David et al. (2015)
Sorghum/Millet – Residue	6.9 t	:	6.4 t	de Leeuw (1997)

Key: tone (t), kilogram (kg), weight percent (wt. %), equivalent (< >), ratio (:)