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BIOETHANOL PRODUCTION FROM MUNICIPAL SOLID WASTE: TECHNICAL OVERVIEW, PROGRESS AND CHALLENGES

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ABSTRACT: *Due to the rapid growth in population and industrialization coupled with the adverse side effects from usage of fossil fuels, there is a high demand for renewable fuel especially ethanol which is environmentally friendly and can be used as substitute for premium motor spirit. Conventional crops such as corn and sugarcane are unable to meet the global demand of bioethanol production due to their primary value of food and feed. Therefore sugar, starch and lignocellulosic materials from municipal solid waste stream are attractive feedstocks for bioethanol production. Agricultural wastes from municipal solid waste stream are cost effective, sustainable, addresses environmental pollution and create wealth and energy. Bioethanol production from wastes could be promising, however, the processes has several challenges and limitations such as feedstock sourcing and finance. This paper gives an overview, the technicality, challenges and the progress for bioethanol production from municipal solid waste.*

KEYWORD: municipal solid waste, feedstock, bioethanol, environment, energy

INTRODUCTION

The Energy requirements for a sustainable, domestic and industrial development are enormous in Nigeria. With increased urbanization and rapid industrial growth, conventional energy sources (Petroleum and Coal) may not suffice to address teaming energy concerns due to their finite nature (Abdulsalam et al., 2012). The economic development of emerging economies is directly proportional to the availability of sustainable energy sources for industrial growth and domestic consumption. In Nigeria, environmental and sustainability concerns have been identified, with the exploration and production of petroleum and Natural gas, coupled with the decline in the proven reserves of these fuels. Thus, for energy security and diversity, other options like Bio-fuels have been considered. Petroleum-based fuels can be replaced by renewable biomass fuels such as

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bioethanol, bio-diesel, biogas derived from biodegradable waste materials. Countries across the globe have considered and directed state policies toward the increased and economic utilization of biomass for meeting their future energy demands in order to meet carbon dioxide reduction targets as well as to decrease reliance and dependence on the supply of fossil fuels. Although biomass can be a huge source of transport fuels such as bioethanol, biomass is commonly used to generate both power and heat, generally through combustion. Ethanol is at present the most widely used liquid biofuel for motor vehicles (Demirbas, 2005). The importance of ethanol is increasing due to a number of reasons such as global warming and climate change. (Nibedita *et al.*, 2012) Bioethanol has been receiving widespread interest at the international, national and regional levels.

The global market for bioethanol has entered a phase of rapid transitional growth. Many countries around the world are shifting their focus toward renewable sources for power production because of depleting crude oil reserves. Ethanol has potential as a valuable replacement of premium motor spirit (PMS) in the transport fuel market. However, the cost of bioethanol production is more compared to fossil fuels. The world bioethanol production in 2001 was 31 billion litters (Berg, 2001*).* It has grown to 39 billion liters in 2006 and is expected to reach 100 billion litters in 2015 (Taherzadeh and Karimi, 2007). Brazil and the USA are the two major ethanol producers accounting for 62% of the world production (Kim and Dale, 2004). Hence bioethanol production could be the route to effective utilization of agricultural wastes from the municipal solid waste stream. Rice straw, wheat straw, corn straw, and sugarcane bagasse are the major agricultural wastes in terms of quantity of biomass available (Kim and Dale, 2004). This paper gives a brief report on bioethanol as fuel while investigating the potential of municipal solid waste as feedstock for commercial production of Bioethanol.

METHODOLOGY

The following materials below were utilized for the actualization of this paper.

MATERIALS

- Wheelie bins (240L)
- Waste Baskets
- Hand Gloves
- Coveralls
- Boots
- Nose Masks
- Hand Sanitizers
- Digital Scale

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- Spring Balance
- Colour Coded Bin Bags
- Questionnaires
- Sampling Notes
- Pens
- Masking Tape
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Sampling

- Preliminary survey: a preliminary survey was conducted in the University of Benin (Ugbowo campus) in order to gather information on the layout of the University community. The type/structure of buildings in the University community was listed, site of dumpsite and composition of waste generated were documented during this survey and it was based on this information that the type of sampling method was decided.
- Stratified systemic sampling method was used to obtain a good spectrum of respondents. The University community was divided into 3 strata based on the activities and type of waste generated in the University community namely residential, commercial and administrative/academic respectively.
- 30% of each stratum was then systematically sampled to get a good spread of respondents.
- Each respondents were given 3 waste baskets to sort their waste into fruit, food and others.
- **NB:** For residential and commercial areas colour coded bin bags of green was assigned for fruit waste, white bags for recyclables (paper and plastic) and black bags for organic waste. While for administrative/academic areas recyclable waste (paper and plastic) would be in green bags, (fruit waste and Lignin material) in white bags and other wastes in black bags.
- The commercial and administrative/academic areas had their waste sorted by waste/sanitation officers who were incentivized for the sorting.

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RESULTS

TABLE 1.0: *Summary of Municipal Solid Waste Generated in Benin Metropolis South-South Nigeria, University of Benin Community as Case Study*

RESIDENTIAL AREA (Senior and Junior staff quarters, Student hall of residents)								
FRUIT (KG)	FOOD (KG)	PLASTIC (KG)	PAPER (KG)	GLASS (KG)	METAL (KG)	COMBUSTIBLE (KG)	LEAVES (KG)	CERAMIC (KG)
724.40	1806.5	1050.40	662.80	130.3	70.24	1002.40	0	47.50
COMMERCIAL AREA (Banks, Business Complex, Food courts)								
FRUIT (KG)	FOOD (KG)	PLASTIC (KG)	PAPER (KG)	GLASS (KG)	METAL (KG)	COMBUSTIBLE (KG)	LEAVES (KG)	CERAMIC (KG)
166.55	816.17	765.49	364.66	24.49	34.71	8.11	208.16	0
ADMINISTRATIVE/ACADEMIC AREA (Administrative Blocks and Academic Blocks)								
FRUIT (KG)	FOOD (KG)	PLASTIC (KG)	PAPER (KG)	GLASS (KG)	METAL (KG)	COMBUSTIBLE (KG)	LEAVES (KG)	CERAMIC (KG)
29.56	169.96	1175.34	595.24	50.65	66.44	30.11	71.77	0

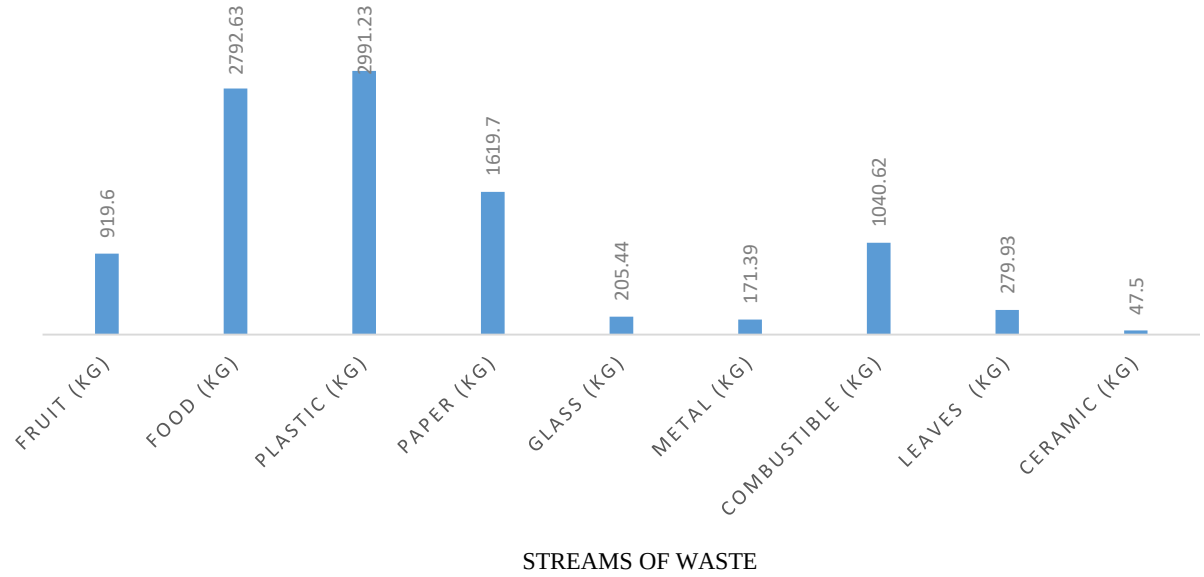

Figure 1.0: Graphical representation showing the total volume of waste streams generated in Study Area

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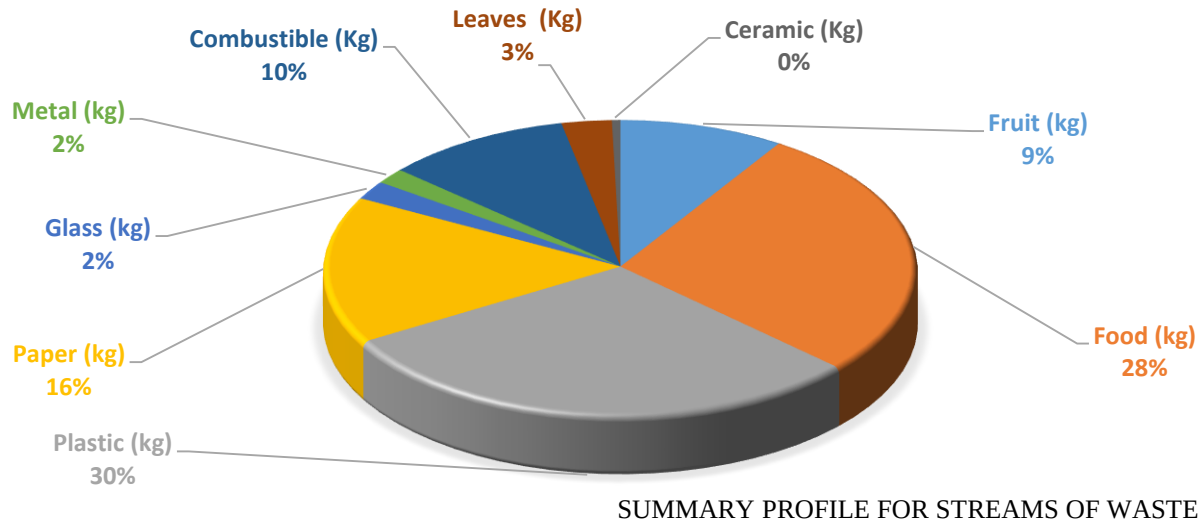

Figure 2.0: Summary Profile of Waste Streams generated in the Study Area

DISCUSSION

The results from figure 1 and figure 2 respectively shows that organic waste is the largest composite of municipal solid waste generated during the study at the University of Benin community, though this may be proof of availability, it may not culminate into feasibility of municipal solid waste (MSW) as a feedstock for bioethanol production. Factors that may affect or challenge the feasibility of municipal solid waste (MSW) as a feedstock for bioethanol production commercially are stated below.

Sourcing

At a glance, it may seem municipal solid waste (MSW) can easily be sourced as feedstock, this may be relatively true for developed countries as they have a sustainable and proper waste management system i.e (from source to dumpsite). It helps the process of sourcing municipal solid waste (MSW) as feedstock a much easier process compare to developing countries such as Nigeria. Thus the first challenge of bioethanol production from municipal solid waste (MSW) in Nigeria is sustainable waste management system. Solid waste management in Nigeria is marred with indiscriminate dumping, inadequate landfill sites and improper waste collection and transportation system, hence it is safe to say that Nigeria suffers from a poor waste management system. Because not all component of waste generated is suitable for bioethanol production, the waste must be sorted either at source of generation or by residents or at the dumpsite by sanitation workers. The best option is source sorting or separation by residents.

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Most residents disposed their waste comingled that is they have a single waste basket for all the waste streams, as there is hardly any form of waste recycling system in Nigeria today. Thus obtaining the organic components of the waste needed for bioethanol production manually by respondents or sanitation officers is very tasking and tedious. This is also proven in this paper as to characterize the waste generated in the University community, colour coded bin bags and waste baskets were deployed to residents to enable at source sorting before disposal. This is the mirrored reality of the waste situation in Nigeria. There is hardly any organized waste sorting in Nigeria, sorting of waste in Nigeria are majorly done by scavengers who ravage waste baskets positioned outside of residential buildings or dumpsites looking for recyclable waste for them to sell. Therefore one of the biggest challenges in the production of bioethanol is the sourcing of waste as feedstock. Sourcing organic components from waste streams generated by respondents is also very untidy, messy and unhealthy as most times the organic waste begin to decay therefore leading to offensive odour which and may also have maggots or rodents. It also cost a lot to provide waste basket for respondents to separate the different type of waste generated to aid sorting at source. A lot of logistics is needed for sensitization and incentives as it was observed during the survey that administrative/academic areas, commercial areas and Student halls of residents where sanitation officers (cleaners) were used to sort the waste generated for the areas complied more than respondents in the residential areas who had to sort the waste themselves. This is probably because the sanitation officers were given stipend for sorting the waste before disposing.

Limited Infrastructures and Professionals

Limited municipal solid waste infrastructures are one of the major contributing indexes of poor waste management system in Nigeria. Nonetheless, experts and professionals to man these machineries are also not on ground. The environmental protection agencies and waste management personnel's are not experts and exposed to workshops and trainings that meet international standards on technology use, information and knowledge management. Most of the state environmental protection agencies lack adequately trained personnel (Agunwamba, 1998).

Composition

The composition of the organic portion of municipal solid waste (MSW) is greatly dependent on socioeconomic factors (Aritha *et al.*, 2020) prevailing local waste management practices and also varies along geographical and temporal scales, this is a sharp contrast to agro waste which generally exhibits relatively consistent composition profiles. This complexity in the composition of waste stream affects to a great deal methodology for processing. It is clear that the higher one goes on the socioeconomic class the less organic waste they produce. Hence this would mean that siting a bioethanol plant in such an area might not be viable based on socio class as it may not generate enough organic component in its waste stream as feedstock for bioethanol production.

The organic component of municipal solid waste (MSW) can also only be sorted manually as the composition varies significantly depending on the location and at what point sorting took place.

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(Aritha *et al.,* 2020). In this research work fruit, food and lignin materials (dried leaves from trees and leaves for packaging rice) were collected separately at source, this may not be feasible in real life scenario as sorting would usually be divided into 3 (three) components; organic, recyclables and combustibles. However, there are 3 (three) different processes of obtaining sugar from organic materials for bioethanol production. It is this difference in the composition of organic waste that leads us to our next challenge.

Processing

The difference in organic composition of municipal solid waste makes room for different processing procedures as it is displayed in figure 3.0 below. This is a challenge as it means that one cannot get the best results when comingled waste is processed, fermented and then distilled. Each class of sugar has its own unique process, the easiest being simple sugar, then starch/carbohydrate (which is the most common in municipal solid waste (MSW) stream) and lastly lignocellulose i.e paper, grass/leaves and woody materials which require pretreatment using heat, concentrated acid and agers to help break down the lignocellulose material into sugar. This means three different methods would be applied to the different composition of organic waste obtainable from municipal solid waste, thus increases cost of Bioethanol production.

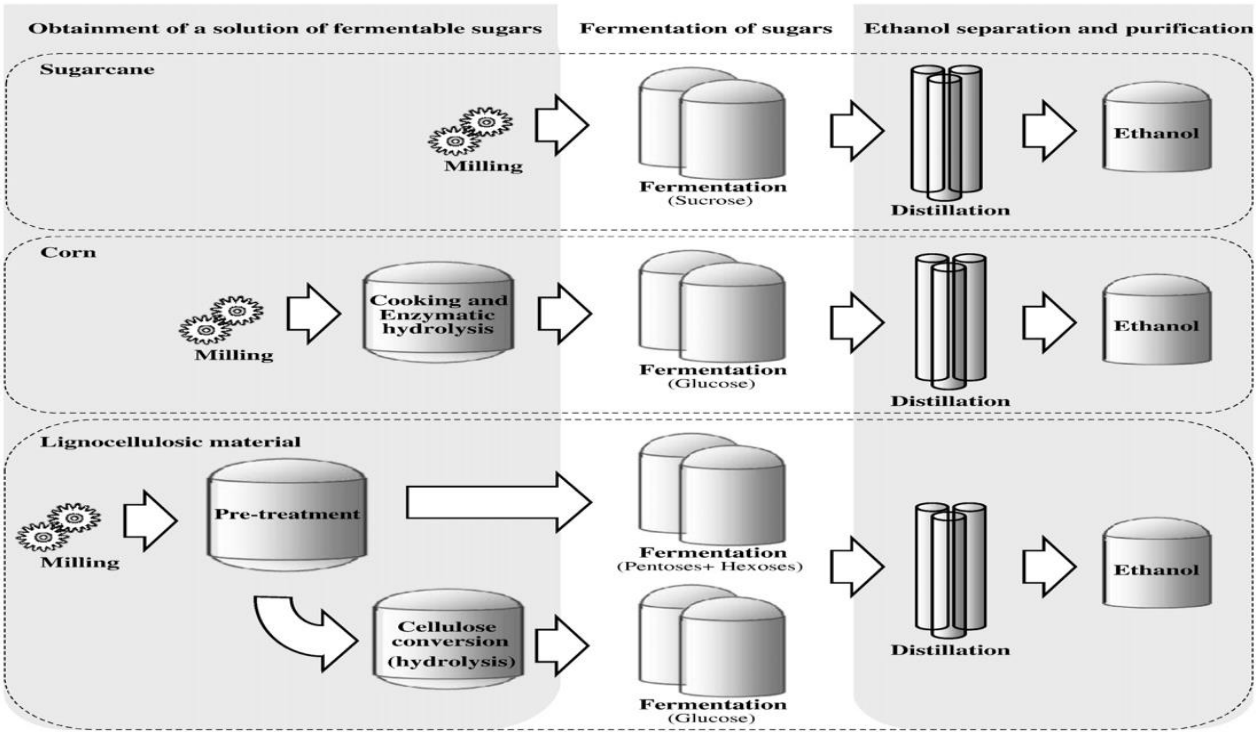

Figure 3.0 Diagram representing the different processes for bioethanol production from the different classes of organic matter. (Solange et al., 2010).

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CONCLUSION

There is no doubting the potential of municipal solid waste to be utilized as feedstock for bioethanol production. The organic fraction of municipal solid waste (MSW) consists of plant derived materials such as food, fruit and garden waste and pre-processed material of plant such as paper and cardboards rich in lignocellulose. Municipal solid waste (MSW) thus possesses a considerable potential as feedstock for biofuels as it does not compete with food and is readily available as human activities would always produce waste.

The use of municipal solid waste (MSW) as feedstock for bioethanol production is very promising; however it is still in its infancy stage due to the challenges raised in this paper. The financial implication of tackling these challenges may make this concept unfavorable to investors as the ready option might be to use agricultural waste and site bioethanol plants at the farms as they usually produce just one stream of waste thus sorting will not be a challenge neither will processing. A major challenge with municipal solid waste (MSW) as feedstock is the amount of sensitization that must be carried out, if sorting at source is to be efficient. This study engaged respondents in a 3 stage sorting at source over a period of a month. It was observed that compliance rate dropped as the days progressed and respondents became unwilling to separate their waste. Hence it is safe to say that the biggest challenge of municipal solid waste (MSW) as feedstock for bioethanol production is sourcing due to the different composition of organic material within the waste stream.

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