



## **Characterization and Composition Analysis of Municipal Solid Waste for Bioethanol Production**

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## ABSTRACT

Every unwanted or non-useful solid substance generated in any human population is referred to as solid waste. Globally, the management of solid waste is an enormous challenge for municipalities. Previous studies have indicated that an increase in population with relating attendant urbanization dynamics and growth of continuous aggregation will further aggravate this challenge. This paper aims at determining the potentials of using municipal solid waste as a feedstock in the commercial production of Bioethanol. The research team which was made up of the coordinator, co-coordinators and research assistants carried out a preliminary survey which consist of mapping the study areas and obtaining some information through the observation of the various sites. The study area which was the residential areas of the University of Benin community were then mapped into Senior Staff Quarters (which comprised of Professorial quarters, senior staff quarters and Blocks of flats), junior staff quarters and Student Hall of Residence. A preliminary survey form was originated for this purpose. Printing of questionnaires, sample notes, pamphlets, stickers and tagging of bin baskets and wheelie bins were done. A three (3) Stage sorting and characterization of respondents' waste were carried out. Composition of waste was determined after which the digital weighing balance was used to determine the mass of the waste which was recorded, before allowing proper disposal of the waste. Samples of sorted waste (organic) were collected into sample bottles and taken to the laboratory for microbial analysis. The solid waste generated is made of nine major components for which color coded bags was used to differentiate them (fruit, food, plastic, paper, glass, metals, combustibles, leaves, and ceramics). The study showed that 58.85% of the total solid waste generated in the residential areas of the University of Benin was made of biodegradable matter (food and fruit) which can be harnessed for the production of Bioethanol. The recyclables (Papers and Plastics) which are 36.34 % of the waste can also be recycled into other useful products. Efforts should be made by stakeholders to evolve sustainable waste management policies for disposal, waste reduction and recycling projects.

**Keywords:** Municipal Solid Waste, Feedstock, Bioethanol, Environment, Recycle

## INTRODUCTION

Every unwanted or non-useful solid substance generated in any human population is referred to as solid waste [1]. Globally, the management of solid waste is an enormous challenge for municipalities. Previous studies have indicated that an increase in population with relating attendant urbanization dynamics and growth of continuous aggregation will further aggravate this challenge. [2], in 2006 reported on five global scenarios compiled from 1990 to 2050, in global post-consumer waste generation. It was stated that global emissions from landfills in 1990 were 340 Tg CO<sub>2</sub> eq. (Total gas CO<sub>2</sub> equivalent) with a large increase to 1500 Tg CO<sub>2</sub> eq. (Total gas CO<sub>2</sub> equivalent) by 2050. [3] and [4], more recently reviewed greenhouse gas (GHG) emissions from landfills and listed many important relief methods as well as development and dissemination of updated knowledge-based framework. At present, the World Bank affirms that 2.01 billion metric tons of municipal solid waste (MSW) are produced annually worldwide, with estimates reaching 3.40 billion metric tons by 2050 [5]. Current worldwide estimates indicate 13.5% of waste is recycled and 5.5% is composted, with an estimated one-third and 40% of municipal solid waste as not managed properly and instead dumped or openly burned.

This mismanagement is significantly split between developed and developing countries. For example, about 80% of solid waste in African Countries is dumped indiscriminately in open spaces, streets, storm water drains, rivers and streams, thereby estimated to contribute to about 29% of the global greenhouse gas (GHG) and expected to increase to 64% by 2030 [5].

Nigerian cities are largely characterized by having solid waste disposal problems. They are embodied by overflowing dumpster, mountains of open refuse dumps (i.e. virtually every street), and temporary landfills on the edge of larger suburbs and towns. As such, the collection and transport of municipal solid waste require the largest demand on municipals budgets. In Nigeria, 68% of municipal solid waste is indiscriminately dumped, 28.8% is disposed through inappropriate landfills sites and 10.7% is burnt [6], [7].

Nigeria is the most populous country in Africa covering an area of approximately 924,000 km<sup>2</sup>, with over 200 million citizens, located in West Africa with an estimated growth rate of 26%. It is placed 7<sup>th</sup> on a global population ranking, behind China, India, the USA, Indonesia, Brazil, and Pakistan [8]. Nigeria is made up of 36 states and a Federal Capital Territory (FCT). It is constituted into 774 Local Government Areas. The administrative framework in Nigeria for solid waste management is categorized into Federal, State, and Local Government, each having their different responsibilities as it regards to waste. The Federal Ministry of Environment is a body charged with overseeing the protection of the environment as well as natural resources preservation to the end of achieving sustainable development. As such, they play the role of promulgation of National environmental laws, enforcement, and monitoring.

According to the greenhouse gas emission inventory 2000 to 2018, the contribution from inappropriate waste was 3.0%, which is expected to double within the next 5 years, considering that the waste generation rate is estimated between 0.5 and 1.0 kg/person/day. Industrial operation is characterized by the generation of large volumes of municipal solid waste in the form of solid, liquid and gas- some toxic. As a result, the Edo state waste management board (EWMB) established by the local authorities put in place a monitoring program to regulate environmental quality and implement steps toward a waste-free society. Despite its effort, Benin City still falls short of achieving the board benchmark levels and ongoing management practices are needed.

The management of solid waste should be a primary function of the municipal/local government in each state, however, this is not so, as no Local Government Area (LGA) in Nigeria has autonomy. What is obtainable, practically is that each state government sets up its state's waste management board to oversee the affairs of waste management in the states. However, this strategy is not effective as the streets are characterized by large heaps of refuse and over 40% of citizens still don't have their waste collected by the authorities. This is essentially the case in Edo State. It is against this background that the Environmental Pollution and Remediation Unit of the National Centre for Energy and Environment embarked on the characterization and composition analysis of municipal solid waste for Bioethanol production in Benin metropolis, south-south, zone of Nigeria, using the University of Benin community as a case study.

Characterization of municipal solid waste is simply a descriptive means of identifying the various constituent of waste streams in terms of quantity and quality generation taking into accounts locations as well as seasons in which this waste is generated. It is a means of finding out how much papers, glass, fruits, food and plastic wastes are discarded in the municipal waste stream [9]. The characterization of municipal solid waste helps in determining the quantity of waste generated in a particular location at a particular time of the year [10]. This helps in identifying the trend of generation as well the influencing factors. It makes proper planning of solid waste management, determining the size and equipment required for managing the waste, the needed resources for the protection of the environment, and public health characterization is also important to determine its possible environmental impacts on nature as well on society [11].

This paper aims at determining the potentials of using municipal solid waste as a feedstock in the commercial production of Bioethanol. To achieve this aim, the following objectives were set which include characterization of municipal solid waste generated, determining the feasibility and viability of generated municipal solid waste as feedstock for bioethanol production.

### **MATERIALS AND METHOD**

The materials used to execute this project are; Wheelie bins (240 L), Wastebaskets, Hand Gloves, Coverall / Lab coat, Boots, Nose masks, Hand Sanitizers, Liquid Soap, Digital scale, Spring balance, Colour coded bin bags, Questionnaires, Sampling notes, Marker pens, Biro, Masking tape and Buckets.

The research team which was made up of the coordinator, co-coordinators and research assistants carried out a preliminary survey which consist of mapping the study areas and obtaining some information through the observation of the various sites. The study area which was the residential areas of the University was mapped into Senior Staff Quarters (which comprised of Professorial quarters, senior staff quarters and Blocks of flats), junior staff quarters and Student Halls of Residence. A preliminary survey form was originated for this purpose, the form furnished us with information on type of waste generated, type of building, duration of waste disposal and location of dumpsite, this exercise lasted for about a week.

Printing of questionnaires, sample notes, pamphlets, stickers and tagging of bin baskets and wheelie bins were done. The questionnaires which were distributed to respondents were designed to obtain information on the status, lifestyle, class and level of awareness on waste management. The sample notes were designed to obtain data of various streams of waste generated. Pamphlets on sensitization and awareness on environmental management of waste were distributed during sensitization of respondents and sanitary officers. A total of 7 Wheelie bins and 250 bin baskets were distributed to accommodate the sorted waste generated by respondents. Color-coded bin bags of White, Green and Black were also distributed to respondents and sanitation officers.

This work made use of primary and secondary data. Questionnaires and interviews were used to source primary data on the current waste practices and the situation in Benin metropolis (the University of Benin Community as a case study), while secondary data were sourced from literature.

A three (3) Stage sorting (by sanitation officers and research assistants) and characterization of respondents' waste were done by research assistants who were supervised by a Coordinator and co-coordinators. The research assistants determine the composition of waste before weighing using the spring balance or the digital weighing balance for large and small volume of waste as the case may be to determine the mass of the waste, and records it before allowing proper disposal of the waste. Samples of sorted waste (organic) were collected into sample bottles and taken to the laboratory for microbial analysis.

For the purpose of this work which is to quantify the amount of waste for the commercial production of bioethanol with emphasis on fruit waste, waste sorting was done in residential areas. Colour-coded bin bags were assigned for fruit waste, recyclables (paper and plastic), and food waste, metal, ceramics, glass, leaves and combustibles.

For the safety of research officers and sanitation officers during the project, personal protective equipment (PPE) were worn at all times and also covid-19 guidelines were strictly observed. All research officers were mandated to be on their identity cards for proper identification by respondents.



**Image i: Research Team ascertaining the composition of waste**



**Image ii: Waste Characterization by Research Team**



**Image iii: Covid- 19 rules Observed**

## Waste

Fruit waste was generated principally from residential areas. Samples of fruit waste were collected on the field by research officers during the characterization of waste and taken to the laboratory for microbial analysis.

Nutrient agar was prepared and inoculated with the samples and kept in the incubator for 24 hours. The growth observed was prepared by weighing 28g of Nutrient Agar in 200 mL of distilled water. This was homogenized and put in a 500 mL round bottom flask and covered with tinfoil. It was then sterilized with an Autoclave and poured into petri-dishes that were already labelled and allowed to solidify. The labelled agar plates were inoculated with the samples following the label according to the waste source. The agar was then allowed to grow

in an incubator for 24 hours. The bacteria were fixed on the slide and dried using crystal violet, Iodine solution to fix and ethanol to decolorize with sefranin as a secondary stain. After which, all the plates were viewed with a microscope and identified. However, the laminar flow was used as a clean bench for inoculation of the fruit waste.

## RESULTS AND DISCUSSION

The results of the microbial analysis are shown in Table 1.0. The fruit waste in these residential areas contained both the Gram-positive and Gram-negative bacteria in all the samples however in some samples there were more of Gram-positive.

**Table i: Result of Microbial Analysis of Municipal Solid Waste in Residential Area.**

| <b>WEEK 1</b>         | Gram+ | Gram- |
|-----------------------|-------|-------|
| JSQ                   | +     | -     |
| Block of flats        | +     | -     |
| Professorial Quarters | +     | -     |
| <b>WEEK 2</b>         |       |       |
| JSQ                   | +     | -     |
| Block of flats        | ++    |       |
| Professorial Quarters | +     | -     |
| <b>WEEK 3</b>         |       |       |
| JSQ                   | +     | -     |
| Block of flats        | +     | -     |
| A30                   | +     | -     |
| Library               | +     | -     |

**++ more of Gram-positive**

**-- more of Gram-negative**

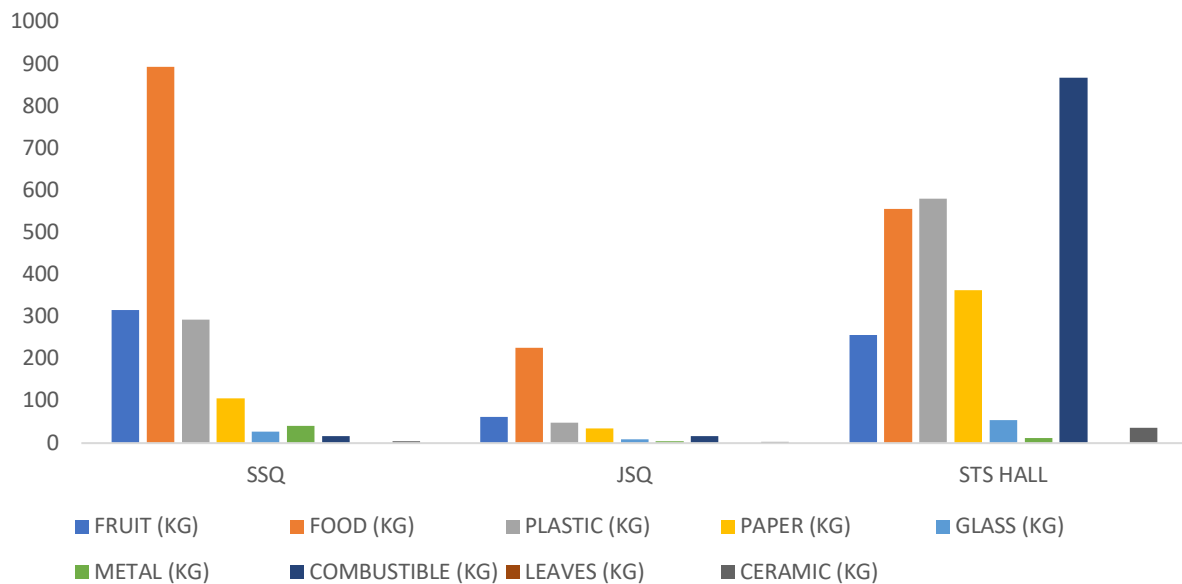
This is mainly due to the nature of the fruit waste (watermelon, orange, pineapple, etc.) and the stage of degradation at the time of sampling. The Gram positive bacteria include *Escheriche coli*, *Pseudomonas aeruginosa* and *chlamydia trachomatis*. While the Gram-negative bacteria are *Staphylococci* and *Streptococci Pneumococci*.

The results of the Municipal solid waste (MSW) collected from the residential areas of the University of Benin for 4 weeks are shown in Table 2 below. The residential areas and the streams of waste generated in each location are outlined below. Also, the total waste generated in each waste stream irrespective of the location is given in table 3 below.

**Table ii: Summary of MSW Data obtained for Week 1 – 4**

| SITE     | FRUIT (KG) | FOOD (KG) | PLASTIC (KG) | PAPER (KG) | GLASS (KG) | METAL (KG) | COMBUSTIBLE (KG) | LEAVES (KG) | CERAMIC (KG) |
|----------|------------|-----------|--------------|------------|------------|------------|------------------|-------------|--------------|
| SSQ      | 316.12     | 893.54    | 292.91       | 106.62     | 27.05      | 41.15      | 16.21            | 0.00        | 3.97         |
| JSQ      | 62.37      | 226.38    | 48.70        | 35.48      | 9.27       | 4.25       | 17.12            | 0.00        | 3.26         |
| STS HALL | 257.47     | 557.28    | 580.93       | 363.69     | 54.73      | 11.93      | 867.65           | 0.00        | 36.52        |
| TOTAL    | 635.96     | 1,677.20  | 922.54       | 505.79     | 91.05      | 57.33      | 900.98           | 0.00        | 43.75        |

SSQ- Senior Staff Quarters  
 JSQ- Junior Staff Quarters  
 STS Hall- Students Hall of Residence

**Figure i: Graphical illustration of the Summary of MSW generated in Residential Areas**

From Table 2 above, the municipal solid waste (MSW) generated are as follows; fruit 635.96 kg, Food 1,677.20 kg, Plastic 922.54 kg, Paper 505.79 kg, Glass 91.05 kg, Metal 57.33 kg, Combustibles 900.98 kg and Ceramic 43.75 kg. From the graphical illustration of municipal solid waste generated in residential areas as shown in Figure 1, the streams of waste obtained in the different locations (SSQ, JSQ and STS) in the residential area of the University of Benin community are represented above. It was observed that food was the highest waste generated in senior staff quarter (SSQ) and Student hall of residence (STS). High volume of plastic, paper and combustibles were also generated in the Student halls of residence (STS) within the period of the research project. In SSQ, the trend of waste generated were as follows Food > Fruits > Plastic > Paper > Metal > Glass > Combustible > Ceramics While in JSQ, food > Fruits > plastic > paper > combustibles > metal > glass > Ceramics and lastly in STS Hall, the trend was combustible > plastic > food > paper > fruit > Glass.

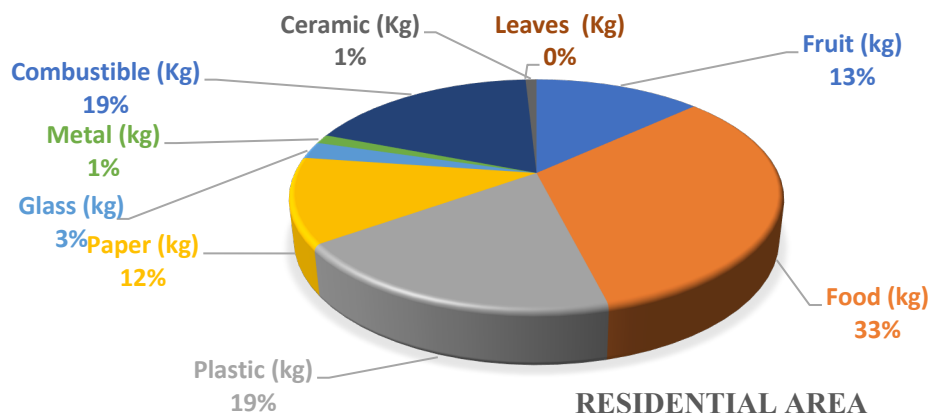


**Figure ii: Pie Chart showing Percentages of waste streams generated in Residential areas.**

Figure 2 represents the percentages of the municipal solid waste (MSW) obtained in the different waste streams in the residential areas irrespective of the three locations. It was observed that food (33%) was the highest volume of waste generated in residential area while plastic and combustibles (19%) respectively and Fruit (13%) were the second and third highest respectively. However, lower volumes of paper (12%) > Glass (3%) > Metal and Ceramic (1%) were generated in these areas.

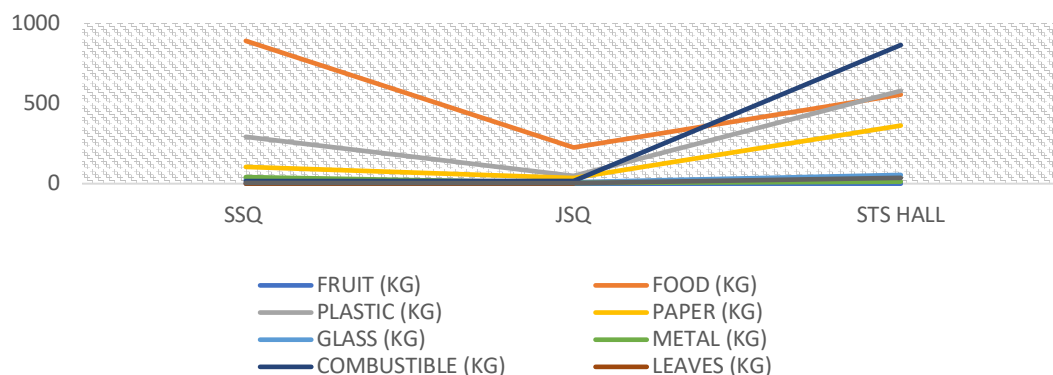


**Figure iii: Line graph showing Summary of MSW Data obtained in the different locations**

The trend of waste recorded across the locations was different for all samples collected. From Figure 3, senior staff quarters (SSQ) recorded the highest food waste as compared to junior staff quarters (JSQ) and student halls of residence (STS). This is probably because the senior staff quarters (SSQ) consist of more residential quarters (Professorial quarters, Senior Staff quarters and Block of flats) compared to junior staff quarters (JSQ) and student halls of residence (STS). The student halls of residence (STS) generated the highest volume of plastics and combustibles because of fact that students buy food and other consumables packaged with Styrofoam materials and plastics. High volume of paper was also generated in Student Halls of Residence (STS) when compared to senior staff quarters (SSQ) and junior staff quarters (JSQ), this is because it is dominated by students who use paper in their everyday academic activities and hence bring them to the hostels after which it is disposed in the hostel as waste after use.

However, for Fruits, Metal and Glass, there was no major disparity in the quantity generated in the three locations.

**Table iii: Total MSW Characterized in each location**

| <b>LOCATION</b> | <b>TOTAL CHARACTERIZED MSW (Kg)</b> |
|-----------------|-------------------------------------|
| SSQ             | 1,697. 57                           |
| JSQ             | 406. 83                             |
| STS HALL        | 1, 826. 03                          |
| <b>TOTAL</b>    | <b>3, 930. 43</b>                   |

It was observed from Table 3 above that, Student Halls of Residence (STS Hall) recorded the highest volume of municipal solid waste (MSW) generated which was 1,826.03 kg this is as a result of respondents (students) from various background, culture and feeding/eating habits that led to the volume of waste recorded especially organic, plastic and combustible waste. This was closely followed by respondents in the Senior Staff Quarters (SSQ) which had a volume of 1,697.57 kg. This is because the respondents in this quarters have a more coordinated feeding/eating habit compared to the Student Halls of Residence (STS) and lastly Junior Staff Quarters (JSQ) which was 406.83 kg. The low volume of municipal solid waste (MSW) recorded in Junior Staff Quarters (JSQ) is probably due to its low population and income.

### **CONCLUSION**

The first step in waste management is to gain an understanding of the waste types being generated to design appropriate collection and disposal strategies and this can be achieved through characterization of waste. The largest proportion of waste in the residential areas of the University of Benin metropolis can be composted rather than disposed. The solid waste generated is made of nine major components (fruit, food, plastic, paper, glass, metals, combustibles, leaves, and ceramics). The study showed that 58.85% of the total solid waste generated in the residential areas of the University of Benin community was made of biodegradable matter which can be harnessed for the production of Bioethanol using the locally fabricated Bioethanol Plant with Fractional distillation column of the National Centre for Energy and Environment. The recyclables (Papers and Plastics) which are 36.34 % of the waste can also be recycled into other useful products. Efforts should be made by stakeholders to evolve sustainable waste management policies for disposal, waste reduction and recycling project. The Edo State Waste Management Board (EWMB) should encourage community participation and involvement in waste management. Also, formal composting and recycling facilities should be set up at the University community and Edo State at large.

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