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EXPLORING THE POTENTIALS OF CEREAL FOOD WASTE IN ANAEROBIC DIGESTION

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ABSTRACT

Cereal food waste makes up a significant part of municipal solid waste, and its proper treatment has become an urgent issue due to its increasing generation. In Nigeria, where around 50% of municipal waste is organic, this study focuses on the need for effective waste management. It highlights the negative environmental and economic impacts of improper disposal methods. The study examines the potential of using cereal food waste in anaerobic digestion for biogas production. Cereal food waste was collected from student hostels at the College of Nursing and Midwifery Malumfashi, sorted, and converted into a composite for anaerobic digestion. An anaerobic digester was constructed using a 25-litre plastic container designed for batch loading. The anaerobic digestion process was carried out for 30 days. The results show that a total biogas volume of 14,634 mL was produced during this time. The daily biogas yields varied, reaching its highest point on the 5th day. This finding underscores the importance of addressing food waste in the cereal supply chain to ensure sustainable food production and consumption. The results demonstrate that cereal food waste has significant potential for biogas production, which can contribute to sustainable waste management and help address environmental challenges linked to food waste. Based on these findings, the study recommends promoting the use of biogas technology to improve food waste management, thus enhancing environmental sustainability and supporting economic development.

Keywords: Cereal, Food waste, Anaerobic Digestion, Biogas

INTRODUCTION

Cereals are an essential part of the human diet, accounting for over 20% of daily food intake and making a significant contribution to global food production (Fârcas et al., 2022). They are a staple food in both developed and developing countries. According to the Food and Agriculture Organization (FAO), global cereal production reached 2,823 million tons in December 2023. However, it is estimated that up to 13% of cereals are wasted along the food chain (Fârcas et al., 2022), which is exacerbated by the increasing demand for food due to a growing global population (Rahut et al., 2022). This increase in food demand is directly linked to an increase in food waste. Food waste not only represents a loss of valuable resources but also has significant environmental and economic impacts (Ishangulyyev et al., 2019).

The alarming rise in food waste (FW) within municipal solid waste is a global concern, with FW constituting a significant portion of MSW (Maalouf & El-Fadel, 2017). Mismanagement of food waste presents a significant challenge in the modern world and poses a major threat to sustainable development in developing countries (Sahoo et al., 2023). Improper disposal methods, such as landfilling and open dumping, are common, leading to slow degradation and contributing to climate change as food waste decomposes and releases methane, a potent greenhouse gas (Everitt et al., 2020). FW originates from various sources, including commercial and household activities, institutions, and industries (Sahoo et al., 2023).

In Nigeria, approximately 50 percent of municipal waste is organic on average, reaching up to 80 percent in certain cities (Amber et al., 2023). According to the World Bank (2020), Nigeria alone produces about 22 million tons of food waste annually, most of which is disposed of through landfilling (open dumping). The rapid increase in food waste within municipal solid waste reflects a global trend and raises concerns due to its negative impact on the environment and public health (Maroušek et al., 2020). The need for effective waste management strategies is urgent in Nigeria, where food waste constitutes a significant portion of MSW. This highlights the importance of addressing the challenges faced by the country. Therefore, it is crucial to address food waste in the cereal supply chain to promote sustainable food production and consumption. Based on this, the aim of this study was to assess the potential for biogas generation from cereal food waste in Malumfashi town, Malumfashi Local Government, Katsina State, Nigeria, by examining the biogas potential of cereal food waste.

MATERIALS AND METHODS

Construction of the anaerobic digesters

The digester design was modified to suit the anaerobic digestion process, based on the designs of Adeleke et al (2020) and Yusuf et al (2020). The components used in constructing the digester included 20-litre plastic containers, bulkhead fittings, hose clamps, PVC ball valves, high-pressure hoses, pressure regulators, hose barbs, elbows, PVC pipes, adaptor plastic threads, and graduate cylinders. The digester was designed with a single aperture that served the functions of slurry intake and gas output. Adaptor plastic threads, Abro PVC glue, bulkhead fittings, and hose clamps were used to strengthen the various couplings between the digester, hose, and junction. The digester design favored batch loading.

Substrate Collection

Cereal food waste (FW) was collected from student hostels at the College of Nursing and Midwifery, Malumfashi. The food waste was sorted, with mixed vegetables, rice, boneless meat, bread, and other food items separated from plastic bottles, tissues, bones, and other unwanted solid waste. A composite of cereal food waste was formed for anaerobic digestion.

Slurry Preparation

After confirming that the substrates were entirely free of any foreign particles, they underwent mechanical pretreatment and thorough stirring before being digested for a 30-day period at mesophilic temperatures. The slurry used for this process had a mixing ratio of food waste to water of 1:1 by mass. In simpler terms, 5 kg of fresh food waste was mixed with an equal amount of water to create the slurry.

Temperature and pH of the slurry

The temperature of the digesters was assessed twice daily, once in the morning and once in the evening, using a digital thermometer (HI 8014, Hanna Instruments). This was done to ensure that the anaerobic digestion process maintained an optimal mesophilic temperature range, which is necessary for efficient biogas production. The pH of the slurry also was measured before and after digestion using a digital pH meter (HI 8014, Hanna Instruments).

Feeding and Operation

The slurry was introduced into the batch digester (Mahushi et al., 2018), which was gently agitated daily to enhance the interaction between microorganisms and organic matter, as well as to stabilize the pH level (Mohammed et al., 2020).

Gas Collection

The biogas production rate was determined using the water displacement method. The gas yield was measured daily using a graduated cylinder until biogas production ceased (Selvankumar & Govindaraju, 2017). This method involves replacing an equivalent volume of water with the generated biogas, and this substitution is used to measure the daily biogas production.

RESULT AND DISCUSSION

pH of the slurry

In this study the pH of the cereal slurry at initial stage was measured at 7.3 before digestion, which decreased to 7.0 after digestion

Daily biogas generation

Table 1: Biogas Potential of Food Waste

SN	Days	Gas Yield mL
1	10th May 2023	380
2	11th May 2023	1070
3	12th May 2023	1532
4	13th May 2023	1620
5	14th May 2023	1507
6	15th May 2023	1200
7	16th May 2023	995
8	17th May 2023	827
9	18th May 2023	927
10	19th May 2023	811
11	20th May 2023	862
12	21st May 2023	790
13	22nd May 2023	645
14	23rd May 2023	532
15	24th May 2023	387
16	25th May 2023	187
17	26th May 2023	157
18	27th May 2023	123
19	28th May 2023	82
20	29th May 2023	0
21	30th May 2023	0
22	31st May 2023	0
23	1st June 2023	0
24	2nd June 2023	0
25	3rd May 2023	0
26	4th May 2023	0
27	5th May 2023	0
28	6th May 2023	0
29	7th May 2023	0
30	8th May 2023	0
Total		14634

Source: Authors computation, 2023

Table 1 present the daily biogas generation from mono-digestion of cereal food waste. The anaerobic digestion (AD) process began on May 10, 2023, and lasted until June 10th, under ambient temperature conditions within the mesophilic range. Biogas production started on the second day of the process, which can be attributed to the mechanical pre-treatment applied to the substrates during slurry formation. The cumulative biogas generated over a retention period of 30 days was 14,634 mL. However, the highest daily cumulative biogas generation occurred on the 5th day, producing 1620 mL. After the 8th day, biogas production decreased and continued to decline until the 20th day when gas production stopped completely.

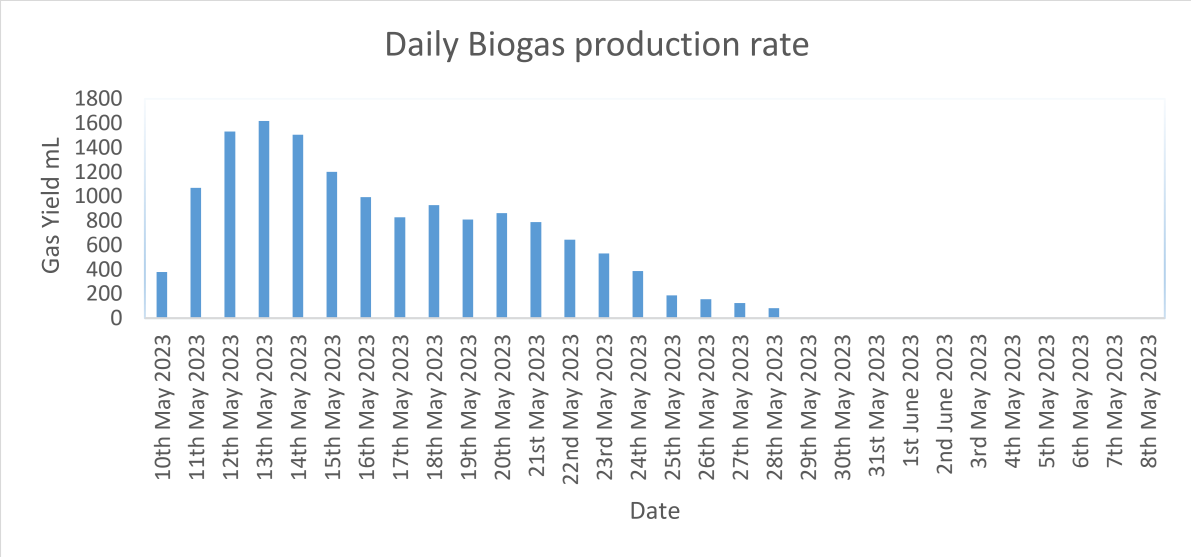

Figure 1: Graphical Representation of Daily Biogas Generation During the Retention Time
Source: Authors computation, 2023

Figure 1 above displays a graphical representation of daily biogas generation during the retention time. The biogas production varies throughout the digestion period. There is a rapid increase in biogas production from the 1st to the 5th day, followed by a minor peak on the 9th and 11th days. Subsequently, there is a decline from the 12th to the 15th day, leading to a gradual decrease until it no gas is produced.

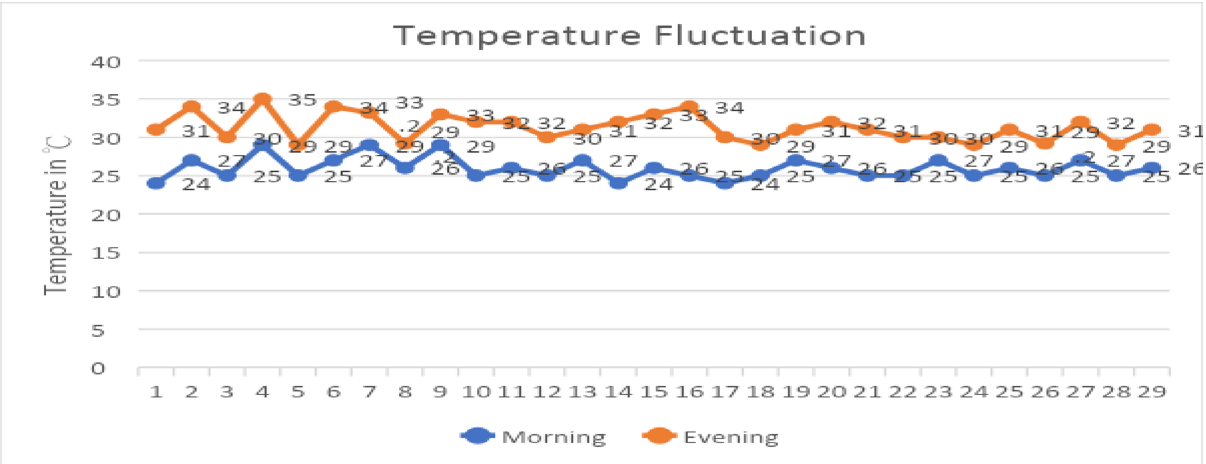

Figure 2: Temperature Fluctuation
Source: Authors computation, 2023

The figure above displays diurnal temperature fluctuations during the digestion process, showing fluctuations between 24 and 34°C, which fall within the mesophilic temperature range.

DISCUSSION

The findings of this study demonstrate the potential of producing biogas from cereal food waste. Anaerobic digestion (AD) of cereal food waste generates 14,634 mL of biogas over a 30-day retention period. This aligns with the work of Atnafu Sema et al. (2020), who reported a high cumulative biogas yield of 1318.83 mL g-1 VSadded-1 obtained from potato peel inoculated with cattle rumen fluid in an anaerobic environment. The study also revealed that the digester operated at optimal temperature conditions for mesophilic digestion, with diurnal temperature fluctuations ranging between 24°C and 34°C. This falls within the mesophilic temperature range, typically between 20°C and 45°C, with an optimum range of approximately 30°C (Wang et al., 2023). Mesophilic digestion is preferred because of its moderate temperature requirement, which can be easily achieved and maintained in various climates and locations. Operating within the mesophilic range facilitates efficient microbial activity and maximizes biogas production from digested organic waste material. Furthermore, pH measurements indicated that the slurry had a pH within the optimal range of 5.5 to 7.3, with only a slight drop after the AD process. Maintaining a pH range of 5.5 to 7.3 is crucial for efficient digester operation under mesophilic conditions.

CONCLUSION

This study highlights the challenges posed by cereal food waste in municipal solid waste (MSW) and emphasizes its burgeoning generation as a critical concern. This study focused on the urgent need for effective waste management, accentuating the adverse environmental and economic impacts of improper disposal methods. This investigation revealed the latent potential of cereal food waste to contribute to biogas production through anaerobic digestion. The significance of addressing food waste within the cereal supply chain is a cornerstone of fostering sustainable food production and consumption practices. Cereal food waste represents a substantial reservoir for biogas production, offering a promising avenue for sustainable waste management. The recommendation to promote the adoption of biogas technology has emerged as a pragmatic solution to enhance food waste management, thereby contributing to environmental sustainability and supporting economic development. This research advocates for a paradigm shift in waste management practices, positioning biogas technology as a pivotal tool in the pursuit of a more sustainable and resource-efficient future.

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