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Short Communication

Anaerobic Co-digestion of Food Waste with Cow Manure

S. Prasad Lohani*

Department of Mechanical Engineering, Kathmandu University, Dhulikhel, Nepal

P A P E R I N F O

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A B S T R A C T

The composition of waste generated in urban areas of Nepal is primarily decomposable which provides scope to convert the waste into energy. In addition, organic fraction of municipal waste is a serious environmental and economic burden in Nepal. In this study, samples from food waste were taken from household of Biratnagar Metropolitan city and Kathmandu University Canteen, Dhulikhel. The samples were analyzed for physical and chemical properties and biogas production. The feed containing 6% TS were analyzed for the potential of biogas production from the canteen food waste (CFW) of Kathmandu University (KU) and household food waste (HFW) from Biratnagar in ambient and control temperature (35 ℃) in a batch reactor. This was also conducted for food waste mixed with 30% cow manure in both the conditions. The average total solid and volatile solid for BFW were 17.7 and 93.2% of TS and CFW were 19.9 and 90.2% of TS, respectively. In every run of the experiment, the volume changes of gas were monitored. Both in the ambient and the controlled temperature, biogas production and yield were higher when 30% cow dung as inoculum was added in both samples. Moreover, the biogas production and yield of CFW was also higher than the BFW at different conditions. This shows that food wastes characteristics and biogas production potential varies depending on the source of the food waste, inoculum added and operating condition for the anaerobic digestion process.

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INTRODUCTION

Biogas typically refers to a gas produced by the biological breakdown of organic matter such as dead plant, animal material, animal faeces, and kitchen waste in the absence of oxygen. The production of biogas from anaerobic digestion has been considered as one of the most energy-efficient and environmentally beneficial technology for bioenergy production [1].

Anaerobic digestion (AD) for treating organic waste can reduce waste volume and enrich plant nutrients in residues [2], which can then be used as fertilizer to return nutrients to the soil ecosystem [3,4]. The Food waste (FW) is one of the important components of municipal solid waste mainly from household waste, food processing waste, canteen and restaurant waste. The accumulation of the FW has become a global issue [5]. It is estimated that the amount of food waste shall increase from 2.78 billion tons to 4.16 billion tons in the Asian countries by 2025 [6].

At present, in Nepal, the food wastes are being directly sent to the landfills. Population density is putting an immense pressure on municipal services to manage the ever increasing wastes. Inadequate solid waste management (SWM) in urban centers poses a serious environmental and health impact [7]. Rapid urban population growth and the continual increase in waste generation intensify the challenges. FW with high concentrations of organic matter (volatile solids/total solids [VS/TS]: 0.8–0.9), high moisture content, and good biodegradability have been regarded as the most promising anaerobic substrates [8, 9].

The AD process depends further on the physical properties of the substrate and the temperature. Dry and fibrous material takes longer to digest than fine-structured and wet substrate. Suitable range of TS contents of the undigested substrate is 7 to 11%. A healthy digestion process shows a pH of 7.0, neutral stage of substrate [10]. Similarly, the gas production also depends on the carbon to nitrogen (C:N) ratio which estimates nutrients deficiency and ammonia inhibition [11]. Optimal C:N ratio in anaerobic digesters are between 16 and 25 [12]. Optimum C:N ratios can be ensured by mixing different feedstock materials, with high (e.g. organic solid waste) and low (e.g. sewage or animal manure) C:N ratios to achieve an ideal C:N ratio level [13]. Microelements like iron, nickel, cobalt, selenium, molybdenum or tungsten are equally important for the growth and survival of the AD microorganisms as the macronutrients carbon, nitrogen, phosphorous, and Sulphur.

Co-digestion helps maintain the factors or necessary

*Corresponding Author Email: *splohani@ku.edu.np* (S. Prasad Lohani)

conditions required for the anaerobic digestion of organic waste [14]. Studies of co-digestion of food waste generally found that inclusion of food waste was beneficial for methane yield [15], while digestion processes with food waste as the sole substrate were often found to be unstable [9]. The beneficial effects of co-digestion are mostly related to a balanced availability of macro- and micronutrient required by the microbial community, optimal moisture content, buffer capacity and dilution of inhibitory or toxic compounds [16].

In the context of Nepal, the major sources of residential energy are fuel wood (86.5%), animal dung (6.5%) and agricultural residue (3.7%), which clearly indicates a huge demand for biomass as household energy [28]. Biogas is a good example of alternative energy which can replace the hazardous fuel sources like burning of firewood. Mainly the female population and children of rural area is highly affected by the smoke produced by firewood. This has led to the increase in respiratory diseases such as ARI (acute respiratory infection) and COPD (chronic obstructive pulmonary disease [17] as well as cut down of large number of trees to sustain the demand of fuel. Huge amounts of organic wastes produced in the household kitchens have a high potential of generating methane gas to sustain themselves. This can be beneficial to families who cannot afford the LPG or electricity.

Considering the factors in which the anaerobic digestion depends, lab-scale anaerobic digesters were setup to test the biogas production from food waste from different places, the effect of temperature on the biogas production and improvement in production through co-digestion, which is the cow manure for this experiment.

MATERIALS AND METHOD

Experimental setup for anaerobic digestion

Biogas production from BFW and CFW were analyzed in laboratory for its physical and chemical properties. The total solid (TS), moisture content (MC), volatile solid (VS), total organic carbon (TOC) and total nitrogen (TN) content were determined by using standard method. Samples for food waste containing TS of 6% were arranged for experiment in ambient and controlled temperature of 35 ℃. The methane potential of food waste only and food waste mixed with 30% cow dung under ambient and controlled temperature conditions were assessed. A 500 ml glass bottle was used as digester fitted with rubber cork. Level pipe was fitted into the cork and checked for leakage. The pipe was also attached to conical flask containing NaOH solution of 1 mole concentration, secured again with cork. Finally, another pipe collected the methane gas into an inverted measuring cylinder where the displaced water indicated the volume of gas collected. Figure 1 shows the laboratory set up of the experimentation. The volume of water that it displaced was recorded daily until the gas remained constant for more than 3 days.

The sample comprises of two different places B being of Biratnagar and C being of Canteen. Each sample comprises of two different feeds one with mono digestion (B1, C1) and one with 30% cow dung (B2, C2). The reactor contained 4 types of feeds with TS 6% i.e., one set for mono-digestion, and the other set for with 30% cow dung for two types of sample. In the second setup, the same procedure was applied but this time, the temperature was controlled and maintained at 35 °C using a water bath.

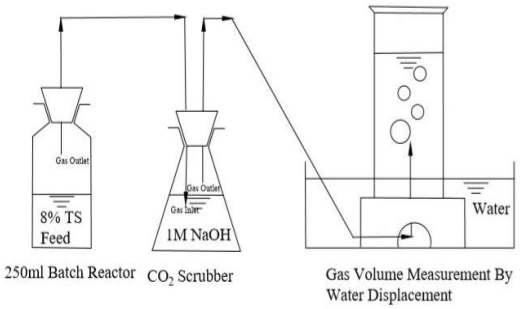

Figure 1. Schematic diagram of Laboratory experimental set up

RESULTS AND DISCUSSION

Physical and chemical properties of the samples

Table 1 presents the TS and VS content of Cow dung, BFW and CFW as well as the C:N ratio of these three samples. It was observed that the C:N ratio of BFW samples were lower than the optimum values required for proper gas production (16-25%). The C:N ratio of CFW were slightly higher than the BFW sample but were still inadequate than the optimum C:N ratio. Table 1 indicates that the food habit of different places affected the characteristics of the food waste. Food waste are perhaps the most variable feedstock as the methane yield value depends not only on the sorting method, but also on the location from which the material was sourced and the time of year of collection [18].

Lower C:N ratio may indicate ammonia accumulation. Optimum C:N ratio is ensured by mixing high C:N ratio substrate, in this case the cow dung, with low C:N ratio to achieve an ideal C:N ratio. Therefore, the food sample was mixed with cow dung for increased gas production.

It was observed that the initial pH of the food waste was found to be mostly acidic. Addition of cow dung as inoculum helped neutralize the pH of the mixed sample (food waste and cow dung), however, still the feed pH was between 6 to 6.2 and C:N ratio was lower than optimum value.

Biogas production

The cumulative gas production of Biratnagar and KU canteen food waste are presented in Table 2. The maximum biogas production was observed in the canteen's food waste with 6% TS mixed with 30% of cow dung and at controlled temperature of 35 °C. This is due to the proper balance of the nutrient's availability to the anaerobes and also a proper temperature in which the anaerobic digestion was successfully carried out.

TABLE 1. Physical and chemical properties of the sample

Sample	TS (%)	VS (% of TS)	CN Ratio	pH
Biratnagar FW	17.7	93.1	15.2	4.5
Cow dung	14.1	87.3	19.1	6.8
KU canteen FW	19.9	90.2	15.9	5.2

TABLE 2. Cumulative biogas production

Sample	Ambient condition	Controlled condition (37°C)
	6% TS	6% TS
B1	190	180
B2	220	255
C1	240	200
C2	270	345

Figure 2 shows that the cumulative biogas production at ambient temperature. The CFW containing 30% cow-dung (C2) produced the highest volume of biogas 270 ml. C1 produced the second highest volume 240 ml. The BFW containing 30% cow dung (B2) produced 220 ml whereas the food waste only (B1) produced 190 ml of gas. This clearly shows the difference in production of gas from food waste collected from different place. Similarly, Figure 3 shows the cumulative gas production of samples containing 6% TS in controlled condition. C2 produced the highest amount of gas 345 ml followed by B2 255 ml. B1 produced the lowest amount of gas 180 ml.

Biogas yield

The biogas yields of the samples were estimated by using VS removal in the anaerobic digestion process and calculated through experimental results of methane production. Using VS, the potential of methane production per gram VS removed was estimated. Table 3 shows the representative biogas yield at ambient and controlled temperatures. The comparison shows that biogas yield of C2 at TS 6% (ambient) is higher than that of B2 at TS 6% (ambient).

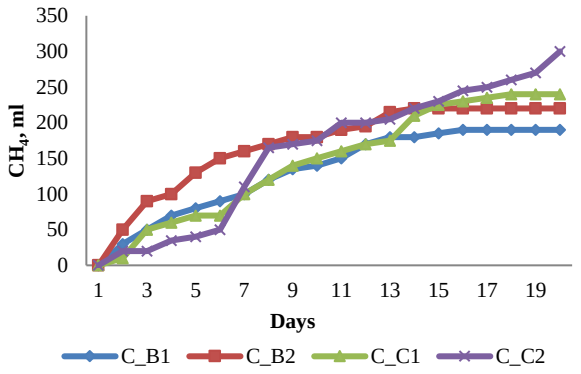

Figure 2. Methane production at ambient temperature

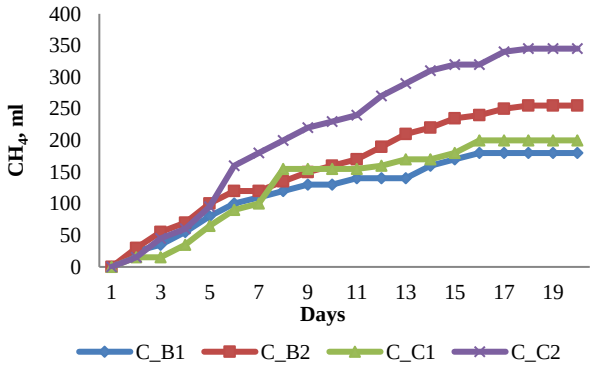

Figure 3. Methane productions at Controlled temperature

TABLE 3. Biogas yield

TS Content	Sample	Condition	Biogas Yield (ml CH_4/g VS removed)
6%	Canteen (C2)	Ambient	347
6%	Biratnagar (B2)	Ambient	320

CONCLUSION

The potential of biogas production from BFW and CFW were assessed in ambient and controlled temperature in food only and food waste mixed with 30% cow dung. From the experiment, it was concluded that the feed which had co substrate of 30% cow dung produced more amount of gas in comparison to the one without cow dung. It was also observed that the biogas production was higher in canteen food waste than that of Biratnagar food waste. This showed difference in food waste characteristics from different places differ amount of biogas production as well. Also, the food waste had acidic in nature and thus co-digestion with other substrate that can neutralize the substrate results in more gas production.

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Persian Abstract

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چکیده

ترکیب زباله‌های تولید شده در مناطق شهری نپال در درجه اول قابل تجزیه هستند که زمینه تبدیل زباله به انرژی را فراهم می‌آورد. علاوه بر این، بخش ارگانیک زباله‌های شهری یک آلاینده جدی برای محیط زیست و تهدید اقتصادی در نپال است. در این مطالعه نمونه‌هایی از زباله‌های مواد غذایی از خانوارهای کلانشهر بیراتنگار و کانتینر دانشگاه کاتماندو ذلیخیل گرفته شد. نمونه‌ها از نظر خصوصیات فیزیکی و شیمیایی و تولید بیوگاز مورد بررسی قرار گرفت. خوراک حاوی ۶٪ TS برای پتانسیل تولید بیوگاز از ضایعات مواد غذایی کانتین (CFW) دانشگاه کاتماندو KU و ضایعات مواد غذایی خانگی (HFW) از بیراتنگار در دمای محیط و کنترل (۳۵ درجه) در یک راکتور ناپیوسته‌ای مورد بررسی قرار گرفت. این فرایند همچنین برای زباله‌های مواد غذایی مخلوط با کود ۳۰٪ گاو در هر دو شرایط انجام شد. متوسط مواد جامد و مواد جامد فرار برای BFW ۱۷/۷ و ۹۳/۲ درصد TS و CFW به ترتیب ۱۹/۹ و ۹۰/۲ درصد TS بود. در هر مرحله از آزمایش، تغییرات حجم گاز مورد بررسی قرار گرفت. هر دو در محیط و دمای کنترل شده، بازدهی و میزان تولید بیوگاز بالاتر بود که ۳۰٪ پهن گاو به عنوان مایع تلقیح در هر دو نمونه اضافه شد. علاوه بر این، تولید بیوگاز و عملکرد CFW نیز در شرایط مختلف بالاتر از BFW بود. این نشان می‌دهد که ویژگی‌های ضایعات مواد غذایی و پتانسیل تولید بیوگاز بسته به منبع ضایعات مواد غذایی، اضافه شدن مایع تلقیح شده و شرایط عملیاتی فرآیند هضم بی‌هوازی متفاوت است.