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Effect of Buffer ($NaHCO_3$) and Waste Type in High Solid Thermophilic Anaerobic Digestion

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ABSTRACT: The large organic matter of solid waste such as agricultural and municipal solid waste offer great potential for biogas production. Anaerobic digestion of green waste-food waste mixture at thermophilic temperature range was carried out with the primary aim of investigating the effect of buffer ($NaHCO_3$) and waste type in the digestion process. For the purpose of initiation of the digestion process, 20 % granular sludge was added to each sample. The level of percentage total solids (TS) and volatile solids (VS) reduction and volume of biogas production was monitored for each sample. From Results obtained, Generally, it showed that cultures containing Food Waste and anaerobic sludge seed in the ratio 4:1 produced the highest volume of biogas of 6700 cc/gVS but with very poor pH stability while cultures containing Food Waste (FW), Green Waste (GW) and anaerobic sludge seed in the ratio 2:2:1 produced the highest biogas production of 5750 cc/gVS and volatile solids destruction with the best pH (6.2) stability when compared with the performances of the other non-chemically buffered cultures studied. The results also revealed the importance of waste type and proportions in natural pH control and regulation.
Keywords: *Anaerobic digestion; Biogas production; Food waste; Buffer.*

INTRODUCTION

Anaerobic biodegradation of organic fraction of solid waste material takes place in the absence of oxygen and the presence of anaerobic microorganisims. Anaerobic digestion is the consequences of a series of metabolic interactions among various groups of microorganism. It occurs in three stages, hydrolysis, acidogenesis and methanogenesis1. The first group of microorganism secretes enzymes that hydrolyses polymeric materials to monomers such as glucose and amino acids. These are subsequently converted by second group acetogenic bacteria to higher volatile fatty acids, H_2 acetic acid. At the last stage, the third group of bacteria, methanogenic, converts H_2 , CO_2 and acetate to CH_4.

It has been reported [2]that food wastes from kitchens and restaurants and green wastes from gardens, parks and forest as well as paper, wood chips and stationeries are some of the organic matter targeted for recycling and exclusion from landfills as required by the EU Landfill Directive (91/31/EC). Food wastes are relatively wet and decompose rapidly[3]. This may lead to high initial acid accumulation resulting in acid pH, thus necessitating the need for chemical buffer to ensure process stability. In comparison green wastes are relatively dry and decompose slowly and consequently with less possibility of high initial acid accumulation. Anaerobic digestion of combined food and green wastes may enhance the degradation of green wastes while slowing the decomposition of kitchen wastes. In addition, green wastes may also serve as a bulking agent[4], thus resulting in a more stabilised and viscous anaerobic digestate. The aim of this study is to investigate the effect of buffer ($NaHCO_3$) addition and waste type in batch thermophillic high solids anaerobic digestion (HSAD) of organic fraction of municipal solid waste. HSAD is reputed to be a suitable method of treating organic fraction of municipal solid waste for optimisation of energy recovery and digestate quality with no requirement for dewatering[5,6]. Thermophilic

HSAD systems have been found to be faster and produce three times more biogas compared to those operated at mesophilic temperatures[6] with less offensive solids[7] and can accommodate higher organic loadings at shorter retention times[8].

MATERIALS AND METHODS

Feedstock

The laboratory simulated feedstock was a mixture of Food Wastes (FW) and Green Wastes (GW). The FW was a blended mixture of food components outlined in Table 1. The GW was a combination of garden waste (grass) and wood chips in the ratio 3:1. The collected green waste components were pre-sorted to remove undesirable materials such as large items and inert materials and to allow more efficient digestion and better digestate quality. The green waste was sieved using 4 mm sieve and milled in a portable kitchen miller. The Anaerobic sludge (AS) seed was obtained from a mesophilic reactor treating paper mill wastewater.

Table 1. Composition and characteristics of food waste

Component	*Weight %*
Cooked pasta	22
Cooked meat	9
Lettuce	11
Carrots	3
Potatoes	44
Milk	11

Preparation of batch cultures

500 g each of five duplicate cultures of food waste, green waste and inoculum (Anaerobic sludge seed) namely A (FW 80 %, AS 20 %); B (FW 40 %, GW 40 %, AS 20 %); C (FW 60 %, GW 20 %, AS 20 %); D (GW 60 %, FW 20 %, AS 20 %) and E (GW 80 % and AS 20 %) as illustrated in Table 2 were prepared in batch digesters (A, B, C, D and E). The batch digesters were three litre capacity bottles. The cultures A_1, B_1, C_1, D_1 and E_1 were buffered with $NaHCO_3$. The chemical buffering agent was added to the cultures as 0.06 % of total solids (TS), as recommended by [3]. Duplicates cultures A_2, B_2, C_2, D_2, and E_2 did not receive $NaHCO_3$ buffer. The total solids content of the cultures at the start of digestion were 19.1 %, 37.4 %, 31.0 %, 44.6 % and 53.0 % respectively for cultures A, B, C, D and E.

Method of analysis

Solids concentrations were determined based on Standard Methods[9]. The pH of the digestates obtained was determined in 1:2.5 (w/v) ratio of digestate slurry to distilled water using METLER TOLEDO MP-230 pH meter. Biogas volume was determined by water displacement using five litre containers. The seed anaerobic sludge was maintained at 55 ^oC for 3 weeks in a basal media in the incubator prior to inoculation. This was carried out in order to adapt the microbes to the higher temperature before exposure to the feedstock. The batch cultures were subjected to thermophilic anaerobic digestion at 55^oC optimum temperature for 15 days during which biogas production, total and volatile solids reduction and pH values were monitored. The waste compositions of cultures in batch digesters are represented in Table 2.

Table 2. Waste Compositions of cultures in batch digesters

Batch Digester	*Food Waste (% by weight)*	*Green Waste (% by weight)*	*Anaerobic Sludge Seed (% by weight)*	*Buffer agent: $NaHCO_3$(g)*
A_1	80	-	20	24.9
A_2	80	-	20	-
B_1	40	40	20	20.43
B_2	40	40	20	-
C_1	60	20	20	20.79
C_2	60	20	20	-
D_1	20	60	20	21.28
D_2	20	60	20	-
E_1	-	80	20	21.28
E_2	-	80	20	-

*Where subscript 1 and 2 indicates buffered and non-buffered cultures respectively

RESULTS AND DISCUSSION

pH variation

Generally buffered cultures showed greater pH stability compared to non-buffered ones. Amongst the sampled cultures, pH resilience was greater in cultures composed mainly of GW as shown in Figure 1. Where FW dominates as in culture A rapid acidification was observed causing excessive accumulation of volatile fatty acids (VFAs) and hence low pH, a condition that may have inhibited methanogenic activity. In contrast cultures with high GW content showed slow acidification, which may be due to the higher proportion of less readily degradable substrates[5]. The pH profile (Figure 1) shows that only cultures A recorded a pH lower than the critical pH limit of 6.1 recommended for good digestion. The pH profile indicates that whilst FW is readily biodegradable and GW is less readily biodegradable, the need for chemical pH correction decreases with increase in the GW proportion of the feedstock. Hence, FW alone is not a suitable substrate for a self-regulating (pH) anaerobic digestion. However, combining FW and GW may increase pH stability as shown in the Figure 1 for both buffered and non-buffered cultures B, C, D and E. The result suggests that waste composition may be a useful tool for pH regulation in anaerobic digestion process.

Volatile solids

Figure 2 shows that comparable volatile solid reductions occurred in buffered and non-buffered cultures. The higher the GW content the lower the VS reduction. The low VS reduction observed in culture A was believed to be due to low pH values in those cultures as shown in Figure 1. The pH values of about 5.0 recorded in both buffered and non-buffered cultures A can adversely affect the digestion process[10].

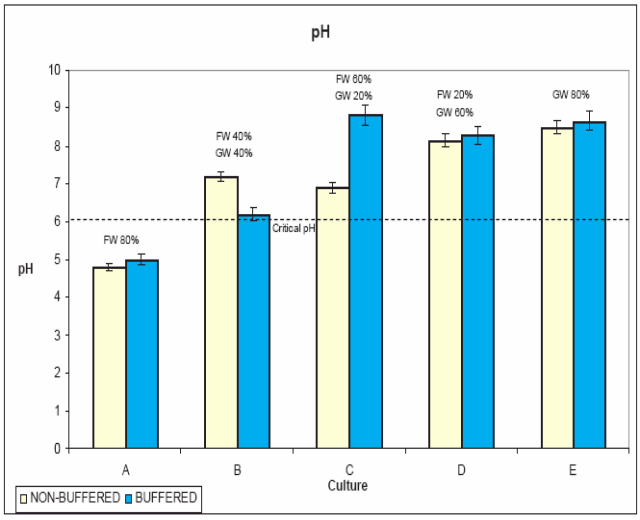

Figure 1: pH comparison in buffered and non-buffered cultures. Dotted lines represent the critical pH. Bars represent standard deviations

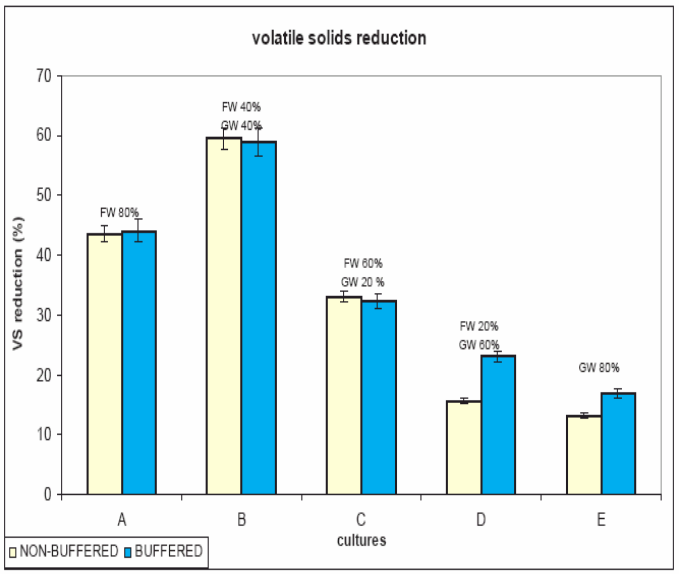

Figure 2: Volatile solids reduction in buffered and non-buffered cultures. Bars represent standard deviation

Biogas

From Figure 3 it also shows that there was gradual decrease in biogas recovery in cultures A to E. The higher the FW content of the feedstock the greater the volume of biogas recovered per organic solids removed. Buffered and non-buffered FW cultures A recorded significant increase in volume of gas production within five days of the digestion beyond which no gas was recorded. This confirmed that process failure took place due to acidification as indicated by low pH (4.8 – 5.0) of cultures A. Buffered and non-buffered cultures B and C produced significant amount of biogas over the two weeks period of the study. Small quantities of biogas were obtained from buffered and non-buffered cultures D and E. Apart from cultures A where process failure was observed, gas production followed the same pattern as volatile solids reduction, that is decreasing with increasing GW content.

Digestate Quality

In general, the moisture content of the digestates increased with increase in the amount of VS reduction, i.e. decreasing with increase in GW content of the raw feedstock. The results suggest that appropriate selection of raw waste composition can reduce the need for post digestion dewatering which may be necessary for the final disposal of the digestates, thus bringing about a significant reduction in the overall waste management costs.

CONCLUSION

The addition of buffer ($NaHCO_3$) based on total solids contents increased the biodegradability of organic fraction of solid waste. It increased the cumulative volume of biogas production and percentage volatile solids reduction in substrate. This research work also shows that Food Waste (FW), Green Waste (GW) and anaerobic sludge seed in the ratio 2:2:1 produced the highest biogas production of 5750 cc/gVS and volatile solids destruction with the best pH (6.2) stability when compared with the performances of the other non-chemically buffered cultures studied. Also little buffering effect is indicated in the case of Food Waste and anaerobic sludge seed in the ratio 4:1 which produced the highest volume of biogas of 6700 cc/gVS but with very poor pH stability this is due to Acetogenesis which lead to accumulation of large amounts of organic acids resulting in low pH value which can inhibit the production of biogas.

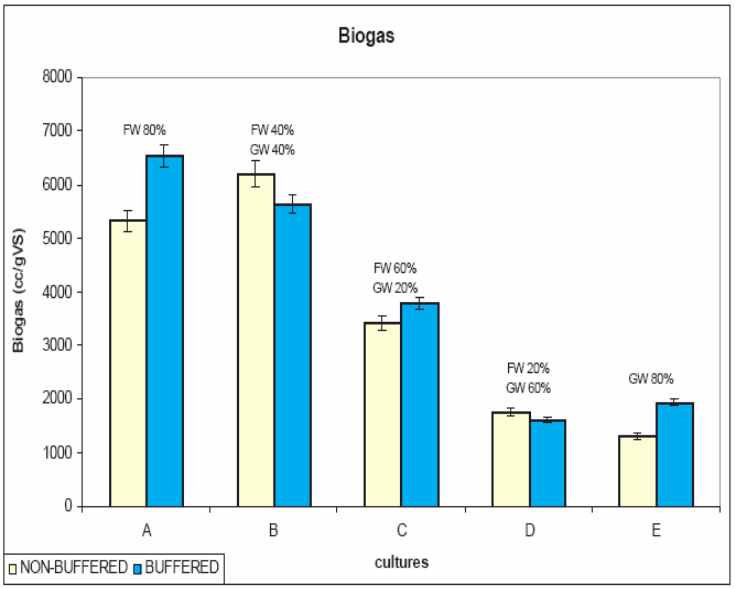

Figure 3: Biogas production in buffered and non-buffered cultures. Bars represent standard deviation

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