THE PRODUCTION OF BIOGAS FROM CATTLE SLURRY, THE EFFECTS OF CONCENTRATION OF TOTAL SOLIDS AND ANIMAL DIET[1]

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Two pairs of young bulls were fed contrasting diets based on grass/ molasses or chopped sugar cane. The faeces and urine from each pair were collected daily and diluted to 1, 3, 5 and 8% total solids (TS). The resulting 8 slurry mixtures were used as substrate for eight 200 1 drum anaerobic. digesters . Biogas production increase, 1inearly with increasing total solids concentration to a maximum of 0.63 m^3/m digester volume/day. This can be attributed to a greater concentration of organic matter being available for degradation to methane and carbon dioxide. The efficiency of gas production however, decreased with increasing TS concentration yielding up to 60% more gas/kg TS at 1% TS than at 8%.

There was a significant difference in the gas production fro. the slurries derived from animals fed the two contrasting diets, with the sugar cane based diet giving consistently higher yields. Physical conditions of pH and organic solids concentration would appear to favour the molasses/grass diet. It is suggested that the higher C:N ratio is the reason for the superiority of the sugar cane diet

Key words: Biogas, anaerobic digestion, total solids, diets.

The majority of work on the factors affecting biogas production has been done on high rate, completely mixed digesters. For developing tropical countries simple plug flow , unmixed digesters operating at ambient temperatures are more appropriate in the majority of cases. One factor affecting both daily production of gas and also important in the economics of digester design and operation is the concentration of total solids in the incoming slurry. Whether the effect of total solids concentration is as significant for unmixed , plug flow digesters as for mixed digesters (Hobson et al 1977) is therefore of importance for determining design criteria.

An anaerobic digester can be likened to a simple animal rumen in which flow rate and substrate are of great importance. The flow rate of degradable substrate can be varied by altering the retention time and keeping the solids concentration constant, or by altering the concentration and keeping the retention time constant (Jewell et al 1976) In the second case a set time is available for the degradation of varying amounts of organic solids.

The substrate itself is the slurry which varies in-physical and chemical characteristics according to the diet of the animal. These characteristics are likely to affect the species and relative population sizes of the groups of bacteria which degrade, acidify and eventually produce gas from the slurry (Meynell 1976), and will therefore have an effect on the quantity and quality of gas produced.

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Materials and Methods

Treatments:

Diets; A. Whole chopped sugar cane ad libitum
750g/d wheat bran
70g/d minerals

B. Molasses/urea 2.5% ad libitum
Grass at 3% body weight
750g/d wheat bran
70g/d minerals

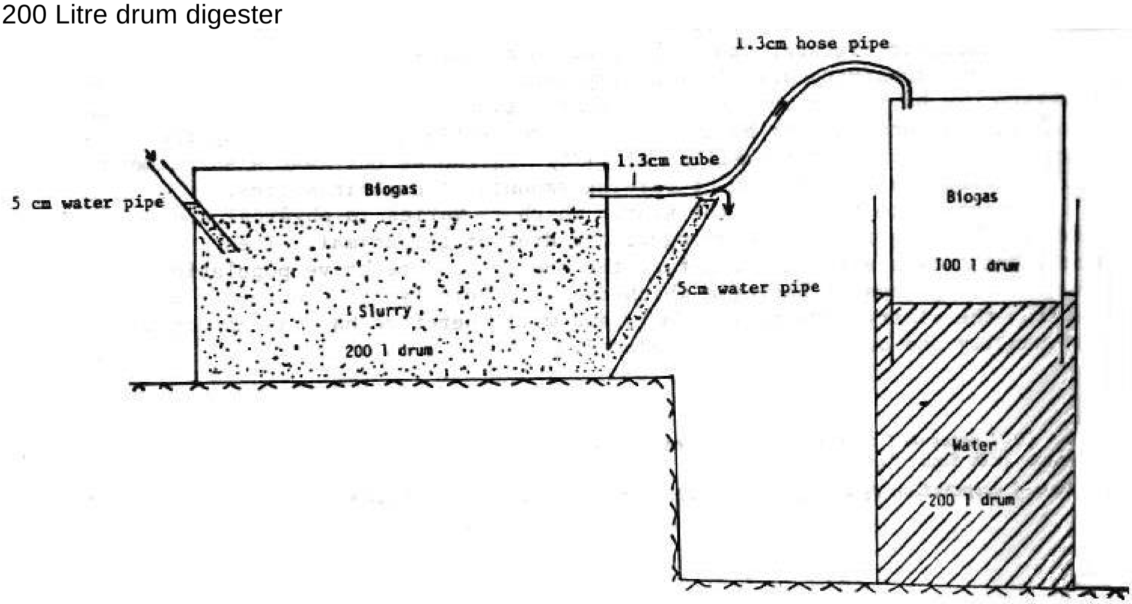
Total solids concentrations; 1%, 3%, 5%, 8% of slurry by weight.

Animals: Four young crossbred bulls of approximately 180kg were used in an unreplicated experiment with two factors (2 x diets and 4 x Total solids concentrations as shown above). The animals were kept in digestibility crates for the duration of the experiment to facilitate daily collection of the faeces and urine.

Slurry: The slurry from each pair of animals was mixed and then diluted with water to give 9 litres of slurry for each of the four concentrations. These mixtures were used to charge 200 litre drum digesters daily.

Digesters: Eight 200 litre drum digesters were built in the farm workshop. Their design is shown in Figure 1. They work on the plug flow principle being unmixed apart from by thermal currents and the disturbance of adding the slurry. The retention time was calculated as 20 days, the slurry volume being 180 litres. There was no heating of the digester contents except by sun light. Temperature of the digester contents had a diurnal range of 25 - 29!C. The gas was collected in 100 litre drums floating on water; There were no scrubbing devices. Gas pressure was approximately 10 cms of water gauge.

Figure 1:
200 Litre drum digester



Measurements: Total production of faeces and urine per animal was measured daily. Dry matter of fresh slurry from each pair of animals was recorded at intervals to give the total solids concentrations of the fresh slurries. Organic solids were determined by heating the dry matter samples in a muffle furnace at 65^{o}C for 2 hours. The weight of ash was subtracted from the dry matter to give organic solids concentration. pH was recorded for the fresh slurries and also for digester contents. The temperature of the digester contents was taken at 8 am and 2 pm to give the diurnal range.

Gas production was measured over a 10 day period, the volume produced every 24 hours being recorded for each gas holder. This was done by measuring the rise of the floating gas holders out of the water by means of a scale painted on the gas holders. A long stabilization period (2 months) was necessary before steady state conditions prevailed for the 10 day sample period.

Results

The physical characteristics of the slurries for the contrasting diets can be seen in Table 1.

The pH of the digester contents as affected by the treatments is shown in Table 2. pH rises for both diets as solids concentrations increase. The pH of digester contents for the molasses/grass diet was consistently higher ($P< 0.05$) than for the sugar cane diet.

Table 1:
Physical characteristics of cattle slurries from two diets

	Sugar cane	Molasses/grass
Weight of slurry/d, kg	16.2	16.1
% Dry matter of fresh slurry	12	14
% Organic solids of fresh slurry	83.8	87.3
pH fresh slurry	7.0	7.7

Table 2:
pH of digester contents

% TS/Diet	Sugar Cane	Molasses/grass
1	6.09	6.82
3	6.83	6.94
5	6.84	7.07
8	7.00	7.16
Mean (SE)	6.84 (0.06)	7.0 (0.05)

Gas production is expressed in Table 3, in two ways: as the volume of gas/ digester volume/day and as volume/weight of total solids. The first is a measure of daily production and the second a measure of the system's efficiency. The daily production for each diet is also plotted in Figure 2 and shows very clearly a linear relationship between gas production/ unit volume and percentage total solids (r^2 = 0.84 and 0.95 for the sugar cane and molasses/grass diets respectively). The difference between the slopes for the two diets is significant (P = 0.08).

Table 3 also shows that at low concentrations of total solids the gas production/ unit weight of solids is greater than at high concentrations. This trend has a moderate correlation (r^2 = 0.73 for both diets) ; there is little difference between diets,

Table 3:
Biogas production at different % total solids concentrations and from slurries derived from different diets

	Gas Production			
	M^3/ M Digester volume/Day		M^3/kg Total Solids	
%TS	Sugar cane	Molasses/grass	Sugar cane	Molasses/grass
1	0.143	0.078	0.25	0.13
3	0.276	0.205	0.18	0.11
5	0.405	0.332	0.15	0.11
8	0.632	0.521	0.15	0.11
	r^2 = 0.84	r^2 = 0.95	r^2= 0.73	r^2 = 0.73
	P = 0.08		P = 0.2	

Discussion

The linear increase in gas production with increasing solids concentration is in agreement with previous work by Hobson et al (1977). This work was however, done with a completely mixed system where all substrate was intimately mixed with bacterial populations. Observations with the fresh slurries used in this experiment showed that fractionation of the solid particles occurred, some rising to the surface and others sinking. This is a study that could be followed up using glass laboratory-scale digesters.

Figure 2 shows that an optimum concentration was not reached for maximum gas production. However practical considerations such as the need to have a sufficiently fluid slurry for flow to, through and from the digester, the need under most conditions for some cleaning water and the likelihood of some entry of drinking water and rain water make the 8% TS level a likely maximum for commercial systems. Moreover the possibility of scum formation and build up of toxic chemicals such as ammonia, volatile fatty acids, heavy metals and microbial by-products are more likely as concentrations increase, particularly for unmixed systems (Albertson 1961; Levi 1951; McCarty 1964; Mosey et al 1971).

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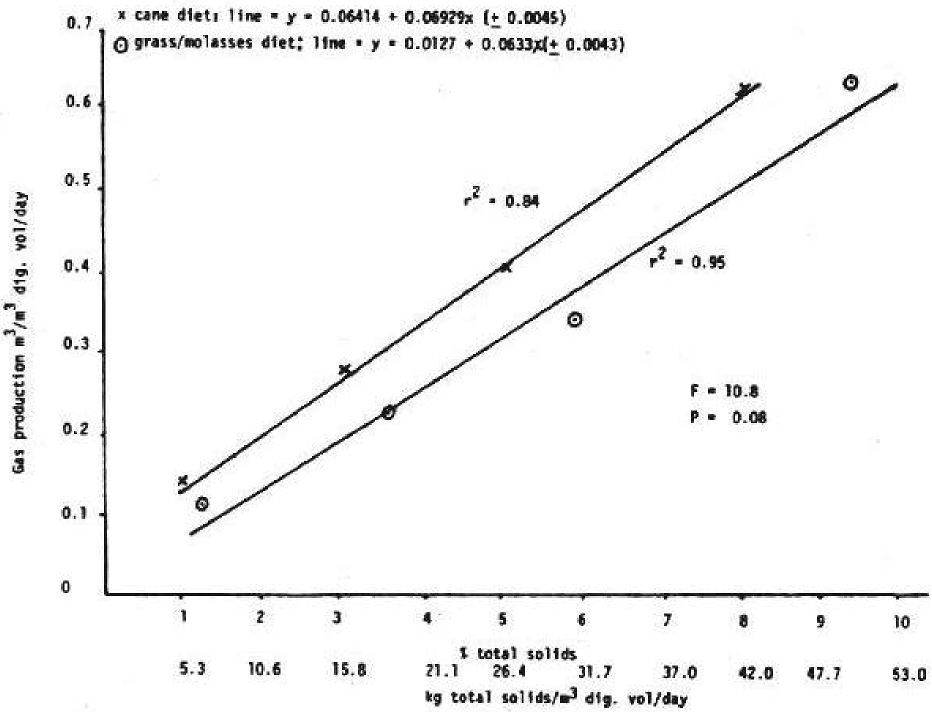
Figure 2
Biogas production for slurries of different % total solids



As concentrations increase and the volumes of slurry entering per day therefore decrease for a particular number of animals, so the size of the digester necessary for a set retention time decreases. This is an important economic point in favour of higher concentrations.

The decreasing efficiency of gas production (volume of gas produced per unit weight of total solids) with increasing solids concentration may be due to intensifying competition as populations increase to deal with the increased amount of substrate. A high pH is normally an indicator of a healthy, productive microbial mixture (Kotze et al 1969; Capri et al 1975) and from this one would have expected the higher pHs at higher concentrations to have been reflected in higher efficiencies of gas production.

The difference in gas production (m^3 /m dig vol/d) between diets is difficult to explain. From the higher organic solids and higher pH of the molasses/ grass diet slurry one would have expected a higher gas production than that for the c hopped sugar cane diet. It is suggested that the cane diet slurry had a C:N ratio nearer the predicted optimum of 25:1 (Sanders and Bloodgood 1965). The C:N ratio affects the amount of N available for the synthesis of carbon dioxide and methane. The balance between these two-elements is of fundamental importance to the productivity of the system. This ratio was unfortunately not measured for either diet but it is likely that the sugar cane die., having a higher fibre content, had a higher C:N ratio. Other possibilities include adverse effects on the digester bacterial populations of the high mineral content and anti-fermentation chemicals contained in the molasses.

Conclusions

There was a linear increase in the gas production between 1% and 8% total solids for both diets. It is suggested that under commercial conditions 8% TS may be nearer the optimum from economic and management points of view.

There was greater production of gas from the slurry derived from a chopped sugar cane diet than from a molasses/grass diet.

Further work is necessary to look at the pattern of fractionation of slurry solids during digestion as a means of predicting the likelihood of scum formation from slurry derived from different diets and the need for mixing of digester contents . This could be done on a laboratory scale with glass digesters.

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