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STUDIES ON BIOCONVERSION

Part III. Laboratory Studies on Utilisation of Bagasse, Rice and Wheat Straws for Biogas Generation

Radia Khatib, Naseem F. Usmani and S. Shahid Husain

PCSIR Laboratories, Karachi-39

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Untreated rice straw yielded 0.038 m^3 gas/kg. solids; bagasse and wheat straw produced negligible biogas. However, pretreatment of bagasse, rice and wheat straw on soaking in water for suitable lengths of time yielded 0.054, 0.057, 0.061 m^3 gas/kg. solid respectively with 34-36% carbon dioxide. During fermentation with untreated rice straw, the acidic phase lasted for 35-40 days and burnable gas evolved after 45-48 days. After treatment of rice straw, the acidic phase shortened to 15-17 days and early evolution of burnable gas (21 days) was also observed.

Key words: Biogas, Bagasse, Rice straw.

INTRODUCTION

The total yield of sugar cane, rice and wheat crops in Pakistan is over 46 million tons/year, [1] generating roughly 31 million tons of residual waste. This waste is in the form of leaves, straws, husks and bagasse. A substantial portion of this waste remains unutilized while some burnt as fuel. This cellulosic rich residue finds very little use and there is no report of its being recycled.

Study on biogas production from residue was initiated as the part of an overall programme to utilize farm wastes as digester feedstock material for biogas generation. This process is one of the more effective methods of converting agrowaste into useful products as well as controlling environmental pollution.

Acharye [2] examined the course of anaerobic decomposition of a variety of plant materials in detail and reported that 60% of hemicellulose, 45% of cellulose and 25-30% of lignin constituents present in rice straw can be decomposed into fatty acids and gases. Hashimoto [3] studied the effect of temperature of straw-manure mixture on the production of methane.

Preliminary laboratory studies by the authors using untreated crop residues (bagasse, rice and wheat straw) either failed or produced negligible yield of gas. Pretreatment of agrowaste prior to fermentation by simply soaking in water for suitable length of time was, therefore, undertaken, which yielded positive results. The present investigations deals with the chemical analysis of untreated and treated bagasse, rice and wheat straws along with bufallo dung and comparative study on utilization of pretreated crop residues for bioconversion (anaerobic) and effect of pretreatment on yield of biogas.

MATERIAL AND METHODS

Rice and wheat straws were obtained from PCSIR Laboratories, Karachi experiemntal farm, while bagasse was purchased from local market. These crop residues were dried in an oven at 105^{o} to constant weights, cut into 1-2 cm. pieces, weighed and soaked in ordinary tap water. Rice straw was soaked for 7 days whereas wheat straw and bagasse required 15 days' soaking time to reach a C/N value around 40/1.

Analysis of both untreated and treated crop residues after drying was undertaken. Total and volatile solids, determined according to the standard methods of analysis [4] and total nitrogen estimated using semi-micro-Kjeldahl techniques [5]. Carbon percentage calculated by dividing percentage volatile solids using factor 1.724, pH of the feed and digested slurry during entire fermentation process was checked weekly on a Jenco digital pH meter model 607.

The gas thus produced was measured on a gas flow meter. Carbon dioxide analysis was carried out by absorption on a potassium hydroxide solution using the orsat technique [7]. Methane was calculated by difference and confirmed by flammablity tests [8].

Preparation of feed for biogas digesters. An appropriate amount of treated crop residues, bagasse rice and wheat straws each were separately mixed with 400 g fresh bufallo dung and water. Similar experiments were conducted with untreated crop residues as well. Bufallo dung was used not only as a source of rumen bacteria but also as nitrogen supplement for balancing C/N values of nitrogen deficient crop residues. Total solid contents were adjusted to 6-8% and pH 7.2 by adding sodium bicarbonate solution in all sets. Feed prepared as above was fermented in separate digesters.

Twenty litres aspirator bottles with 18 litres working capacity (Fig. 1) were used as digesters. The neck of each bottle was secured with a rubber stopper through which 2 bent tubes were inserted. One end of the tube remained above the surface of the feed material and the other was attached to a rubber scooter tube for collecting evolved gases. The second glass tube was inserted deep down into the feed slurry for the periodical removal of samples for analysis.

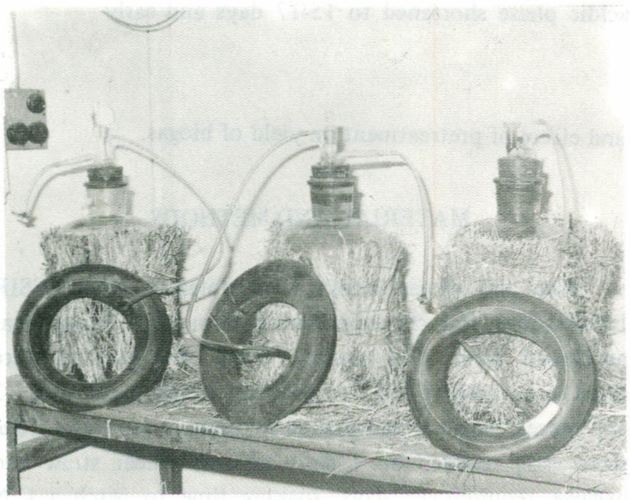

Fig. 1. Aspirator bottle digesters with scooter tube gas holder

Four hundred g of bufallo dung alone was anaerobically fermented in 1 litre flasks as control. This is done to evaluate and compare its effect on gas generation vis-a-vis crop residues.

Fermentation experiments were carried out for 19 weeks on batch scale at 39-40^{0} anaerobically and all aspirators and flasks used as digesters were sealed with silicon adhesives.

RESULTS AND DISCUSSIONS

Untreated rice straws produced 0.038 m^3 gas/kg., whereas treated straw yielded 0.057 m^3 gas/kg. solids added. Initially negligible amount of gases were obtained from untreated wheat straw and bagasse, however on treatment they yielded 0.061 m^3 and 0.054 m3 gas/kg. solids respectively (Table 1). This indicates that crop residues prior to any treatment either failed or produced lower yields. This may probably be due to the presence of lignocellulosic complex structures which act as a barrier, hindering penetration of microbial enzymes into straw cells. Besides, high C/N ratio as noticed in chemical analysis (Table 2) of untreated straws could possibly be another factor hindering fermentation. Optimum C/N ratio required for normal fermentation process ranges between 25/1 to 35/1, whereas C/N ratios as obtained in our experiments were 64/1, 126/1 and 69/1 for untreated rice straw, wheat straw and bagasse, (Table 2). In order to partially break down this lignocellulosic complex economically, straws were soaked in ordinary tap water and exposed to air. Pretreatment of rice straw, wheat straw and bagasse for 7, 15, and 15 days (water soaking) resulted in 41, 40 and 42% reduction in the total solid content as well as their C/N ratios also reduced to 41/1, 40/1, and 43/1 respectively (Table 3). Rice straw requires less soaking time, i.e. 7 days for attaining a C/N ratio of 41/1, probably due to its less complex chemical nature. In order to further reduce C/N ratios of these treated crop residues to optimum range (as required for fermentation process) bufallo dung having 1.6% nitrogen was mixed with treated residues as mentioned above. This thus resulted in formulating feed with C/N ratios 30/1 - 32/1 using rice, wheat straw and bagasse respectively (analysis of bufallo dung, Table 3).

Untreated straws, being dense, usually float on the surface forming impermeable scum disturbing the normal

Table 1. Effect of treatment on crop residue on biogas generation

Crop residues	m^3 gas/kg untreated residue	m^3 gas/kg treated residue
Bagasse	Negligible	0.054
Rice straw	0.038	0.057
Wheat straw	negligible	0.061

Table 2. Chemical analysis of untreated crop residues

	Bagasse	Rice straw	Wheat straw
pH	6.8	7	7
Moisture	5%	4%	5%
Total solids (%)	95	96	95
Volatile solid (%)	81	83	86
Carbon (%)	45	46	48
Nitrogen (%)	0.65	0.72	0.38
C/N	69/1	64/1	126/1

Table 3. Chemical analysis of treated rice straw, wheat straw and bagasse after pretreatment for 7, 15 and 15 days respectively alongwith analysis of bufallo dung.

	Bagasse	Rice straw	Wheat straw	Bufallo dung
Initial weight of straws (untreated)	700 g	1200 g	1750 g	–
Soaking time	15 days	7 days	15 days	–
Total solid reduction %	42	41	40	–
pH	7.5	8.2	7.4	7.3
Voltile solid (%)	74.5	83	48	77
Carbon (%)	41	46	27	43
Nitrogen (%)	0.95	1.13	0.67	1.6
C/N	43	41	40	–

Table 4. Analysis of feed prepared with treated bagasse, rice straw, wheat straw mixed with bufallo dung and bufallo dung alone.

	Bagasse	Rice straw	Wheat straw	Bufallo dung
Initial weight of untreated crop residue (g)	700	1200	1750	–
Bufallo dung(g)	400	400	400	400
Ratio of straw to dung	1.75:1	3:1	4.5:1	–
Total solids	6-8%	6-8%	6-8%	10%
pH	7.2	7.2	7.2	7.2
C/N	32:1	32:1	30:1	23:1

smooth functioning of the process. Pretreatment of straw therefore was an added advantage in keeping straws suspended in the digester fluids, facilitating smooth running of digestion process.

Gases collected from each experimental digester during 19 weeks' fermentation period were periodically measured. On fermentation treated rice straw resulted in 71% conversion of organic matter and yielded 0.057 m^3 gas/kg. solids. The first sign of burnable gas was noted after 21 days of fermentation period with 8-10 weeks' retention time (Table 4). On the contrary, 78% conversion of organic

Table 5. Comparative results on fermentation of treated bagasse, rice straw and wheat straw

	Bagasse	Rice straw	Wheat straw	Bufallo dung
Incubation period (days)	19	19	19	5
Final pH	7.0	7.4	7.1	7.20
Retention time (weeks)	10-12	8-10	10-12	4
Burnable gas noted in (days)	25	21	10	7
Volatile solid (% conversion)	77	71	78	55
m^3 gas/kg solid feed	0.054	0.057	0.061	0.039
Carbon dioxide (%)	34-36	34-36	34-36	36

matter with 0.061 m^3 gas/kg. yield was observed in treated wheat straws. Burnable gas was noted on the 10th day with 10-12 weeks retention time. Bagasse showed 77% conversion of organic matter and produced 0.054 m^3 gas/kg. solids, burnable gas was noted on 25th day with 10-12 weeks retention time. Control (bufallo dung) resulted in 55% conversion of organic matter and yielded 0.039 m^3 gas/kg. solids in 4 weeks. It took 7 days for the evolution of burnable gas and the retention time in this case was only 28 days. Though all the above crop residues can be converted into appreciable amount of burnable gas or methane with 34-36% carbon dioxide, wheat straw appears to be comparatively better for utilization as a digester feed stock material since it produced more burnable gas in relatively less time, with higher percentage of organic matter conversion (78%) than rice straw (71%).

Effect of treatment on rice straw with regard to pH and gas production. Two fermentation phases are generally noted in anaerobic fermentation. The acidic or celluloytic phase where organic matter breaks into fatty acids and carbon dioxide, and the methanogenic phase where the products thus produced are converted by methanogens into methane. The duration of the acidic phase is short in treated rice straws, 15-17 days, and burnable gas is evolved in 21 days, as compared with untreated straws which takes 30-35 days for completion of this phase with a delay in burnable gas production (Fig. 2).

In untreated fermentation process the maximum pH peak (7-7.1) was noted between 7-11 weeks, during which time gas production was optimum (21 litres). In the treated process, the maximum yield of gas (28.5 litre) was noted

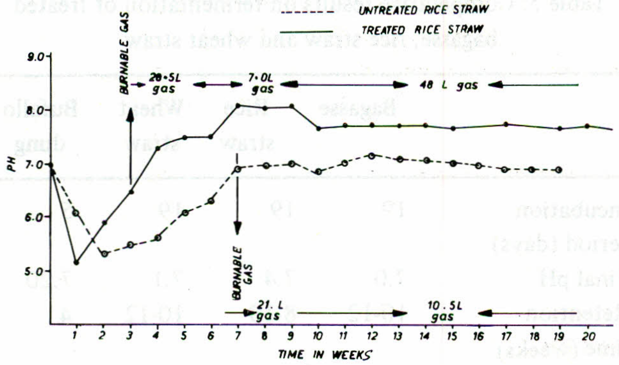

Fig. 2. Effect of treatment of Rice straws with regard to pH and gas production.

between 3.5-5.5 weeks at pH 7.2-7.6. Increase in pH value from 7.8-8.1 as observed during 6-9 weeks in treated rice straws resulted in lower gas yields (7.0 litres only), thus confirming that higher pH values due to ammonia toxicity are detrimental to gas production. However, during the normal course of fermentation this alkalinity was found to be temporary and pH value was again lowered to 7.8 and remained so till the end resulting in restoration of gas production. Total yield of gas as reported above from treated rice straws was 0.057 m^3 in 19 weeks, which could be improved further by the addition of calculated amounts of mild acids, (lowering pH value from 8.1 to 6.8-7.4) during 6-9 weeks of fermentation period. However, in order to avoid risk of overdosing and upsetting natural course of digestion, it was not undertaken.

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