Waste Management & Resource Utilisation

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Dr. Sadhan K Ghosh

Proceedings of 4th International Conference on
Solid Waste Management
January 28-30, 2014, Hyderabad, Andhra Pradesh

Oxford Publishing House
Kolkata

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ISBN 81-86862-49-8

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1st Edition : 28th January, 2014 at Hyderabad

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www.iswmaw.com / www.iconswm.com

Price: Rs. 3,000/-

This e-proceedings
ISBN : 81- 86862 - 49-8

The hard copy
ISBN : 81- 86862 – 50 - 1

Published by:
Oxford Publishing House,
185 (old 39) M.G. Road, Kolkata –700 082,
Ph. 0091 (0) 9831050447 / 033 2402 0954 / 9433857588
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International Society of Waste Management, Air and Water (ISWMAW)

Anaerobic Degradation Pattern of Urban Solid Waste Components

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ABSTRACT *The anaerobic digestion characteristics of ten specific types of the fermentable fractions commonly occurring in urban solid waste (USW) in Bangalore were examined. The rate of decomposition, the pattern of fit and extent and rate of biogas production from these potential feedstocks are analyzed and reported. More specifically, decomposition of vegetables wastes [cauliflower, onion, flat beans, radish and peas] and dominant fruit wastes [banana, sweet lime (Mosamby), orange, papaya and watermelon] were studied. Each of the fruits and vegetables were fermented singly and as mixtures by biological methane potential (BMP) assay to determine the process stability during anaerobic digestion. Typical mixtures of these vegetables and fruits were also fermented anaerobically to determine BMP. At periodic intervals samples of biogas produced were analyzed and their gas composition determined to monitor the decomposition rates and process health. Citrus fruits, orange and sweet lime had 95% and 94% of volatile solid, respectively, followed by peas shells (94%) and onion (92%). Among the ten feedstocks, flat beans, banana and citrus fruits (orange and Mosamby) showed a decomposition pattern similar to each other with a rapid initial decay pattern. The biogas production ranged from 205 to 616 ml/g of TS. Orange and sweet lime showed low gas production levels. Pea shells, flat bean, cauliflower and radish wastes showed a high gas production whereas banana peel had showed a moderate gas production level (c.465 ml/g TS). Such results provided an insight on the extent and rates of the major biodegradable organic fractions of urban solid waste in anaerobic degradation and likely process control required.*

Key words: *Anaerobic degradation, Organic waste, BMP, Biogas, Decomposition rate.*

1. Introduction:

Resource recovery and treatment of organic fraction of waste material has received considerable attention primarily due to the large fraction of organic waste generated in most of the Indian cities and the environmental problems associated with alternative disposal methods. Bangalore city is one among the five metros in India which produces more than 3500 tons per day of municipal solid waste (MSW) and a major fraction is contributed by organic biodegradable waste of 72% (Chanakya et al., 2009). From general observations it appears that approximately, half of the total waste generated in the city generally reaches these authorized waste disposal sites whereas a small fraction of wastes are composted and rest of the wastes are dumped in unauthorized places without any treatment. This approach is permitted as a stop gap arrangement but is environmentally unsatisfactory (Shwetmala et al., 2012).

Possible treatment methods for organic waste treatment are aerobic composting and anaerobic biomethanation. The investigation of decomposition of organic materials is essential for an understanding of the relative worth of different materials. Waste degradation process has also been considered in aerobic composting (Chanakya et al., 2007a, Hamoda et al., 1998) and in anaerobic biomethanation (Barlaz et al., 1989, Chanakya et al., 2007b). Waste decomposition in these processes requires monitoring of biodegradation rates. To determine the waste biodegradation rate and to generate a usable measure for the loss of organic matter, it is necessary to determine process kinetics using experimental data obtained under controlled conditions.

Organic waste type and its chemical composition have long been considered as a critical factor in determining the extent and rate of decay (Singh and Gupta, 1977). The content of pectin, cellulose, hemicellulose and lignin and the C/N ratio are the most important controlling factors in the rate of the decomposition process. All fractions of organic waste substrates do not degrade at the same rate; especially when relative content of pectin, cellulose, hemicellulose and lignin vary from one substrate to another. Typically there are two classes of degradability among the fractions, the rapidly degradable with a higher rate constant and the slowly degradable with a low decay constant. In experimental studies the degradation rates may be split into a rapid early decay followed by a slower second phase of digestion (Chanakya et al, 2009).

Therefore, in this study a two phase first order kinetic model is used to measure the rate of anaerobic decomposition of ten specific types of fermentable fractions commonly occurring in urban solid waste in Bangalore. These estimated biodegradation kinetic rate constants can be used to predict degradation rate of organic matter during anaerobic treatment.

Table 1: Fresh weights of individual samples used for experiment

Waste category	Substrate	Fresh weight (gm)
Vege-table	Cauliflower	153
	Onion	43
	Flat beans	150
	Radish	30
	Peas	217
Fruit	Banana	128
	Sweet lime	100
	Orange	96
	Papaya	184
	Watermelon	575

Table 2: TS and moisture content in waste substrates

Waste Substrate	TS (%)	Moisture (%)
Cauliflower	22	78
Onion	91	9
Flat beans	29	71
Radish	10	90
Peas	22	78
Banana	21	79
Sweet lime	27	73
Orange	28	72
Papaya	14	86
Watermelon	7	93

2. Materials and methods

Ten specific biomass wastes in the larger basket of fermentable fractions of urban solid waste in Bangalore were collected from IISc campus in Bangalore, India. We selected 5 vegetable wastes [cauliflower, onion, flat beans, radish and peas] and 5 fruits waste [banana peel, sweet lime (Mosamby), orange rind, papaya and watermelon] as shown in Table 1. Individual components were collected fresh, within 12 hours of generation.

The TS (total solids) and VS (volatile solids) content of individual samples were determined from fresh samples. Total solid was determined by drying wastes samples at 105±2°C till constant weight. One gram of dried powdered sample was placed in pre-weighed porcelain crucibles and placed in the muffle furnace at 550±5˚C for 3 hrs. Samples were allowed to cool and weighed. The percent weight loss on ignition gave the total of volatile solids or organic matter.

Biological methane potential (BMP) was determined by fermenting powdered dry individual feedstock and their typical mixtures of equal proportion (vegetables, fruits and vegetables-fruits). This test was carried out in 135 ml serum vials with 0.5% (0.25 g/vial) of feedstock with 49.75 ml of inoculum for 60d (Chanakya et al., 2007a). Inoculum was collected from a working biogas digester enriched with methanogens. After addition of inoculum in vials, the air in the headspace was immediately displaced with biogas from a biomass fed biogas plant, the bottles capped. The headspace was flushed with nitrogen and incubated upside down. The head space gas composition was determined immediately and after reaching a stationary phase of gas production for all the vials using a gas chromatograph with a Porapak-Q column connected to thermal conductivity detector. These vials were incubated upside down at ambient temperatures (25±3˚C). The gas production in these vials was determined by downward water displacement at intervals of 1, 3, 5, 8, 11, 15, 20, 25, 30, 37, 45 and 60 days after start. Controls were included to estimate the biogas production evolved from feedstock without addition of inoculum. All incubations were carried out in triplicate, except for feedstock mixtures where one replicate was used for incubation.

The non-linear regression approach was used to estimate the anaerobic degradation pattern of different feedstock. The first-order rate constant (k) was used to determine the rate kinetics of decomposition.

3. Results and discussion

Composition of waste substrate

The TS content ranged from 14 to 29% except for onion peels (>90%) and watermelon (<10%; Table 2). Onion, hyacinth beans, peas, sweet lime and orange have a high concentration of VS (>90%; Fig 1), so these can be good substrates for biogas production. Cauliflower had the maximum content of ash indicating the presence of inorganic constituents which does not lead to gas production (Figure 1).

Biological methane production assay

In this study BMP assay has been defined as a measure of substrate decomposability under typical anaerobic biomethanation conditions and also to estimate the gas production from different category of waste substrate under near ideal conditions of TS, inoculum and physico-chemical conditions.

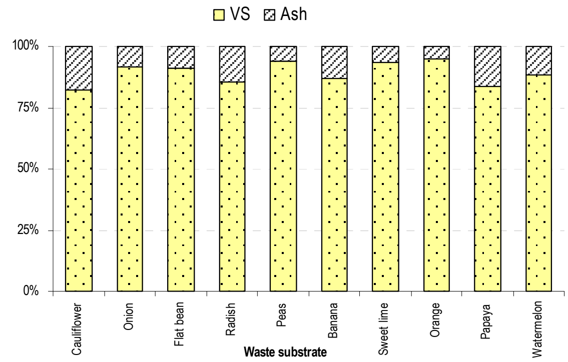
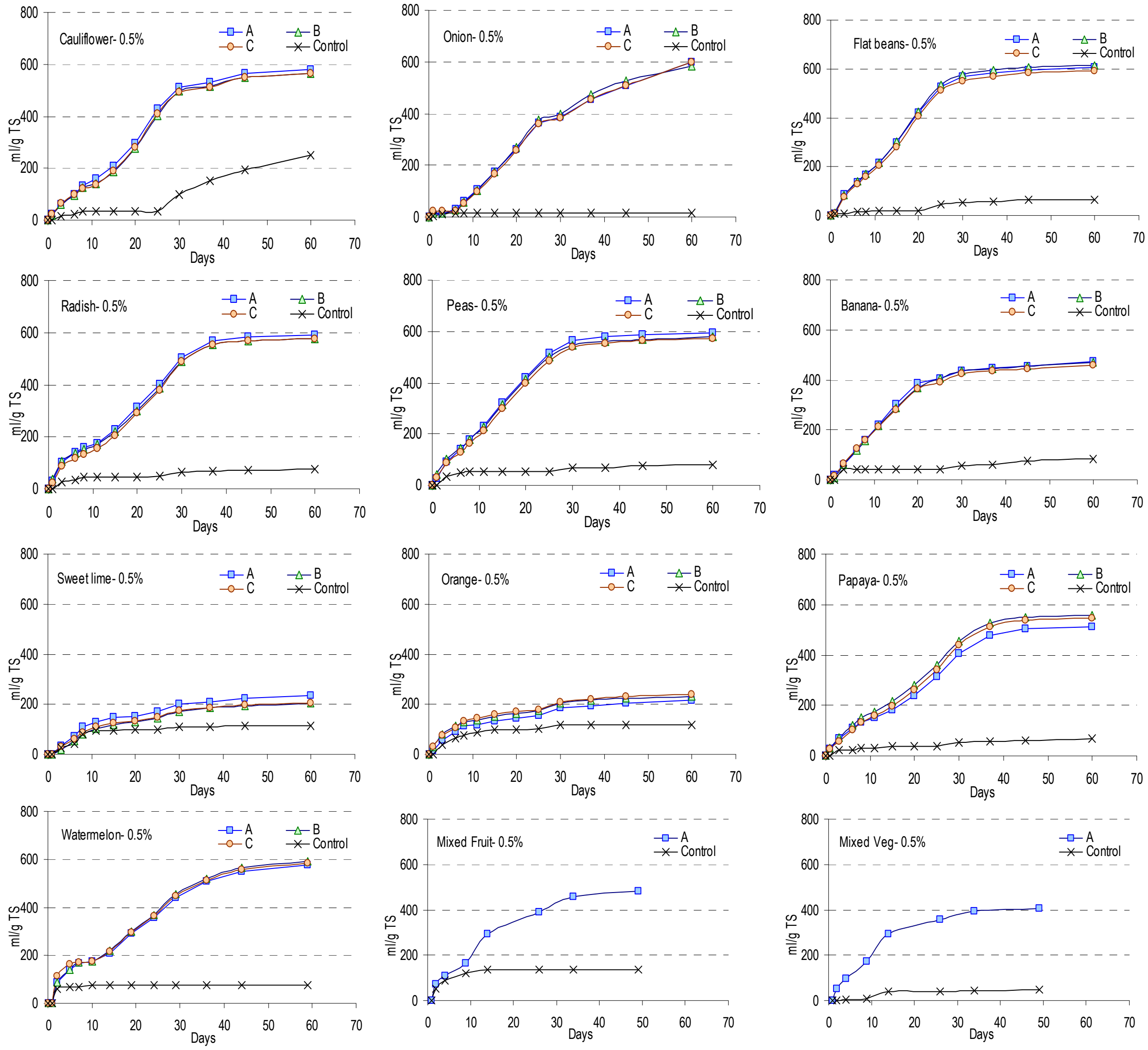


Figure 1: VS and Ash constituents of waste substrate

Table 3: First order rate constants for decomposition of waste substrate

Waste Substrate	Rate constant (day^{-1})	
	k_1	k_2
Cauliflower	0.224	0.006
Onion	0.127	0.016
Flat beans	0.419	0.009
Radish	0.216	0.011
Peas	0.231	0.010
Banana	0.362	0.010
Sweet lime	0.231	0.021
Orange	0.341	0.019
Papaya	0.200	0.015
Watermelon	0.084	0.014
Mixed Fruits	0.126	0.015
Mixed veg	0.172	0.009
Mixed fruits and veg	0.155	0.008

The result of BMP assay at a 0.5% concentration of feedstock is presented in Fig 2. The biogas production ranged from 205 to 616 ml/g of TS. Orange and Sweet lime showed low gas production levels. Citrus fruit peels have a tendency for rapid volatile fatty acid (VFA) formation which interrupts methanogenesis. Pea shells, flat bean (Vicia sp), cauliflower, onion and radish showed a high gas production whereas banana peel showed a moderate gas production level (≈465 ml/g TS). Mixed fruit, mixed vegetable and mixed fruit+vegetable had moderate gas production of 404, 407 and 446 ml/g TS, respectively.



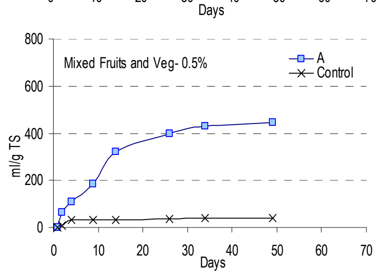


Figure 2: Biological methane potential (BMP) measured during various stages of BMP assay for three replicates (A, B, C) at 0.5% TS concentration of the 13 feedstocks (5 vegetables, 5 fruits, 1 mixed fruit, 1 mixed veg and 1 mixed fruits and veg) studied

The gas composition measurements showed the presence of >50% of methane from most of the waste substrates. This indicates that the rate of acidogenesis and methanogenesis are well balanced. Cauliflower, peas, watermelon and flat beans showed a good methane content (>60%) and it is an indication of absence of VFA induced suppression of methanogenesis. Whereas onion, orange and sweet lime showed poor methane yield of 11%, 22% and 20%, respectively, due to accumulation of VFA and subsequent methanogenic inhibition.

Degradation pattern and rate kinetics

The biogas evolution data revealed that anaerobic decomposition of different organic wastes occurred in two to three phases. The results obtained are shown in Figure 2. Among the feedstocks only banana peel and pea shells showed two phase degradation whereas other feedstocks showed three phase decomposition.

The extent of organic carbon evolved in phase 1 is expected to emerge from the easily decomposable fractions of waste - pectin, starches, etc., whereas phase 2 represents breakdown of the slowly decomposing and/or resistant fractions. Stationary phase is considered as phase 3. Among the ten feedstocks, banana peel, cauliflower leaves and citrus peels had similar kinds of decomposition patterns, involving a very rapid initial decay. In most cases the phases 1 and 2 representing decomposition of pectins and structural materials were merged as phase-I and stationary phase (phase 3) is considered as phase-II. Usually, phase-II occurred between 20 to 30 days of incubation. Flat bean and banana show a single degradation over a 20 to 25 days period. Decomposition of only sweet lime and orange waste occurred with a second phase after 8-12 days of incubation.

BMP of waste degradation was assumed to follow the first-order rate of decay, as solid waste degradation in composting and landfill also follows first order kinetics (Hamoda et al., 1998; Qdais et al., 2008). The first-order rate constant was determined using gas yield on either 1st day for different categories, whereas 3rd day is considered for sweet lime and watermelon as gas production has started from 3rd day of incubation. For all kinetic constants, the linear correlation of data was assessed by the coefficient of determination (R^2). Decomposition rate constants k_1 and k_2 corresponding to phase-I and II were determined for various waste substrate (Table 3). Among the ten feedstock, flat bean showed a most rapid initial decay with k_1 and k_2 value of 0.419 and 0.009 day^{-1}.respectively, whereas onion peels showed a very slow initial decay with k_1 value of 0.127 day^{-1}, probably due to high sulphur content (H_2S). Thus kinetics constants can be used to know the time required to oxidize the readily and slowly degradable fraction of organic waste substrates.

Conclusions

Anaerobic degradation of organic waste is a biological process representable by two phases of degradation that can be modeled by first-order kinetics. Rate of degradation of phase I is much faster than phase II degradation. The rate constants and potential biogas formation at each phase of decomposition varied widely among different waste categories and indicate potential of VFA accumulation.

References

1. Barlaz M.A., Ham R.K., and Schaefer D.M., 1989. Mass-balance analysis of anaerobically decomposed refuse. J. Environ. Engg., 115, 1088-1102.
2. Chanakya H.N., Ramachandra T.V., Guruprasad M., and Devi V., 2007a. Micro-treatment options for components of organic fraction of MSW in residential areas. Environmental Monitoring and Assessment, 135, 129-139.
3. Chanakya H.N., Ramachandra T.V., and Vijayachamundeeswari M., 2007b. Resource recovery potential from secondary components of segregated municipal solid wastes. Environmental Monitoring and Assessment, 135, 119-127.
4. Chanakya H.N., Sharma I., and Ramachandra T.V., 2009. Micro-scale anaerobic digestion of point source components of organic fraction of municipal solid waste. Waste Management, 29(4), 1306-1312.
5. Chanakya H.N., Ramachandra T.V., and Shwetmala, 2009. Towarsd a sustainable waste management system for Bangalore. 1st International Conference on Solid Waste Management and Exhibition on municipal services, Urban development public works, IconSWM 2009, Kolkata, India.
6. Hamoda M.F., Qdais H.A., and Newham J., 1998. Evaluation of municipal solid waste composting kinetics. Resources, Conservation and Recycling, 23, 209-223.
7. Qdais H.A. and Alsheraideh A.A., 2008. Kinetics of solid waste biodegradation in laboratory lysimeters. Jordan Journal of Civil Engineering, 2(1), 45-52. Shwetmala, Sangunni K.S., Chanakya H.N. and Harish B., 2012. Experience of involving school students in providing experiential learning and long-term participation in reducing solid wastes generation in Yelahanka New Town – Karnataka, 3rd International Conference on Sustainable waste management – municipal, industrial and agricultural, IconSWM 2009, Mysore, India.
8. Singh J.S., and Gupta S.R., 1977. Plant decomposition and soil respiration in terrestrial ecosystems. Bot. Rev, 43, 449-528.