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STUDIES ON BIOCONVERSION

Part II. Conversion of Domestic Garbage into Compost Using Three Different Techniques – A Comparative Study

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Domestic refuse from Orangi township communal bins contains 55-56 % organic vegetable matter. Three aerobic composting methods, Chinese, Windrow and Forced Aerated Pile techniques were applied for the conversion of this organic matter. Employing these techniques almost 2/3 garbage was converted into compost. On analysis the composts obtained by the above methods did not show any significant difference in carbon, nitrogen and phosphate content. The Chinese method requires less time, is more cost effective and comparatively simple.

Key words: Garbage, Bioconversion, Compost.

INTRODUCTION

Utilization of domestic refuse into composts, purely for monetary purpose, has gradually changed over the years and the process of composting is now evaluated in terms of its complete social benefits. Previously, the evaluation of compost was primarily judged for its nitrogen, potassium and phosphorus value, however, of late emphasis has been on environmental protection and improvement in soil quality.

Flintoff [1] reported increase in refuse by 1 ton/family/year in developed countries. Metropolitan Karachi generates one kg. refuse/capita per day (excluding industrial wastes) and with more than six million population, therefore, 5000-6000 tons of garbage/ day is produced. One-third of this solid waste is removed by municipal and other civic agencies, leaving behind a large proportion in the form of decaying heaps creating social and environmental problems. Recently, Beg *et al* [2] showed variation in garbage composition of different localities of Karachi based on eating habits and living standards of residents, and they suggested that it may be suitable for conversion into compost employing aerobic disposal techniques.

Disposal methods generally employed include dumping and incineration of garbage on waste lands or on edge of dry river beds. Presently, a commercial composting plant based on the Dano system [3] is in operation in the suburbs of Karachi which is not sufficient to take care of disposal of entire city garbage.

The present study has, therefore, been undertaken to develop, select and suggest a simple and economically feasible technique for composting, so as to eliminate pollution, create hygienic conditions, develop green belts and vegetable gardens. Besides, non-compostible wastes after completion of composting process become conspicuous and easy to sort. This will provide material for recycling and an extra income generating source, thus raising socio-economic status. Physico-chemical analysis of Orangi domestic refuse, utilization and subsequent comparison of two rurally and one urban(mechanical) oriented technique of composting, chemical and biological evaluation of compost thus obtained and its subsequent effect on the yield of plants was undertaken.

MATERIAL AND METHODS

Orangi township – a Katchi Abadi (squatter settlement) spread over 2000 hectre [4] and inhabited by 600,000 people, settled in substandard conditions, was preferred for this study as ratio of non-compostible material like tins, plastics, etc. were less due to poor socio-economic conditions and scavanging from refuse bins. Extensive sorting and shredding of refuse prior to composting was, therefore, not done.

Three truck loads of garbage (each truck of 1 ton capacity) from houses, dumped into communal bins, was collected and brought to the laboratories. A representative sample of 120-125 kg was drawn out using quartering technique [5] from each truck load for analysis.

Physical analysis of each garbage sample was carried out by sorting out different ingredients and weighing seperately. To carry out chemical analysis, dried refuse samples, after determining moisture were ground to homogeneous powder in a ball mill, and analyzed using methods described by Bhide [5]. Samples from each truck were separately analyzed and average values calculated. Microbiological analysis of refuse for total bacterial count was made on nutrient agar plates incubated at different temperatures. Enteric bacteria were determined on S.S. Agar and EMB agar medium. Fungi and actinomycetes were enumerated on Czapeck's Dox and Sabourad's agar.

Isolation and detection of intestinal parasites was made by homogenizing the refuse sample in 0.2 % sodium hypochlorite. After repeated washings and centrifugation, the sediment was microscopically examined on a haemocytometer slide.

Preparation of feed. Prior to feed preparation no extensive sorting or shredding of the material was done. Only large pieces of material like polyethylene rags, leather bags, shoes, newspaper, broken glasses and earthenware etc. were removed by manual random picking. To balance and supplement nitrogen deficiency as well as optimize C/N value of refuse feed, 20 % poultry droppings (chemical composition of poultry droppings was predetermined according to methods described earlier) were added along with sufficient water to have a feed of 29/1 – 30/1 C:N value with 48-50 % moisture content. This feed was then subjected to aerobic composting techniques [6] described below,

(a) *The Chinese method.* Being rurally oriented, it involves placing of bamboos in a criss-cross manner over a bed of straw. Eight hundred and fifty kg. feed dumped over this bamboo structure was then plastered with mud/straw mixture. Bamboos were withdrawn once the plaster had dried leaving behind holes for natural aeration. A thermocouple was burried deep in the middle of the mound before plastering to monitor the temperature and the working of the process.

(b) *The Windrow method.* Windrow or open composting system, also known as the Indore system is simple and rural oriented. Eleven hundred kg. and 2 metres long and 4.5 metres high feed was prepared and subsequently placed on open ground. On every fifth day, the dried surface of the refuse feed mound was watered and the pile overturned. This was accomplished in such a way that the inner layer which was in an anaerobic state was brought over to the surface for exposure to air, and the outer aerated layer was burried inside. This turning over process was thrice repeated and the temperature monitored by thermocouple.

(c) *The Forced aerated pile system.* A mechanical system based on B.A.R.C. (Beltsville aerated rapid composting) system of the United States is quite similar to the windrow techniques except that instead of turning over the refuse pile manually (for aerating garbage feed), aeration was accomplished by a three horse-power air blower, connected to especially arranged perforated G.I. pipes in the manner of sub-surface drains. Three thousand six hundred kg. refuse feed, forming a layer of 1-2 metres height was dumped over these pipes and then covered with straws for insulation. To monitor the temperature thermocouples were burried at different points to check and ensure the overall efficient functioning of the process.

Composts thus produced by three processes were analyzed for chemical composition and microbial flora evaluated to determine the inhibition of pathogenic microorganisms.

Study of composts on plant growth. Seeds of *Petra hybride* (Gourd or Dish cloth) were sown in 1 m^3 size plots in 2 sets (in duplicate). One set of plot was given 2.5 Kg. cowdung (dry wt.) manure whereas to the other set, garbage compost and cowdung in 1:1 ratio was added. The yield of crop from each set of experiments was weighed separately and the data analysed.

RESULTS AND DISCUSSIONS

The garbage from Orangi town had an average density of 246 kg/m^3 and 55-56 % organic vegetable matter (Table 1). This high ratio of vegetable matter in the refuse is in accordance with the fact that in developing countries due to consumption of fresh and unprocessed foodstuffs (unlike Western countries where food is mostly processed and packed in tins) organic content in garbage is generally high.

The organic refuse had 16.3 % moisture, 83.7 % total solids, 43 % volatile solids, pH 8.6 and C/N ratio 39. This analysis (Table 1) suggests that Orangi refuse is suitable for employing aerobic composting technique. In order to balance the slightly high C/N value, poultry droppings – a suitable nitrogenous waste and easily available in vicinity, was supplemented in feed. Chemical analysis of poultry droppings, as well as feed prepared by mixing garbage with 20 % poultry droppings is given in Table 2.

Analysis of feed thus prepared had 48 % moisture content, 42-43 % volatile solids, pH 8.1 and C/N 29. This feed was subjected to three techniques of composting. Twenty-one days, 30 days and 35-37 days were required for the Chinese, windrow and forced aerated pile compost-

Table 1. Physico-chemical analysis of Orangi refuse

		Types of material	% Composition
1.	Physical analysis	Density	246 kg/m^3
		Organic matter (putrescible matter)	55 %
		Sand and ash	9.1
		Stones	8.5
		Rags	8.7
		Paper and card boards	4.9
		Wood	1.46
		Glasses and ceramics,	3.46
		earthen pots etc.	3.46
		Plastics	1.76
		Bones	0.9
		Metals	0.23
		Miscellaneous	3.5
		Chemical composition	Composition (%)
2.	Chemical analysis	Calorific value	1320 kcl/ton dry wt.
		pH	8.6
		Moisture content	16.3
	(Analysis based on dry wt.)	Total solids	83.7
		Volatile solids	43
		Carbon	24
		Nitrogen	0.62
		C/N	39

Table 2. Chemical analysis of poultry dropping and feed.

Analysis	Poultry droppings average analysis	Feed (Garbage + poultry droppings (20 %) Avg. analysis
pH	7.6	8.1
Moisture	27 %	48 %
Total solids	73 %	52 %
Volatile solids	43 %	42-43 %
Carbon	24 %	24 %
Nitrogen	2.10 %	0.83 %
Carbon/Nitrogen	11.5	29

ing systems with 69 %, 78 % and 64 % yield of composts respectively (Table 3). The above results show that by employing any of the above methods, approximately 2/3 of refuse can be converted into compost. High temperature recorded in (Fig. 1) Chinese (65-66°), windrow (75-78°) and forced aerated pile system (69-70°), may be the major factor involved in inhibiting pathogenic microbes. Table 4 indicates reduction in total, fungal and actnomycetes count, and complete inhibition of pathogenic bacteria as evident from enteric count. Encysted and motile protozoans, present in the initial feed, were also absent in composted material. This suggests that the compost obtained through these techniques is pathogen-free as high temperatures generated during fermentation were above the thermal death points of most pathogens [7].

Table 3. Comparison of Chinese, Windrow and Forced Aerated Composting methods with regard to yield and other factors.

Sr. No.	Parameters	Chinese system	Windrow system	Forced aerated pile system
1.	Total time required	21 days	30 days	37 days
2.	Yield of green compost	69 %	78 %	64 %
3.	Undigested vegetable matter	4.2 %	3 %	6.6 %
4.	Uncompostable material (after fermentation)	26.5 %	19 %	29.5 %

Table 4. Microbiological analysis of initial feed and compost produced employing Chinese, Windrow and Forced Aerated Pile techniques.

	Feed	Compost from the Chinese method	Compost from Windrow method	Compost from BARC method
Total bacterial count	8.6 x 10^7	6.3 x 10^6	4.5 x 10^5	5.5 x 10^6
Enteric count	6.3 x 10^3	0	0	0
Actinomycetes count	3.5 x 10^5	1.6 x 10^6	4.3 x 10^3	4.2 x 10^5
Fungal count	7.5 x 10^6	3.3 x 10^5	8.0 x 10^6	7.4 x 10^5
Parasites (Protozoans)	Few motile and encysted protozoans present.	0	0	0

Composts obtained from these techniques were almost similar in their nutritive value (Table 5). The pH

Table 5. Chemical analysis of green composts and cow dung.

	Compost from the Chinese system	Compost from the Windrow system	Compost from the Forced Aerated system
pH	7.25	7.8	7.2
Moisture	17 %	12 %	18 %
Total solids	83 %	88 %	82 %
Volatile solids	30 %	19 %	27 %
Carbon	17 %	10.0 %	15 %
Nitrogen	1.3 %	1.22 %	1.5 %
C/N	12.8	8.1	14.3
Potassium	1.2 %	1.2 %	0.7 %
Phosphate	0.42 %	0.42 %	0.46%

(Analysis based on dry weights)

Table 6. Percent of non-compostable material obtained after completion of composting processes.

Composting system	·Glass ceramics and stones	Wood	Bones	Plastics metal rags, leather
Chinese system	58.9	6.6	2.96	31.4
Windrow system	70.5	13.7	2	13.5
Forced Aerated Pile system	68	4.66	0.49	26.64
Average from 3 Composting systems	65.8	8.32	1.8	23.8

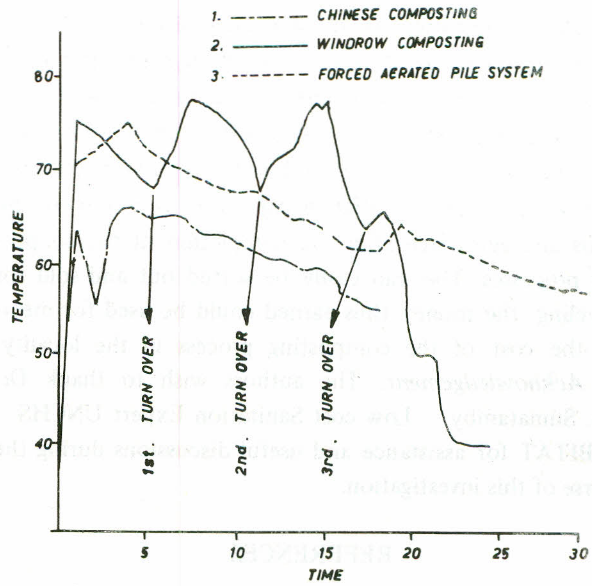

Fig. 1. Theromogenesis of composting process.

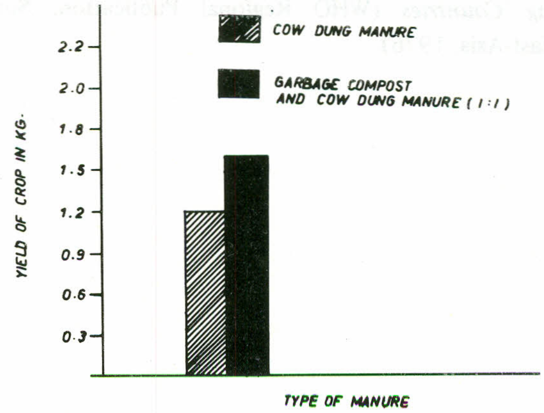

Fig. 2. Effect of compost on yield of *Petra hybride* (gourd) crop.

value ranged from 7.2–7.8, nitrogen and phosphate values were fairly close and C/N ratio was stabilized between 8.1–14. Potassium was slightly low in the compost from forced aerated pile system. Effect of composts on plants show that when mixed with cow dung manure (1:1), resulted in 25 % increase in the yield of *Patra hybride* crop (Fig. 2). In addition to nutrients like nitrogen, potassium and phosphates composts also possess water holding capacity, improve soil structure, increase buffering power of the soil and when mixed with cow dung, increase and improve availability of nutrients to the crop which may possibly be the reason for this 25 % increase in the yield of crop.

The Chinese and Windrow systems are simple to operate and do not require any specific equipment, whereas the forced aerated method is mechanical, expansive and requires large volumes of refuse for treatment. Another disadvantage of this process is the requirement of electricity which at times may not be available due to load shedding, thus disturbing the process. The windrow system of composting needs skill in turning over the mass which should be done in such a manner that every part of the matter comes in contact with air. Moreover moisture loss due to surface exposure has to be adjusted before each turning. Frequent turning with addition of water requires manual labour quite often vis-vis the Chinese process, where the whole refuse mass is insulated with mud plaster resulting in the prevention of water and heat loss. This probably may be one of the reasons why less time is required for the Chinese process.

Time required for completion of composting process can further be shortened if detailed sorting and uniform shredding of refuse mass is to be effected. However, this was discouraged in this study so as to prevent the risk of contact of human hands with pathogens.

The Chinese method of solid waste disposal technique is recommended as it is economical, hygenic and more suitable and compost thus obtained can be used for developing kitchen gardens and green belts in the surrounding areas. Besides, 25 % of the total non-compostable material in (listed in Table 6) initial garbage feed becomes conspicuous and germ free after the completion of the conposting processes. The can easily be sorted out and sold for recycling. the money thus earned could be used for meeting the cost of the composting process in the locality.

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