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Recycling of Biomass Waste from Herbal Pharmaceutical Industry by Windrow Composting

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Abstract- Herbal solid waste being generated by pharmaceutical industry has been mixed with cow manure and thereafter composted by windrow method. Physico-chemical parameters were monitored before and after 60 days of composting process. pH and EC values of 7.49 and 2.97 respectively were found within the acceptable limit in the finished compost whereas C: N ratio decreased from 26.10 to 10.42 and approximately 42.39 % of the total C was lost during the whole period of composting. Moreover, considerable amount of macro and micro nutrients were found and heavy metals were detected within the permissible limit. Hygienization was determined by disappearance of faecal coliforms and S*almonella* after composting process. Total number of faecal coliforms significantly decreased from $2.1x10^9$ to $1.5x10^2$ while *Salmonella* was eliminated and not found in the finished product. Marked increase in the seed germination (%G) and germination index (GI) values at the final stage has been found while phytotoxicity was observed only in the initial stage of composting.

I. Introduction

Increasing difficulties in the management of solid waste generated through a variety of human activity has become a significant problem all over the world [1, 2]. Waste stream comprising of food and agricultural wastes, animal manure, paper products, municipal organic waste, sewage sludge and domestic waste [3, 4] are the potential sources of organic matter and play a key role in achieving sustainability in agricultural production, as all these provide a good source of nutrients to improve soil productivity [5].

Direct application of organic waste as such in the field has many draw backs as un-composted organic material having wider C: N ratio causes immobilization of nitrogen and hence nitrogen becomes unavailable to the plants. Composting is the natural process of rotting or decomposition of organic matter by microorganisms under controlled conditions [4], it is regarded as the most common method used for recycling the organic fraction of solid wastes by reducing biodegradable waste and transforming organic portion of solid waste into an stabilized agricultural amendment, having potential of mitigating the deficit of organic matter encountered in many agricultural soils, probably due to the low use of organic materials in the fertilization programmes of crops [6, 7].

In Pakistan, huge amount of such solid waste has been generated by the herbal pharmaceutical industry and it is dumped without any pre-treatment into the municipal landfills, resulting in loss of potentially valuable organic material and also fair amount of transportation cost is incurred on its disposal. An alternative and profitable disposal method is therefore required to overcome the problem.

Present study has been initiated for recycling Herbal Pharmaceutical Solid Waste (HPSW) and mixed it with cow manure by windrow composting process for its conversion into a value added product. Physico-chemical, microbiological and phytotoxic characteristics at the initial and final stage of composting were evaluated.

II. Results and Discussion

Considering the problems in managing the huge quantity of HPSW being generated by herbal pharmaceutical industries and also its disposal, its bioconversion into value added profitable product is of vital importance. Present study indicates that it is possible to recycle HPSW into a valuable product that can be utilized in agriculture.

Results of daily temperature record showed that the temperature of the compost pile at day 2 reached up to 70°C and this indicated the thermophilic phase of the composting process, thermophilic phase with temperatures above 45 °C was lasted for a bit over three weeks and during this period 70 °C has been recorded as the peak reading. Some researchers have suggested that temperature higher than 45 °C not only maximized the degradation rate but also eliminated pathogenic and allergenic microorganisms [6, 13]. After day 23rd, the temperature began to decrease gradually and at the end of fifth week average temperature inside the windrow reached at ambient level i.e. 33°C, after that the temperature was remained unchanged in spite of watering and overturning of the windrow.

Physico-chemical properties of the raw materials, compost feed and finished compost are depicted in Table 1 &2. Optimum pH values described earlier for composting are in the range of 5.5-8.0 [14]. In the present work initial pH of compost feed was slightly acidic which increased with the progress of composting process, it causes the degradation and mineralization of organic compounds that resulted in release of ammonia [15, 16]. Final stage composting material showed pH 7.4 which was within the acceptable limit 6.9-8.0 and hence the application of these materials to soil may support the soil micro flora [17].

Compost conductivity is of great importance from agricultural view point; it can be a limiting factor for plant growth and seed germination [6]. Similarly like pH, EC levels were also increased with the progress of present composting process, this increase in EC levels during composting is an indication of release of cations as a result of organic substance degradation [18]. Finished compost showed the EC value 2.97 mS/cm which is acceptable for the agricultural use [19].

The initial C: N ratio of our composting material was 26.10. Researcher found that C: N ratio between 25:1 and 35:1 is optimum to initiate composting process [20]. Usually during organic matter composting C: N ratio decreases in start due to the Co_2 losses and then stabilizes later on [21]. Similarly during this 60 days composting process C: N ratio decreased rapidly and stabilized to 10.42, indicated the good biological stabilization and preferred value for compost maturity and application of the compost to cropping systems [22].

Minerals and heavy metal concentrations have also been estimated in the initial and final stage composting materials and it was noted that concentrations of all elements (macro, micro and heavy metals) such that K, P, Na,Ca, Mg, Fe, Cu, Mn, Zn Cd, Pb, and Cr were increased and higher in the finished product as compared to the starting compost feed material 20.20, 14.4, 3.72, 51.07,7.59,(g/kg), 1253, 25.04, 820, 96.05, 1.81, 11.13 and 5.61 ppm respectively (Table 2) and these results are in agreement with the findings of other workers [23]. This increase in the nutrient and heavy metals concentration can be attributed to the net loss of compost dry mass associated with organic matter degradation that led to increase in concentration of nutrients and heavy metals in the final compost product [24]. It is documented that most of the heavy metals like Zn and Cu are essential elements for plants but their excess may result in metabolic disorders and growth inhibition in most of the plant species [25]. In spite of increase in heavy metal contents in the product, the estimated values have been found within the USEPA standards and could be safely used for agriculture purposes.

Sanitary quality of the finished compost was determined by examining it for the presence of indicator organisms including coliform, faecal coliform and *Salmonella* sp. Total number of fecal coliform significantly decreased from $2.1x10^9$ to $1.5x10^2$ whereas *Salmonella* has been eliminated after 60 days composting process (Table 2). The decrease in the number of coliforms and faecal coliform is a consequence of high temperature and occurrence of unfavorable conditions during thermophilic phase [26].

The phytotoxicity was analyzed by *Zea mays* seed germination test. Data presented in Fig.1 revealed that phytotoxicity was evident only in the initial stage composting material. It was also observed that in the final stage composting material the seed germination and germination index were increased such that 85.18% and 117.07% respectively, the increase in these values has been supported by previous study [27]. The results of phytotoxicity of present study demonstrate the promotional effect of composted HPSW on seed germination and root elongation, high germination index value of HPSW compost has not only been reflected the disappearance of phytotoxicity but also the substrate is considered as a carrier for stimulating growth properties [28], whereas inhibition of seed germination and low germination index value in the initial stage composting material has indicated an un-stabilized product or the presence of any other toxic substances for these seeds [29].

III. Experimental

Source Materials

HPSW was collected from a local herbal pharmaceutical industry (Herbion Pvt Ltd. Karachi). It contained several medicinal herbs like Saunf (*Foeniculum vulgare*), Bad-e-musk, Balchar (*Nardostachys jatamansi*), Banafsha (*Viola odorata*), Subistan and Tea (*Camellia sinensis).* Fresh Cow Manure (CM) collected from Al-Fatima cattle farm located at Cattle Colony Landhi, Karachi was also used in composting.

Feed preparation:

300 Kg compost feed was prepared by mixing HPSW with fresh CM (2:1 w/w) to achieve C: N ratio 26. The composting material was thoroughly homogenized on a concrete platform by manual mixing with occasional watering to bring the final moisture in the range of 40-60% [8].

Composting Experiment:

The experiment was carried out in the premises of PCSIR Labs Complex Karachi during the month of September-October 2010-2011. Compost feed was piled up in the form of windrow having initial height 55 cm on outdoor unpaved ground and exposed to the temperature 40-45°C for duration of 08 weeks. Temperature was recorded daily, windrow pile was overturned on weekly basis for sufficient aeration and thorough mixing of material and left for one week for maturing of the compost.

Chemical Analysis:

Representative samples from composting pile at zero day and after 60 days were air dried and ground to pass through a 2x2 mm sieve. The aqueous extracts of compost were prepared by mechanical shaking of the samples with double distilled water (1:10 w/v) for one hour, the suspensions were thereafter centrifuged at 10,000 rpm and the supernatants were used for the measurement of pH (Orion pH meter) and EC (HACH conductivity meter). Moisture content and organic matter were determined by using moisture determination balance (OHAUS), and through combustion in a muffle furnace at 750°C for 2 hours respectively. Total nitrogen was determined by Kjeldahl method [9]. Nutrients and heavy metals were estimated by digestion of compost feed and final compost samples with concentrated nitric acid and hydrochloric acid and then determination was made by using Atomic Absorption Spectrophotometer (AAS) Z-8000 Hitachi [10].

Microbiological analysis:

Sample Preparation:

50 g compost samples and 450 ml sterile distilled water were taken in sterile Erlenmeyer flasks, mixed well and shaken on an orbital shaker at 500 rev min^{-1} for 30 min. ten fold serial dilutions were prepared.

Enumeration of Total Coliform and Faecal Coliform Bacteria:

Numbers of total coliform and faecal coliform bacteria were determined by Most Probable Number (MPN) method as described in ISO 9038-Part 2. The MPN of bacteria was calculated by using the MPN index.

Detection of Salmonella:

Qualitative analysis was done by using two selective media, the Rappaport Vassiliadis and tetrathionate broth supplemented with iodine solution while XLD, Bismuth sulfite agar and Hektoen enteric agar were used as growth medium [11].

Phytotoxicity Assay:

The Phytotoxicity of feed material and finished compost was determined by extraction in distilled water (1:10 w/v) following the method of [12]. 5 ml of aqueous extracts were taken in 90 mm petri dishes lined with Whatman No. 1 filter paper. Ten seeds were placed in each dish and incubated in the dark for 48 h. Assay was carried out in triplicate using distilled water as control. Percent seed germination (%G), percent Relative Root Growth (%RRG) and Germination Index (GI) were calculated as follows:

1. %G = (No. of seeds germinated in extract / No. of seeds germinated in control) x100
2. %RRG = (Mean root length in extract / Mean root length in control) x100
3. GI = (%G x %RRG) x 100.

IV. Conclusion

It may be concluded from the present study that the recycling of HPSW by windrow composting method is an environmental friendly strategy to reduce pollution which produce an acceptable, non-toxic and nutrient rich substrate for agronomic purposes. In addition, since Karachi soil is sandy with low organic matter, the application of HPSW compost would be beneficial for the health of soil and plants.

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Table- 1: Physicochemical parameters of raw materials used in windrow composting.

Parameters	Measuring Units	Cow Manure	HPSW
pH	-	5.88 ± 0.08	6.39 ± 0.03
EC/ Soluble Salts	mS / cm	1.35 ± 0.06	1.06 ± 0.01
Organic Matter	%	86.51 ±2.67	93.06 ± 3.28
Ash	%	13.49 ± 3.5	6.94 ± 2.89
Total Carbon	%	50.17 ± 2.3	53.97 ± 4.5
Total Nitrogen	%	1.70 ± 0.09	2.08 ± 0.06
C/N	-	29.51 ± 0.2	25.94 ± 0.7

Table-2: Complete characterization of composting material at initial and final stages of composting process

Parameters	Measuring Units	Compost feed	Finished compost
pH	-	6.36 ± 0.030	7.49± 0.052
EC/ Soluble Salts	$mScm^{-1}$	1.14 ± 0.026	2.97± 0.025
Organic Matter	%	91.38 ± 3.02	52.64 ± 7.4
Ash	%	8.26 ±2.70	47.36 ± 3.3
Total Carbon	%	53.00 ± 4.50	30.53 ±3.50
Total Nitrogen	%	2.03 ± 0.05	2.93 ± 0.60
C/N	-	26.10 ± 0.2	10.42 ± 0.8
Total coliform count	dl	$2.1X10^{9}$±1.73	$1.5X10^{2}$±0
Total faecal coliform count	dl	$2.1X10^{9}$±1.73	$1.5X10^{2}$±0
Salmonella count	Cfu gm^{-1}	Present	Absent
Macro elements			
K	gm kg^{-1}	19.76 ± 1.65	20.20 ± 1.28
P	gm kg^{-1}	13.7 ± 1.06	14.4 ± 0.86
Na	gm kg^{-1}	3.26 ± 0.06	3.72 ± 0.09
Ca	gm kg^{-1}	39.98 ± 1.25	51.07 ± 1.25
Mg	gm kg^{-1}	4.78 ± 0.09	7.59 ± 1.07
Micro elements			
Fe	mg kg^{-1}	626 ± 3.40	1253 ± 12.65
Cu	mg kg^{-1}	13.49 ± 1.25	25.04 ± 2.10
Mn	mg kg^{-1}	380 ± 0.75	820 ± 1.35
Zn	mg kg^{-1}	59.2 ± 2.56	96.05 ± 4.75
Heavy Metals			
Cd	mg kg^{-1}	1.53 ± 0.22	1.81 ± 0.28
Pb	mg kg^{-1}	8.69 ± 0.06	11.13 ± 0.06
Cu	mg kg^{-1}	13.49 ± 0.5	25.04 ± 0.80
Zn	mg kg^{-1}	59.29 ± 1.05	96.05 ± 1.20
Cr	mg kg^{-1}	4.98 ± 0.05	5.61 ± 0.07

Fig-1: Phytotoxicity of composting materials at initial and final stages of the process