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Lab Scale Composting of Fruits and Vegetable Waste at Elevated Temperature and Forced Aeration

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Abstract.- Consequent to the ever increasing human population and the process of urbanization solid waste management is one of the biggest recent environmental challenges. Simulating the conditions of composting in the field in the present study apple (A), banana (B), oranges (C) and potatoes peels (D) were composted in glass jars under aerobic condition. Filtered aeration was provided with the help of electric air pump. Four jars including one control (containing autoclaved substrate) for each substrate were kept at 50°C for 21 days. Samples were taken at zero and every seventh day for analyses of pH, electrical conductivity (EC), ash , moisture, seed germination and bacterial C.F.U. pH and ash content of all the four compost substrates increased, while EC of the substrates B and D increased and that of A and C decreased. A significant increase in seed germination was observed for the substrate D. Significant reduction in *E. coli* count was observed in all samples within 14-days of composting. Provision of filtered aeration and 50^{o}C incubation temperature appeared promising in terms of reducing harmful bacterial contents, as envisaged by low *E. coli* C.F.U. during different phases and total absence of these indicator microorganisms at end of the composting process. Whereas 114.3% and 62.55% seed germination indices for the composted substrates D and B, respectively, indicated conversion of the wastes into value added phytotoxin free fertilizer, which can escalate the agricultural output.

Key words: Controlled composting, composting of potatos peels, composting of banana peels, composting of apple peels.

INTRODUCTION

Several biotechnologically upgradable organic residues, mainly in the forms of urban and agricultural wastes, are continuously produced and piled up in different urban and suburban locations for varying periods of time. Consequently, solid wastes generation has become a significant management problem. Great volume of such wastes can cause serious environmental problem (Taylor and Kosson, 1996; Garcia *et al.*, 2005; Neves *et al.*, 2009). Increasing generation of the wastes needs environmentally sound, cost-effective and high efficient technology (Colleran, 1997). Different treatment strategies including composting, anaerobic digestion, incineration, thermolysis and gasification are the most usual treatment methods. Composting being an economical technology not only removes organic wastes and recycle nutrients but also converts organic matter into stable soil conditioner (Keeling *et al.*, 2003; Devault, 2004; Grigatti *et al.*,2004; Adhikari *et al.*, 2009; Monson and Murugappan, 2010). Compost application to agronomic soils increases crop production due to its nutrient content and moisture retention properties (McConnel *et al.*, 1993; Wong *et al.*, 2001).

Composting in controlled environments reduces dissemination of pathogens by killing many harmful microorganisms (Lodha *et al.*, 2002; Sinha and Herat, 2002; Heinonen-Tanski *et al.*, 2006). In fact, many workers have reported disappearance or reduction of specific bacterial species of public health concern from composted material. Compost may inoculate soil with vast number of beneficial microbes (bacteria and fungi) whose activities promote soil systems. For example, use of composted materials raises the number of nitrogen fixing and phosphate solubilizing bacteria in soil (Kale *et al.*, 1992; Lodha *et al.*, 2002). Cellulolytic bacteria appear frequently in biowastes comprising mainly of vegetables, fruit and garden wastes. Monitoring processing of various bio/municipal solid wastes results into a composted material rich in sodium, potassium and phosphorous as well as certain trace elements, which may be required in certain selected agricultural areas (Sanchez-

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Monedero *et al.,* 2001; Sinha and Herat, 2002; Ryckeboer *et al.,* 2003).

From above description it is apparent that properly prepared compost not only manage the solid wastes' disposal with resultant betterment of urban environment regarding the public health issue, rather it may generate soil fertilizer of choice. Tons of solid waste comprising mainly of kitchen and restaurant left overs are produced daily in the city Lahore. The present study was aimed at establishing controlled composting of peels of apple, banana, oranges and potato for urban solid waste management with provision of coliform free composts with promising seed germination indices.

MATERIALS AND METHODS

Peels of apples, bananas, potatoes and oranges were collected from different fruit shops of students' hostels of the University of the Punjab Lahore. These wastes were then separately chopped in a chopping machine to pieces of 2-3 mm to give better exposure for microbial treatments. Small sized sterile screwed capped glass containers measuring 12 and 06 cm in length and diameter, respectively were employed for the controlled composting of 120 g of each substrate in separate jars. The containers were closed with lids fitted with inlet and outlet plastic pipes for aeration and incubated at 50°C for three weeks, with a constant flow of filtered sterilized air. Turning was done on alternate days to maintain porosity of the substrate for effective aeration. Compost was sampled every seventh day and processed for the determination of various physiochemical and biological parameters. Moisture contents were measured following drying of a weighed portion at 105°C for an over night (Mohee *et al.,* 2008).The dried samples were ignited at 550°C for 5-6 h for measuring ash content (Gupta, 2000) To measure pH and EC, 1 g of a sample was mixed in 10 ml of distilled water, shaken at 150 rpm for one h and then centrifuged (10,000 rpm) for 10 min and filtered. The parameters of the filtrate were recorded by using calibrated pH and electrical conductivity meter.

For seed germination test, one g of a given sample was mixed in ten ml of distilled water, shaken for one hr at 200 rpm. Then 5 ml of each extract was pippeted into sterilized petri plates lined with Whattman filter paper No.1. Ten gram seeds were evenly distributed on filter paper and incubated at 20-25°C for 48 h (Wong *et al.,* 2001). Observations recorded were then used for calculating the germination index (GI) according to the following formula

$$\text{Seed Germination Index} = \frac{\text{Seed Germination \% x Root Length of Treatment \%}}{\text{Seed Germination \% x Root Length of Control \%}} \text{ X100}$$

For Microbial Analysis, 0.5 g of a sample was added in 9 ml of 0.85% saline and shaken at 200 rpm for half an hour (Ryckeboer *et al.,* 2003; Heinonen-Tanski *et al.,* 2005; Nair *et al.,* 2006) Serial dilutions were then prepared whose measured amounts (0.1ml) were subsequently spread on cellulolytic (Ogbonna *et al*., 1994), nitrogen fixing (Benson, 1994), amylolytic (Bernfeld, 1955) and eosin methylene blue (Oxoid) agar media. The Petri plates were incubated at 37°C for 24 h and then observed for measuring C.F.U./g of respective bacteria.

Statistical analysis

The data were analyzed statistically by comparisons between means values of different parameters employing SPSS 12 programme for ANOVA.

RESULTS AND DISCUSSION

Moisture contents of all the four substrates decreased, while their ash contents and pH increased with the progression of composting from day zero through the last composing point. pH of the substrates A (apple peels) and C (orange peels) appeared in acidic range (3.3-3.8) whereas that of the substrates B (banana peels) and D (potato peels) were in basic range *i.e.,* 6.2-8.3 throughout the study period (Tables I, II). Increase in pH has been considered indicative of active composting (Strom, 1985) and could be attributed to microbial decomposition of the organic matter, proteins and amines producing ammonia (Bishop and Godfrex, 1983; Sanchez-Monedero *et al.,* 2001; Jolanum *et*

Table I.- Moisture and ash contents of peels of apples (A), bananas (B), oranges (C) and potatoes (D) at different stages of composting. The lower case alphabets (a,b,c and d) represent respective autoclaved (control) substrates.

Substrate	0 Week		1 Week		2 Weeks		3 Weeks	
	Moisture (%)	Ash content (g)	Moisture (%)	Ash content (g)	Moisture (%)	Ash content (g)	Moisture (%)	Ash content (g)
A	72.33±0.004 a,B,b,c,D,d	10± 0.03 a,b,C,c,D,d	49.33±0.02 B,b,C,c,D,d	2.5± .02 a,B,b,C,c,D,d	23.33±0.03 D,d	4.65± .03 a,B,b,C,c,D,d	10.3± 0.03 B,b,D,d	4.4± .11 B,b,C,d,D
a	81±0.11 A,B,b,C,c,D,d	5.26±.01 A,B,b,C,d	53±0.03 B,b,D,d	2.29± .03 A,B,b,C,c,D,d	25± 0.03 d	2.3± .03 A,B,b,C,c,D,d	12± 0.02 d	4.0±.03 A,B,b,C,D,d
B	91.33±0.03 A,a,b,C,c,D,d	11.11±.03 a,b,C,c,D,d	64.33±0.07 A,a,C,c,d	13.84± .07 A,a,b,C,c,D,d	37± 0.01 d	26.51± .03 A,a,b,C,c,D,d	9.33± 0.03 A	26.31± .02 A,a,b,C,c,D,d
b	88± 0.02 A,a,B,C,D,d	5.55±.03 A,B,b,C,d	46±0.004 A,a,C,c,d	13.33± .02 A,a,B,b,C,c,d	23± 0.02 d	10.1± .07 A,a,B,b,C,c,d	11± 0.01 A	12.1± .01 A,a,B,b,C,c,d
C	76.33±0.01 a,B,b,c,D,d	7.14±.03 A,a,B,b,c,D,d	45.33±0.11 B,b,D,d	9.45± .11 A,a,B,b,c,D,d	29.66±0.03 d	5.55± .02 A,a,B,b,c,D,d	9± 0.03 d	9.6± .03 A,a,B,b,c,D,d
c	81±0.03 A,a,B,C,D,d	5.26±.01 A,B,b,C	72±0.03 A,B,b,D,d	5.68 ±.03 A,a,B,b,C,D,d	43± 0.07 d	3.44±.03 A,a,B,b,C,D,d	16± 0.03 d	4.2±.3 B,b,C,D,d
D	82±0.03 A,a,B,b,C,c,d	8.33±.01 A,a,B,C,c,D,d	64.66±0.02 A,a,C,c,d	24.07± .004 A,a,B,C,c,D,d	30.66±0.004 A	23.37± .01 A,a,B,C,c,D,d	14± 0.07 a	22.4±.01 A,a,B,C,c,D,d
d	78±0.01 A,a,B,b,C,c,D	4.54±.01 A,a,B,b,C,D	42±.01 A,a,B,b,C,c,D	11.36± .01 A,a,B,b,C,c,D	28± 0.11 A,a,b,C,c	8.69± .004 A,a,B,b,C,c,D	15± 0.004 A,a,C,c	7.3± .02 A,a,B,b,C,c,D

*Means of three replicates ± S.E.M.

Mean showing similar letters in each column are not significantly different from each other (univariate ANOVA)

Table II.- pH and electrical conductivity (EC) of peels of apples (A), bananas (B), oranges (C) and potatoes (D) at different stages of composting. The lower case alphabets (a,b,c and d) represent respective autoclaved (control) substrates.

Substrate	0 Week		1 Week		2 Weeks		3 Weeks	
	pH	EC	pH	EC	pH	EC	pH	EC
A	3.36±0.03 B,b,c,D,d	210±0.03 D,d,a,B,b,c	3.36±0.02 B,D,d	208.6±0.01 B,b,c,D,d	3.51±0.03 B,D,d	200±0.07 D,d	3.44±0.02 B,D,d	202.6±0.004 B,b,C,d
a	3.58±0.07 B,b,C,c,D,d	197±0.01 A,a,B,b,C,c,D,d	3.79±0.03 B,D,d	184±0.03 A,a,C,c,D	3.77±0.004 B,D,d	186±0.11 d	3.86±0.01 B,D,d	180±0.11 d
B	6.53±0.004 A,a,B,b,C,c,D,d	27±0.02 A,a,B,b,C,c,D,d	8.62±0.01 A,a,b,C,c	95.66±0.02 A,a,C,c,d	8.99±0.03 A,a,b,C,c	117.3±0.02	8.32±0.03 A,a,b,C	123±0.03 A
b	5.78±0.11 A,a,B,b,C,c,D,d	68±0.03 A,a,B,C,D,d	4.87±0.03 B,D,d	102±0.07 A,a,C,c,d	4.85±0.01 B,D,d	117±0.03 d	5.00±0.03 B,D,d	114±0.02 A
C	3.23±0.03 a,B,b,c,D,d	216±0.07 a,B,b	3.67±0.004 B,D,d	191±0.02 B,b,D,d	3.64±0.03 B,D,d	193±0.07 d	3.66±0.019 B,D,d	192.3±0.01 d
c	4.18±0.02 A,a,B,b,C,c,D,d	61±0.004 A,a,B,C,D,d	4.26±0.03 B,D,d	158±0.01 A,B,b,D,d	4.15±0.01 A,a,b,C	164±0.004 d	4.28±0.02 B,D,d	156±0.03 d
D	6.25±0.01 A,a,B,b,C,c,D,d	43.6±0.11 A,a,B,b,C,c,D,d	7.65±0.03 A,a,b,C,c,D	89.33±0.03 A,a,C,c,d	8.82±0.02 A,a,C,c	106±0.11 A	8.08±0.03 A,a,b,C,c	104.3±0.03 A
d	7.81±0.03 A,a,B,b,C,c,D,d	51±0.03 A,a,B,b,C,c,D,d	7.12±.03 A,a,b,C,c	9±.02 A,a,B,b,C,c,D,d	7.43±.03 A,a,b,C,c	27±.03 A,a,b,C,c	8.02±.07 A,a,b,C,c	62±.01 A,a,C,c

Values represent means of three replicates ± S.E.M.

Mean showing similar letters in each column are not significantly different from each other (univariate ANOVA)

Table III.- Colony Forming Units (C.F.U. x 10^2) of *E. coli*, cellulolytic, amylolytic and nitrogen fixing bacteria per gram of the compost at different stages.

Bacteria	Composting period (wk)	Substrates			
		Apple peels	Banana peels	Orange peels	Potato peels
E. coli	0	24.1±19.5	TMC	33.7±17.9	TMC
	1	1.5± 0.8	0.5±0.3	0.6±0.1	49.5±24.5
	2	0.4± 0.2	0	0	14.2±13.4
	3	0	0	0	0
Cellulolytic	0	2.4± 1.4	TMC	29.3±27.4	TMC
	1	49.2±24.7	51.3± 25.7	0.3±0.3	9450.00±755.00
	2	3.0± 0.3	2.3± 0.3	0.9± 0.1	28.3±26.9
	3	0.1±0.00	15.0±7.9	53.4±53.4	7316.00±524.1
Amylolytic	0	3.0±1.2	TMC	44096.00±1087.00	TMC
	1	19.8±19.8	81.7±9.0	0.3± 0.3	5366.7±549.4
	2	2.0±0.3	2.0±0.00	1.0±0.00	0.8±0.2
	3	0.1±0.00	12.3±8.9	0.8±0.6	8290.00±447.6
Nitrogen fixing	0	21.4±19.8	TMC	66.9±65.6	TMC
	1	19.2±19.2	12.4±18.0	81.4± 78.00	9813.3±953.8
	2	1.2±0.2	4.7±32.0	1.0±0.00	168.7±39.9
	3	28.3±27.9	20200.0±40.0	4.0±3.7	5686.7±328.1

Values represent mean±S.E.M; TMC = Too many to count due to excessive bacterial growth.

al., 2008; Mohee *et al.,* 2008). EC of the substrates B and D increased as the process progressed, while decline in the parameter was noticed for the substrates A and C (Table II). Many types of composts characterized with higher EC values have been reported (Inbar *et al.*, 1993; Kirchmann and Widen, 1994; Roig and Bernal 1996).

Ash contents decreased for substrate A, while for the substrates B, C and D the parameter increased following the process of composting (Table II). Increase in ash content has also been reported by other authors and is reflective of mineralization trend of organic matter (Wong *et al.*, 2001). Seed germination assay exhibited that of all the substrates, D had highest seed germination index (GI) *i.e.*, 114.3%. Second to the rank was substrate B having a GI value of 62.55%. The GI of the substrates, in general, increased progressively during the composting process, except that of the substrate C (Fig.1). This revealed the fact that compost prepared from these substrates may result into reduction/inactivation of phytotoxin. According to Zucconi *et al. (*1981), GI value of greater than 50% indicates a phytotoxin-free compost.

Regarding microbial analysis, decline in coliforms C.F.U. was observed as the composting proceeded in all the substrates (Table III). Composting is usually efficient for reducing the pathogens. Most pathogens are inactivated during the thermogenic phase of the composting (Bollen *et al*., 1980; Ylimaki *et al*., 1983). The concentration of thermotolerant coliforms, which are usually considered as sanitation indicators (Deportes *et al*., 1998; Hassen *et al*., 2001; Ryckeboer *et al*., 2003) reduced during composting of all the four substrates. This might be attributed to elevated (50°C) incubation temperature. Total absence of coliform C.F.U. at the end of composting period may certify completion of the process regarding the elimination of pathogens. Nitrogen fixing, amylolytic and cellulolytic bacterial profiles expressed in general, elevation at 2nd week stage followed by declines in the C.F.U. /g contents at the last study point. This trend may prove of practical importance .As application of compost of this stage may act as inocculant of the useful cellulolytic, amylolytic and the nitrogen fixing bacteria to soil systems. Especially the soil with interrupted organic material decomposition may be rejuvenated with the application of such compost materials. According to

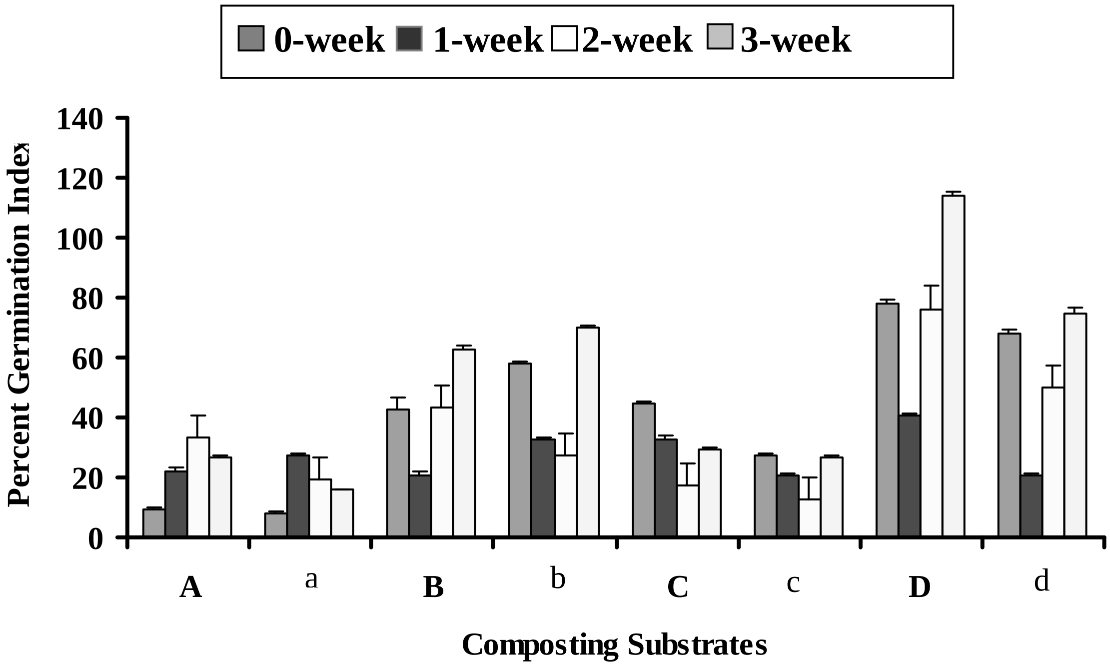

Fig. 1. Percent seed germination indices of composts of the substrates A, B, C and D at different stages. Respective autoclaved control substrates are shown as a, b, c and d.

Strom (1985) increase in bacterial C.F.U. is indicator of active composting. Plate count of substrate A showed that cellulolytic, amylolytic, and nitrogen fixers increased in the first phase and then decreased as the composting progressed at the last sampling point. This might be due to feed back inhibitions of the products of hydrolyses. Conclusively, composting of the waste fruits and vegetables at 50°C with forced aeration can be accomplished within three weeks. Provision of the desired temperature can be managed without expense in most parts of this country almost throughout the year. While expense of aeration can be compensated for obtaining composts free of coliform contents and with much higher GI indices than the limit defining phytotoxicity.

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