Environment & Ecology 27 (1A) : 403—406, 2009
 ISSN 0970-0420

Bio-Chemical Changes During Composting of Coffee Wastes with Different Substrates

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Abstract

Coffee pulp, husk and effluent are the main by-products generated by the coffee processing units. Disposal of these by-products into ecosystem will affect the soil and water courses. Among all the available disposal options, composting is gaining importance as a sustainable strategy to recycle coffee processing wastes for agricultural purposes. This study ascertaints the changes in nutrient content and enzyme activities during composting of these wastes. The basic organic raw materials used for composting comprising coffee pulp (33.3%), coffee husk (33.3%), forest litter (16.6%), eupatorium, a weed (16.6%) and coffee effluent (20 liters) in different proportions and decomposed by aerobic process in the cement cistern of dimension 70 cm height and 55 cm diameter. For enrichment of compost, 12 kg cow dung, 2.5 kg rock phosphate and 300 ml of microbial consortia were used to prepare 60 kg of compost. The composting was allowed up to 120 days by regularly turning at 30-day intervals. The compost was fortified with Zn and B (200 ppm in wt/ wt basis) at 30 days before the termination of composting. The results indicated that this composting technique reduced the organic matter to an extent of 40% and stabilized the pH to around neutrality with decline in organic carbon content and increase in the concentration of almost all nutrients on day 120 of composting. In addition, there was an increase in acid and alkaline phosphatase activities on day 120 of decomposition. Whereas, reverse trend was observed in urease and cellulase activities.
Key words : Coffee processing wastes, Enriched composting, Fortification, Nutrient composition, Enzyme activities.

In the era of globalization and industrialization, there is increasing demand for good quality produce and pollution free environment. On the contrary, many of the industries make use of large quantities of good quality water and other raw materials and generate almost entire quantity of water as effluent with objectionable odor, taste and harmful constituents and appreciable quantities of solid wastes which may pose threat to water and soil, the two most important natural resources which hold the key for our safe living. In the bio-diverse Western Ghats of Karnataka, coffee is being grown over decades and recently emphasis is being given to production of quality coffee by subjecting coffee fruits to pulping. In this process, large quantities of pulp, pulp effluent and husk are generated as major by-products (1). In the coffee curing industries, on an average 1.01 lakh tons of fresh pulp is being produced annually in the country and to process 2.23 lakh tons of coffee fruits through wet processing, 8.4 million m^3 of waste water is generated which is rich in organic materials such as pectin, sugar, mucilage and is known to have high biological oxygen demand (BOD), chemical oxygen demand (COD) and suspended solids (2) and thus, posing problems of disposal as it has high pollution potential. In contrast to this, the pulp, pulp effluent and husk are rich source of nutrients and organic matter and hence can be used as a resource for growing crops. Presently, these coffee wastes are disposed without any treatment and left to degrade naturally in the pits or heaps with uncontrolled liberation of noxious odors and nutrients leaching as a consequence of natural degradation. These coffee wastes contain high quantities of cellulose, pectin and lignin which are not easily decomposable. Hence, composting represents a possible eco-friendly technology for dealing with coffee processing wastes recycling. Since, it can be carried out with a low capital invest-

Table 1. Chemical composition of major organic materials used for composting.

Parameters	Coffee pulp	Coffee husk	Cow dung
pH (1 : 10)	6.8	5.3	7.8
EC (dS/m)	3.20	2.51	0.85
Organic carbon (%)	38	35	43
N (%)	2.05	2.25	1.87
C : N ratio	19	16	23
P (%)	0.56	0.47	0.78
K (%)	2.56	2.85	0.93
Ca (%)	1.29	1.40	1.43
Mg (%)	1.09	0.75	1.14
S (%)	0.25	0.31	0.57
Fe (ppm)	1120	1033	1957
Mn (ppm)	69	73	215
Zn (ppm)	83	79	98
Cu (ppm)	16	9	2

Table 2. Nutrient composition of compost samples collected at different periods of composting.

	Period of composting (days)			
Parameters	30	60	90	120
pH (1 : 10)	9.09	8.20	7.59	7.41
EC (dS/m)	1.44	1.05	1.04	0.55
OC (%)	42	33	25	25
N (%)	2.38	2.45	2.87	2.99
C : N ratio	18	14	9	7
P (%)	1.97	2.15	2.18	2.45
K (%)	2.28	2.48	2.90	2.94
Ca (%)	2.64	3.92	4.54	4.68
Mg (%)	1.15	1.21	1.81	1.88
S (%)	0.20	0.43	0.53	0.63
Fe (ppm)	1012	998	956	922
Mn (ppm)	153	183	251	269
Zn (ppm)	121	196	218	247
Cu (ppm)	9.0	13.6	14.0	14.2
B (ppm)	8.0	11.0	15.0	27.0

ment, producing a high quality organic manure within a shorter period (3), researchers have reported on the successful use of organic materials for composting of various substrates i.e. instant coffee residues. In this context, an attempt was made to produce enriched organic manure from coffee wastes, forest litter (silver oak leaves) and eupatorium which are abundant in coffee growing areas and enrichment of compost with rock phosphate. Besides, inoculation of microbial consortia (*Bacillus megaterium* and *Phenerochete chrysosporium,* which are phosphate solubilizer and cellulose decomposer, respectively) and fortification with micronutrients to enhance the quality of compost which has been less explored so far. Moreover, treatment of coffee wastes by composting enhances the mineralization and biological activity and allows a more complete conservation of the residual energy stored in the organic material. Therefore, one should know the changes in mineralization and enzyme activities during composting to assess the compatibility of final product for agricultural utilization.

Methods

Collection of Organic Raw Materials

Coffee pulp and coffee effluent were collected from coffee pulping units in coffee growing areas of Coorg, Hassan and Chikmagalur districts of Karnataka and coffee husk from coffee curing plants in Chikmagalur district. Eupatorium weed and forest litter were collected from coffee estates and forest, respectively. The microbial cultures were obtained from the Department of Agricultural Microbiology, UAS, GKVK, Bangalore.

Method of Composting

The basic organic raw materials used for composting comprising coffee pulp (33.3%), coffee husk (33.3%), forest litter (16.6%), eupatorium weed (16.6%) and coffee effluent (33.3% : 20 liters) in different proportions and remaining 26.7% of moisture was met by water and decomposed by aerobic process in cement cistern of dimension 70 cm height and 55 cm diameter. For enrichment of compost, 12 kg cow dung, 2.5 kg rock phosphate and 300 ml of microbial cultures were used to prepare 60 kg compost. The composting was allowed up to 120 days by regularly turning at 30-day intervals. The compost was fortified with Zn and B at 200 ppm at 30 days before the termination of composting.

Collection of Samples and Analysis

The representative samples were collected periodically from several points at the center of the heap at the time of each turning. The samples were dried under shade, crushed and screened through 1.0 mm

Table 3. Changes in enzyme activities on 30—120 days of composting of coffee processing wastes with different substrates.

Period of composting (days)	Alkaline phosphatase (µg PNP/g/hour)	Acid phosphatase (µg PNP/g/hour)	Urease (µg N/g/hour)	Cellulase (µg glucose/g/hour)
30	140	108	353	1264
60	433	348	332	694
90	497	417	290	564
120	547	492	233	488

sieve. The samples collected were analyzed for various parameters viz. pH, EC, organic carbon and nutrients content including enzyme activities on fresh wet samples. The pH was determined potentiometrically in 1 : 10 suspension and EC conductometrically while organic carbon by wet oxidation method (4), total nitrogen by micro Kjeldahl distillation method (5), nutrients viz. P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B contents of the diacid-digested extracts were determined by procedures given by Piper (5). The enzyme activities viz. alkaline phosphatase, acid phosphatase, urease and cellulase in fresh wet samples were determined by the procedures given by Sadasivam and Manickam (6).

Results and Discussion

Chemical Composition of Composting Materials

Chemical composition of two major organic materials viz. coffee pulp and coffee husk used for composting presented in Table 1 revealed that the organic carbon content was higher in both coffee pulp (38%) and husk (35%). The coffee pulp and husk contained high amount of nitrogen (2.05 and 2.25%, respectively) with C : N ratio of 19 and 16, respectively. Coffee pulp had high amounts of phosphorus (0.56%) and magnesium (1.09%) as compared to husk whereas potassium, calcium and sulfur contents were more in husk (2.85, 1.40 and 0.31%, respectively).

The Fe, Mn, Zn and Cu contents of coffee pulp were found to be higher (1,120, 69, 83 and 16 ppm, respectively) in coffee pulp than coffee husk (1,033, 73, 79 and 9 ppm, respectively). Cow dung is usually used as inoculum for decomposition of cellulolytic plant materials. It is conventionally used as a starter for composting apart from its use as manure. It was found to be fairly rich in organic carbon (43%) with C : N ratio of 23. It had 1.87, 0.78 and 0.93% N, P and K, respectively and fairly rich in secondary nutrients to an extent of 1.43, 1.14 and 0.57% Ca, Mg and S, respectively. The amount of micronutrients viz. Fe, Mn, Zn and Cu contents of cow dung were 1,957, 215, 98 and 2 ppm, respectively.

Chemical Changes During Composting

Chemical changes during 30, 60, 90 and 120 days of composting of different substrates presented in Table 2 revealed that a reduction in organic carbon from 42% on day 30 to 25% on day 120. There was a slight increase in the total nitrogen content (2.38 to 2.99%) of the compost as decomposition process proceeded. This might be due to the reduction in the total weight of the initial composting materials. This change in organic carbon and nitrogen content of the compost is reflected in narrowing of C : N ratio. The C : N ratio of the composting materials decreased (17.6 to 7.2) with the advancement of decomposition process. The inoculation of microorganisms combined with rock phosphate application during composting showed increase in the CO_2 evolution and also N concentration by loss in initial weight of composting materials. This resulted in narrowing the C : N ratio of the matured compost (7).

Addition of rockphosphate and inoculation of microorganisms might have increased the P content of matured compost from 1.97 to 2.45%. The organic acid such as carbonic acid and chelating substances, which are produced during decomposition process helps in solubilizing P from rockphosphate. According to Radhakrishna et al. (8), the enrichment of compost with nutrients results in high value compost with high degree of decomposition. Due to composting of K rich organic residues like coffee pulp and coffee husk, matured compost recorded higher K content (2.94%). Also, there was an increase in the calcium and magnesium content of enriched compost due to the addition of microbial inoculants and rock phosphate. The content of Ca, Mg and S in the compost could be attributed to the presence of these elements in the raw materials.

The micronutrients contents of matured compost recorded 922, 269, 247, 14.2 and 27 ppm of Fe, Mn, Zn, Cu and B, respectively. Fortification through Zn and B showed an increase in Zn and B contents of matured compost due to the chelating effect of organic materials and also higher amounts of micronutrients in the composting materials.

Enzymatic Changes During Composting

The alkaline phosphatase activity (140 µg PNP/g/hour) at 30 days of decomposition was maximum as compared to acid phosphatase activity (108 µg PNP/g/hour). At initial days of decomposition, pH of decomposing materials was alkaline to neutral in reaction and as decomposition process continues, the pH of the decomposing materials become slightly acidic due to break down of organic materials and production of organic acids by the microorganisms. Addition of N rich organic materials like coffee effluent, coffee pulp and cow dung has increased the microbial activity which in turn resulted in depletion of nutrients for the growth of microorganisms. As reported acid phosphatase activity in soil was higher under acidic conditions.

Carbon is one of the factors stimulating the urease activity which brings about the hydrolysis of urea. The availability of carbon is more during early decomposition process due to slower decomposition rate. Hence, there was more urease activity (353 µg N/g/hour) during early periods of composting. The decrease in carbon content of composting materials due to oxidation could be one of the reasons for the decrease in urease activity (from 353 to 233 µg N/g/hour) in the later periods of decomposition.

The cellulase activity (1264 µg PNP/g/hour) was highest at initial stages of composting because of the organic materials like coffee husk, coffee pulp and forest litter had higher cellulose content. As decomposition continues, the cellulase activity was decreased from 1,264 µg glucose/g/hour on day 30 to (488 µg glucose/g hour) on day 120 of decomposition due to break down of cellulose by the native microorganisms.

Conclusion

The direct application of coffee wastes such as coffee pulp, coffee husk and effluent on land without treatments may affect the crop growth and soil health due to presence of higher amounts of toxic phenolic compounds in them. However, these wastes can be made into good compost for utilization in agriculture after composting and enriching with other additives and thus allows a more complete conservation of residual energy stored in the organic materials. Hence, enriched and fortified coffee wastes compost act as a potent source of carbon and plant nutrients which are required for sustainable productivity of soil.

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