Co-composting of coconut coir pith with solid poultry manure

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Coir pith, a ligno-cellulosic biomass formed during extraction of coir fibre from coconut husk, accumulates as a waste material near coir processing factories causing environmental and disposal problems. The feasibility of co-composting coir pith with solid poultry manure was tested with and without lime and rock phosphate amendment. The results revealed that the composting process facilitated by poultry manure amendment brought about bioconversion of coir pith to a final product in 45 days and the final product possessed physico-chemical characteristics required for quality organic manure. C : N ratio, which is considered as a maturity index of composting process, reduced during the composting process, to 21.42. The results of plant test using cowpea as bioassay plant revealed that the compost reached adequate maturity from biological point of view for use as an organic input in crop production.

Keywords: Coconut coir pith, growth promotion, poultry manure, quality compost.

COCONUT palm is an important plantation crop grown in 1.89 million ha in India supporting livelihood of many Indians. One of the important cottage industries related to coconut palm is the coir industry. It is estimated that the coir-processing factories in India produce roughly 0.5 million tonnes of coir pith waste every year that accumulates in the vicinity and creates an environmental hazard. At present about 10 million metric tonnes is available in southern India[1].

Coir pith has many beneficial characteristics, making it a potentially productive resource for use in agriculture if used after proper composting[2]. Composted and stabilized coir pith resembles peat and has characteristics similar to that of sphagnum peat, the most commonly used rooting medium in horticulture and hence it is commercially known as coco peat. It has high moisture retention capacity[3] of 500–600% and high cation exchange capacity (CEC) varying from 38.9 to 60 m eq/100 g (ref. 4), which enables it to retain large amounts of nitrogen and the absorption complex has high content of exchangeable K, Na, Ca and Mg. It has also been valued for its high potassium content and low bulk density and particle density. Even though all these properties make it an ideal material for use as soil amendment and rooting medium for soilless plant culture, direct use of raw coir pith is not recommended due to its high C : N ratio, lignin and polyphenol contents. Nitrogen content is 0.25%, C : N ratio, lignin and polyphenol content being 100 : 1, 37% and 100 mg per 100 g respectively. Agricultural use of this untreated coir pith could lead to microbial immobilization of soil nitrogen and subsequent nitrogen deficiency in plants. But these shortcomings of fresh coir pith can be managed if it is used after composting process.

Composting of organic materials requires a C : N ratio of 30 : 1 or less[5], the development of composting technologies for coir pith with high C : N ratio and lignin content involved fertilizer nitrogen supplements and lignin-degrading microbial cultures. These technologies have enabled the utilization of composted coir pith as a valuable plant growth medium, plant nutrient source and soil conditioner[2]. The availability of a low-cost, simple and rapid composting technology based on local resources, which is capable of producing good quality compost, is the key factor influencing the acceptance and widespread use by resource-poor farmers. For composting organic materials with high nitrogen content and low C : N ratio such as animal manure, addition of high C : N ratio bulking agents is required[6] to facilitate proper microbial activity and is popularly known as co-composting. This method can conserve nutrients in the compost produced[7]. Co-composting of coir pith having low nitrogen content and wide C : N ratio with poultry manure having high nitrogen content and narrow C : N ratio has been hypothesized to solve the current problems in coir pith composting. Poultry manure has been successfully used in the stabilization of organic wastes particularly high in lignin and cellulose, including wood wastes[8]. There are indications from a study on the use of coir pith as a bedding material in poultry farms, that poultry droppings can enhance coir pith composting[9]. The objective of the present study was to evaluate the feasibility of co-composting coir pith with solid poultry manure, lime and rock phosphate amendment and to assess the quality of compost produced by this method for its use in agriculture.

Unretted coir pith obtained from a coir fibre extraction unit at Kasaragod, Kerala, India was used for the study. Solid poultry manure was collected from a broiler poultry unit, which forms a component of mixed farming system at Central Plantation Crops Research Institute, Kasaragod. Lime (calcium oxide) and rock phosphate under the brand name 'Rajphos' were obtained from the local fertilizer shops.

The experiment was performed in large cement tanks in open condition of the shaded yard. The daily temperature ranged from 25°C to 30°C and relative humidity from 85% to 95%. The experiment was conducted with five treatments replicated thrice under completely randomized design. The treatments were: T1 – coir pith (95 kg) +

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poultry manure (5 kg); T2 – coir pith (95 kg) + poultry manure (5 kg) + lime (0.5 kg) + rock phosphate (0.5 kg); T3 – coir pith (90 kg) + poultry manure (10 kg); T4 – coir pith (90 kg) + poultry manure (10 kg) + lime (0.5 kg) + rock phosphate (0.5 kg) and T5 – control coir pith (100 kg). Coir pith was taken in lots and the amendments according to the treatment details were applied. Heaps of dimensions 1.8 × 1.1 × 0.45 m in length, breadth and height were made and moisture of substrate material was maintained at about 50% by spraying the surface with water every two days using a spray can. The composting process was performed for 45 days. After the trial, watering was stopped. The product was air-dried and collected in polythene bags for further analysis.

Compost stability was measured based on CO_2 evolution rate, a measure of the microbial respiration of the compost samples, using a modified procedure[10]. The treatments involved were: T1 – coir pith; T2 – coir pith + poultry manure and T3 – coir pith + poultry manure + lime + rock phosphate with three replications. Approximately 100 g dry weight of compost sample at 60% (w/w) moisture content was sealed in a 0.5 l vessel along with a beaker containing a known volume of 0.5 M NaOH solution. The samples were incubated for one day at room temperature. During incubation, the released CO_2 was captured by the NaOH solution, which was then analysed titrimetrically at the end of incubation period with 0.5 M HCl. The rates of CO_2 evolution at different intervals, viz. 7, 13, 20, 28, 36, 48, 56, 65, 73 and 84 days of incubation were estimated.

Ten gram samples were drawn from each treatment replicate and analysed for general (bacteria, actinomycetes and fungi) and plant beneficial microbial communities (asymbiotic N_2-fixers, P-solubilizers, associative N_2-fixing *Azospirillum* and fluorescent pseudomonads). Enumeration was done by serial dilution and pour plate method. The bacteria were counted on nutrient agar[11], actinomycetes on Ken Knights and Munaier's agar[11] and fungi on Martin's rose Bengal agar[12]. The free-living nitrogen-fixing bacteria were counted on N-free medium[13], phosphate solubilizers were counted by locating the clear halo formed around the colonies on Pikovskaya agar[14] and King's B agar[15] was used for fluorescent pseudomonads producing green or greenish-blue fluorescence and the colonies were counted under UV light. The population of *Azospirillum* was estimated by the Most Probable Number method[16].

The compost samples from the treatments and the control were dried at 60°C in hot air oven, powdered and analysed for physico-chemical characteristics. The pH and electrical conductivity were determined in the aqueous extract of a 5 g aliquot of sample with distilled water at a solid/water ratio of 1 : 2.5 (w/v). Organic carbon content of the samples was determined and the samples were analysed for total N by the Kjeldahl digestion and steam distillation method[17]. Total phosphorus and potassium were estimated after acid digestion of the compost by spectrophotometry and flame photometry respectively.

The composted samples were evaluated in a greenhouse study using cowpea as test plant to determine whether the compost has reached maturity from biological point of view. Air-dried sandy loam soil from a coconut plantation was amended with the composted samples at the rate of 10% and taken in plastic pots of 15 cm top and 11 cm bottom diameter with 14.5 cm height. Cowpea seeds were sown in the pots and two plants were maintained in each of the pots. The pots were watered regularly and the plants were uprooted after 45 days. Observations on shoot length, root length, number of leaves and number of nodules were recorded. The plants were dried in an oven at 50°C for three days and plant dry weight recorded.

The physico-chemical characteristics of the composted coir pith are presented in Table 1. Composting of coir pith having a C : N ratio of more than 100 : 1 to a good compost having C : N ratio of 21.42 : 1 to 22.3 by co-composting with 10% (w/w) poultry manure alone (T3) and poultry manure + lime + rock phosphate (T4) was recorded. T1 (coir pith + poultry manure @ 5%) and T2 (coir pith + poultry manure @ 5% + lime + rock phosphate) had significantly higher C : N values than T3 and T4, indicating lesser degree of composting. However, all the four amended treatments were superior in terms of C : N ratio compared to unamended coir pith (T5). The pH and EC of coir pith + poultry manure @ 5% were highest when compared to all the other treatments. In the poultry manure-treated samples, there was reduction in organic carbon content and the extent of reduction was more in the combined treatment of poultry manure, rock phosphate and lime (T2 and T4). The nitrogen content showed increase in all the treated samples and the values increased to a greater level in 10% poultry manure amendment. C : N ratio, which indicates the maturity of compost, decreased drastically to the acceptable level of 21–22 in the 10% poultry manure amendment, whereas it was 58.80 in control treatment. There was also significant improvement in the content of other major nutrients, phosphorus and potassium in all the composted samples and highest values were recorded in 10% poultry manure amendment along with lime and rock phosphate treatment. Among the minor nutrients analysed, Fe and Cu did not show any significant difference in their concentrations among different treatments, however, Mn and Zn showed significantly high values in composted coir pith, particularly T3 and T4.

Composted coir pith prepared by poultry manure amendment was also characterized for the different groups of plant beneficial microorganisms, viz. bacteria, fungi, actinomycetes, asymbiotic N_2 fixers, phosphate solubilizers, *Azospirillum* and fluorescent pseudomonads. The composted coir pith was of superior quality compared to the non-decomposed control coir pith. Among the amended

Table 1. Physico-chemical characteristics of coir pith compost prepared by poultry manure amendment (values are average of three replicates)

Treatment	OC (%)	N (%)	C : N ratio	P (%)	K (%)	Fe (ppm)	Cu (ppm)	Mn (ppm)	Zn (ppm)	pH	EC (μs/cm)
T1	32.75^b	1.22^b	27.1^{bc}	0.46^c	1.36^a	4419	36.7	160^b	105^b	6.6^a	183^a
T2	28.88^d	0.99^c	29.4^b	0.82^b	1.39^a	6576	53.1	236^a	126^b	6.6^a	177^b
T3	30.15^c	1.41^a	21.4^c	0.88^b	1.33^a	5078	44.3	266^a	183^a	6.1^c	185^a
T4	28.95^d	1.30^a	22.3^{bc}	1.21^a	1.66^a	4648	46.2	293^a	173^a	6.4^b	178^b
T5	35.25^a	0.61^d	58.80^a	0.05^d	0.63^b	4889	22.3	70^c	34^c	5.5^d	169^c
CD (P = 0.05)	0.63	0.15	7.66	0.22	0.42	NS	NS	62	20.7	0.21	4.15

Means followed by the same letter are not significantly different at P = 0.05 using analysis of variance and mean separation (LSD).

Table 2. Microbial characterization of composted coir pith (× 10^4 cfu g^{-1}) (results are average of three replicates)

Treatment	Bacteria	Fungi	Actinomycetes	Free living N_2 fixers	P-solubilizer	*Azospirillum*	Fluorescent pseudomonads
Coir pith	1.0^b	5.7	6.3^a	0.5^c	0.5^c	0.1^c	0.5^c
Coir pith + poultry manure	11.2^a	5.2	11.6^b	4.2^a	1.0^b	2.3^b	2.3^b
Coir pith + poultry manure + lime + rock phosphate	9.7^a	4.3	18.2^a	2.1^b	1.4^a	5.1^a	4.0^a
CD (P = 0.05)	3.3	NS	3.9	1.1	0.3	1.1	1.5

Means followed by the same letter are not significantly different at P = 0.05 using analysis of variance and mean separation (LSD).

treatments, the counts of plant beneficial microorganisms such as P-solubilizers, *Azospirillum* spp. and fluorescent pseudomonads were significantly higher in the coir pith + poultry manure + lime + rock phosphate treatment compared to coir pith + poultry manure alone (Table 2).

The flux of CO_2 evolution showed maximum values during the first week of incubation and a decreasing trend was observed with increase in incubation period (Figure 1). The cumulative CO_2 evolution was higher in the poultry manure treatment. The cumulative CO_2 evolution of poultry manure-amended coir pith was three times that of unamended coir pith during the first two weeks and it increased to four times at the end of the incubation period.

The greenhouse evaluation of composted and fresh coir pith by mixing with potting mixture revealed the effectiveness of composted coir pith to enhance growth characteristics and nodulation in cowpea (Table 3). The plant growth parameters such as shoot length, root length, number of leaves and plant dry weight were significantly high in cowpea plants grown in potting medium amended with composted coir pith (T1 to T4), compared to the plants grown in uncomposted coir pith (T5) amended potting medium. On numerical basis, the T2 treatment however gave consistently higher values for all the observed plant growth parameters. The influence of composted coir pith to enhance the nodulation and symbiotic N_2 fixation was evident in the increase in the nodule number in composted coir pith treatment. The increase in the nodule number was 5 to 7 fold in cowpea plants grown in the composted coir pith treatment. Thus, the biological test revealed that the composted coir pith produced by poultry manure amendment had reached maturity from biological point of view for application to crop plants.

The natural degradation of coir pith takes place very slowly due to the nature of ligno-cellulose complex in coir pith. Composting trials undertaken so far have mostly relied on inorganic nutrient addition such as urea and application of biopolymer degrading fungal cultures, viz. *Pleurotus sajor caju* for conversion of coir pith to a stabilized product[1,2]. The present study revealed the effectiveness of poultry manure amendment in eliminating the use of microbial inoculants and inorganic nutrient supplements for composting of coir pith and supporting the other findings where chestnut burr and leaf litter[8], yard trimmings[18] and wheat straw[19] were co-composted with poultry manure. Doubling the quantity of poultry manure from 5% to 10% did not have any significant impact on the organic carbon content in all the four treatments (T1 to T4), but it had strong effect on reducing the C : N ratio to the accepted level of 21–22 in the T3 and T4 treatments. This clearly showed that the quantity of poultry manure addition was critical in the process of the coir pith decomposition.

Along with poultry manure, inclusion of lime and rock phosphate in the treatments was seen to hasten the decomposition of coir pith and bring down the C : N ratio to the accepted level of 21 to 22 : 1 in our studies. Addition of lime is known to enhance the process of decomposition of recalcitrant plant materials rich in lignin. It increases the humification process in plant residues by enhancing microbial population and activity and by weakening lignin structure. It also improves the humus quality by changing the ratio of humic to fulvic acids and decreases the amount of bitumens and humins, which interferes with the decomposition process. As rock phosphate also has a lot of lime, its inclusion helps in a similar way. In addition, phosphates and micronutrients contained in rock phosphate can improve the nutrient contents of the finished compost. In our studies, addition of lime would have helped in the weakening of the ligno-cellulosic constituents of coir pith thereby making it amenable to quicker decomposition. In addition to direct liming, poultry manure is rich in calcium because poultry birds are usually fed ground limestone. So, it has some liming value and could have contributed to the humification process and production of good-quality compost[20].

Successful composting depends on a number of factors that have both direct and indirect influence on the activities of the microorganisms involved in the process. Coir pith as a source of carbon and poultry manure as a source of nitrogen[19] and active microbial biomass were found to be complementary. Another important factor that must have helped in quicker coir pith degradation in our studies could have been the production of high heat from addition of poultry manure. Higher temperatures help in effective breakdown of the complex plant constituents leading to their degradation and suppression of pathogenic microbes, typical in any composting process[19].

Composting is a complex and dynamic process carried out by a consortium of indigenous mixed microbial communities and degradative enzymes produced in the substrates. In one of the earlier studies, it was reported that poultry manure contained higher microbial populations and hydrolytic enzymes than pig manure[21]. In our studies too, we observed that the overall microbial population was significantly higher in composted coir pith than the untreated coir pith. Higher microbial population results in higher enzymic activity as indicated by CO_2 evolution in our studies, causing quicker degradation of the coir pith. Our findings support the report that good microbial and enzymatic activities were observed during co-composting of poultry manure with other organic wastes[21].

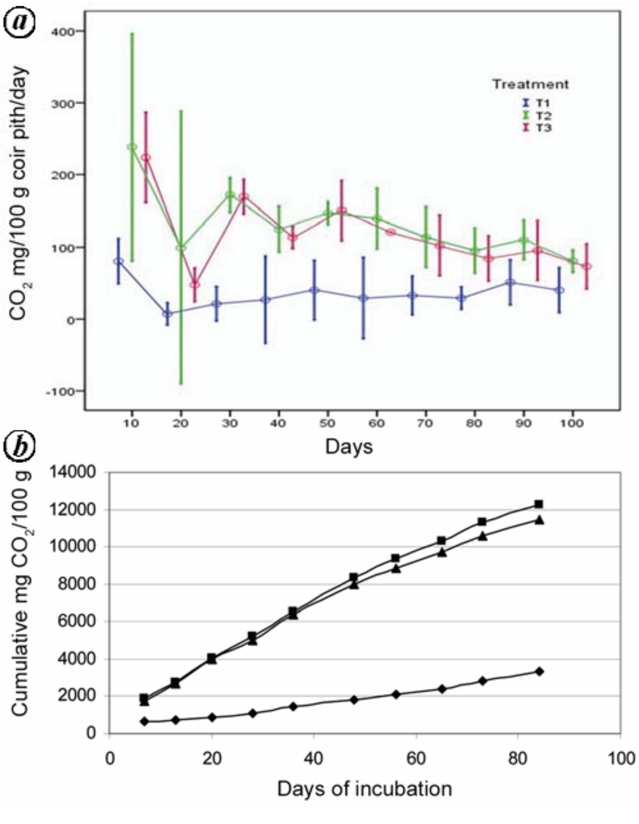

Figure 1. CO_2 evolution during composting of coir pith by poultry manure amendment. (T1, ♦) Coir pith; (T2, ■) Coir pith + poultry manure; (T3, ▲) Coir pith + poultry manure + lime + rock phosphate: (***a***) Rate of CO_2 evolution; (***b***) Cumulative CO_2 evolution.

Poultry manure composting generates copious amounts of ammonia[19]. The volatilizing ammonia can be easily trapped and conserved by the process of immobilization by organic materials such as coir pith with low nitrogen content and high cation absorption capabilities into organic molecules[7]. Ammonia binds tightly with the components of the bulking agent and therefore N losses are reduced during composting. Co-composted chicken litter with yard trimmings in forced aeration piles and their research demonstrated that nitrogen losses were reduced significantly[18]. This kind of process would have occurred in the current study, leading to uniform reduction of C : N ratio of coir pith to a level capable of supporting microbial activity, leading to rapid degradation of biopolymers and conservation of nutrients.

The microbial respiration estimated by evolution of CO_2 is a good indicator of microbial activity and compost stability. Many studies have shown that the compost stability is achieved from 60 to 120 days composting period based on microbial respiration[22]. In our studies, we observed that the microbial respiration in terms of CO_2 evolution stabilized during 40–60 days of incubation of the coir pith with poultry manure amendment and poultry manure + lime + rock phosphate (Figure 1). In a compost stability prediction study, Hue and Liu[22] reported that CO_2 evolution in 14 commercial composts was at the threshold level of 120 mg CO_2 kg^{-1} h^{-1} as the compost stabilized, based on the average of the last 2 days of a 3 day incubation test. However, in the present study, poultry manure-treated coir pith compost evolved 120–150 mg CO_2 100 g^{-1} day^{-1} (i.e. 50–63 mg CO_2 kg^{-1} h^{-1}). This is much less than the other reported values, indicating the effectiveness of the poultry manure and poultry manure + lime + rock phosphate in degrading the coir pith. It is also indicated that poultry manure-amended coir pith compost attains maturity within 60 days of incubation as seen in the CO_2 evolution rate. A simple comparison of the CO_2 evolution rates with the C : N ratio of the treated and untreated coir pith indicates a negative co-relation with unamended coir pith (T5) having low CO_2 evolution rate and higher C : N values even after 80 days of incubation whereas in poultry manure/lime/rock phosphate-amended coir pith (T1 to T4), the values were opposite. This clearly indicated that the microorganisms

Table 3. Effect of application of composted coir pith on growth characters of cowpea

Treatment	Plant dry wt (g)	No. of nodules	Shoot length (cm)	Root length (cm)	No. of leaves
T1	27.3[a]	56.4[a]	177.8[a]	32.3	17[b]
T2	32.3[a]	65.1[a]	249.3[a]	29.6	22.8[a]
T3	35.1[a]	37.4[a]	240.8[a]	26.8	19.6[a]
T4	26.5[a]	45.9[a]	195.5[a]	24.3	16.9[b]
T5	16.0[b]	8.6[b]	91.8[b]	24.3	8.8[c]
CD ($P = 0.05$)	9.80	29.71	76.50	NS	4.44

Means followed by the same letter are not significantly different at $P = 0.05$ using analysis of variance and mean separation (LSD).

had used up the carbon contents of the coir pith for their growth, resulting in the reduction of C : N ratio in treatments T1 to T4.

An increase in the counts of bacteria and actinomycetes was recorded in the composted coir pith along with increase in the number of plant beneficial microorganisms like the N-fixers, P-solubilizers and fluorescent pseudomonads. This overall increase in the populations of the microorganisms and their activity was confirmed by the concomitant increase in CO_2 emission during the process of co-composting. Similar studies of increase in heterotrophic microorganisms were reported during co-composting of polycyclic aromatic hydrocarbon (PAH) contaminated soil with poultry manure amendment[23]. This population increase could be attributed to the increase in the presence of readily available nutrients in the substrate and loss of excess N as gaseous ammonia.

Coir pith composting is normally carried out with fungal cultures like *P. sajor caju* or *P. florida* after suitable modification in physical characteristics of coir pith has taken place[1,2]. In the present study, a substantial increase in the number of bacteria and actinomycetes was noticed, which indicates that these microbial communities would have played an important role in the degradation of coir pith. This assumption is based on another important fact that addition of poultry manure would have increased the temperature of the substrates, enabling the spore-forming bacteria and actinomycetes communities to survive and carry out the degradation. Similar increase in populations of *Pseudomonas*, *Bacillus* and *Rhodococcus* along with fungi was reported in studies on bioremediation of PAH-contaminated soil with poultry manure[23]. In another study, where poultry manure was used along with yard trimmings for composting, the authors reported an increase in actinomycetes and fungi (microorganisms active in degradation of cellulose, hemicellulose and lignin), which they found were positively correlated with esterase, valine amino-peptidase, alpha-galactosidase, beta-glucosidase and lipase enzyme activity[18].

The ultimate parameter of compost stability is proven by its plant growth-promoting capacity. The trials conducted on cowpea plants showed that poultry manure/lime/rock phosphate-amended coir pith enhanced all the growth parameters compared to unamended coir pith. It points to the fact that the amended coir pith had been composted and the unavailable nutrients present were made available to the plant easily, which was not the case in unamended coir pith. Similar increase in growth, yield and yield components and total crude protein of faba bean plant was observed on application of rice straw co-composted with poultry manure[24].

It can be concluded from the present study that the recalcitrant coir pith wastes produced from coir processing industries can be composted to useful manure with addition of poultry manure. The composting process can be enhanced upon inclusion of lime and rock phosphate along with poultry manure. The composted coir pith has near-neutral pH, a C : N ratio in the range nearly 20–27, %N and %K ranging above 1 and stable CO_2 evolution after 60–65 days of composting. Addition of composted coir pith significantly increased the growth parameters and nodule numbers in the cowpea plants, indicating its use as an organic input. This technology can be adopted for converting the coir pith wastes, generated by coir processing industries, to quality manure which can be used in agriculture at local levels.

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ACKNOWLEDGEMENTS. We thank the anonymous referee for critical comments and suggestions that helped improve the manuscript. We also thank C. H. Amarnath, CPCRI Kasaragod for data analysis.

Received 6 January 2012; revised accepted 30 November 2012