A Novel Method for Accelerated Composting of Coir Pith

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Hillocks of coir pith accumulate in the vicinity of coconut coir-fiber extraction units, of which disposal and management remain a major problem. Southern states of India, especially Kerala, Tamil Nadu, Andhra Pradesh, Karnataka, and Orissa, face this problem. A simple technology for accelerated composting of coir pith was developed, and on-site composting of coir pith hillocks was demonstrated. The composting of pith was complete in 21 days. The composted pith was an excellent organic manure, with a reduced C/N ratio of 20:1, pH of about 6.5, and electrical conductivity of 0.23 dS/cm, making it a more desirable soil organic manure. The composted pith did not contain or carry weeds and undesirable pathogens, thus providing a rich soil environment for plant and vegetation growth.

1. Introduction

Coir pith is a biomass residue generated during the extraction of coir fiber from coconut husk and is a byproduct of the coir manufacturing industry. Normally, they are dumped as agricultural waste and become accumulated as a waste product in the form of heaps of coarse and fine dusts. Figure 1 shows typical coir pith dumps (hillocks) in the southern states of Kerala and Tamil Nadu in India, where such a problem is widely prevalent. It is estimated that at present there is an accumulated stock of 10×10^6 metric tons of coir pith in the southern states of India. These agricultural wastes have traditionally been disposed of by burning. This burning has resulted in various environmental problems, including carbon deposits as well as the warming of the atmosphere. During the rainy season, the tannins and phenols of the coir pith are leached out into the soil and into the irrigation canals, thereby making agricultural lands unproductive. Moreover, the water pollution caused by such leaching is harmful to the aquatic and soil biological life. Therefore, alternate ways to dispose of coir pith, such as composting, is of critical importance in these areas.

Coir pith is a fluffy, light, spongy material with increased water-holding capacity and extremely compressive and has a sizable percentage of combustible matter along with a low ash content. It is essentially a ligno-cellulosic material that decomposes very slowly in soil, because its pentosan/lignin ratio is 1:0.30; the minimum required for moderately fast decomposition in the soil is 1:0.50.[1] It has been reported that coir pith in combination with cow dung gives a considerable amount of biogas.[2] About 7.5×10^5 tons of coir pith is produced annually in India.[3] It can be available from either retted or unretted processing industries of coir fiber, where, for every ton of fiber extracted, the coir dust is produced to the extent of 2 tons. Because coir pith is a fluffy material (density = 0.2 g/cm^3), its transportation is not economical. Its use in sandy soil is considered beneficial because of its high water-holding capacity.[4]

Figure 1. Typical coir pith hillock in the southern Indian state of Kerala.

Coir pith has been found to be an effective substitute for natural peat.[5,6] The pH of the composted coir pith is close to neutral, while the pH of natural pith is acidic.[7−11] The electrical

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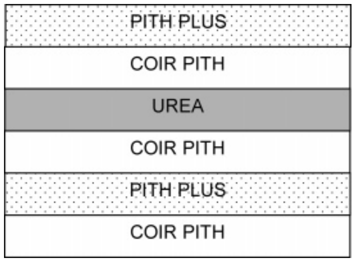

Figure 2. Multilayered arrangement of coir pith, PITHPLUS, and urea for composting of coir pith.

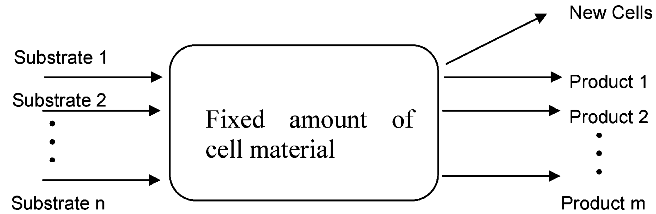

Figure 3. Schematic diagram of the overall biochemical process. The cell material uses the substrates to produce additional cell mass and different metabolites.

conductivity of the composted coir pith drops to 0.23 dS/cm, in comparison to over 0.7 dS/cm for peat moss.[12] Because coir pith is organic in nature, there are some advantages of its use in agriculture.[13]

Coir pith when inoculated with a proprietary bioformulation, such as PITHPLUS, and enriched with urea shows a definite reduction in lignin and cellulose contents with an increase in total nitrogen and other nutrient elements after a period of 30 days. PITHPLUS is derived from *Pleurotus sajor caju*,[14] which is a fast-growing, edible oyster mushroom, originally found in India and grows naturally on a succulent plant (*Euphorbia royleans*) in the foothills of the Himalayas. Even though the use of coir pith on the basis of quantities of 10−15 tons/hectare has also been found to improve the physical conditions of soil and the productivity of many field crops, the use of composted coir pith (prepared by using PITHPLUS and urea as mentioned above) provides better material for soil amelioration. The microorganisms in PITHPLUS have also been used to treat different organic wastes. Recent report mentions the uses of *P. sajor caju* for treating seaweed and organic wastes from brewing industries.[15]

Coir pith, both in raw as well as in the composted forms, is gaining increased popularity in developed countries for soil conditioning and in horticulture. Cost-effective technologies that address the development of value-added products from coir pith, therefore, become relevant for countries producing coir pith.[16−18]

There are some descriptions in the literature for the composting of coir pith. According to these processes,[19] the pith is composted in a multilayered structure, where the different pith layers are interspersed with layers of edible PITHPLUS mushroom and urea. A typical schematic diagram of such a multilayered structure is shown in Figure 2. As shown in the figure, the first layer of pith is covered with a layer of PITHPLUS. The layer of PITHPLUS provides the necessary cellular organisms to biodegrade the coir pith. The layer of PITHPLUS is covered by an additional layer of coir pith, followed by a layer of urea. Urea provides the necessary nutrient media to proliferate the growth of the cellular organisms that cause the composting of the coir pith. The urea layer is finally topped off by a layer of pith and PITHPLUS, respectively. The final assembly is a six-layered arrangement, which is continued until the height of the heap reaches a maximum of 1 m. The moisture in the heap is maintained at 200% by sprinkling water every day. The PITHPLUS composts the coir pith in open air in about 30−45 days until the pith becomes black in color, indicating the composting of the coir pith moving toward completion. The organic manure thus obtained is richer in nitrogen, phosphorus, and potassium.

The method described above, although effective in composting coir pith, suffers from two limitations. First, it takes over a month for composting when the heaps are larger in dimensions. Second, the height of the coir-pith heap that this process can compost has to be less than 1 m, which results in a large area of land usage for composting, for a given heap of coir pith. Both of these limitations originate because of the absence of a proper aeration system in the heap of the coir pith. The process described above relies on natural aeration, which can be limiting, especially when multilayered heap structures are designed. The lack of a proper flow of air also results in longer composting times. Both of these issues are addressed in this work that has resulted in accelerated composting times and a smaller use of land acreage for composting. Specifically, we present a simple and improved process for effective composting of coir pith that is rich in both ligno-cellulose and polyphenols. The process enables *in situ* composting of large heaps of coir pith and thereby eliminates land pollution.

2. Theoretical Basis for the Work

Composting is an oxidative process that demands excessive quantities of oxygen. The microorganisms in the process consume the substrates and liberate, as end products, large quantities of carbon dioxide. The composting process is exothermic and usually conducted in heaps. As a result of the heap structure, access of oxygen into the bulk of the heap and release of carbon dioxide and heat are slow. These conditions result in the lowering of the rates of composting. We were therefore interested in devices and methods that could accelerate the rates of composting. However, before we describe our method of composting, it is instructive to discuss some of the basic biochemical reactions that are at the crux of the composting process.

The overall biochemical process involves the consumption of substrates by cells to produce additional cell mass and products and is schematized in Figure 3. Figure 3 is described in a very generic way, where there are n different substrates and m different products formed. Usually, n is about 2−5 main substrates, and m is about 3−7 major products. In our case, we

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have three substrates, namely, the uncomposted coir pith, urea, and calcium carbonate, and five major products that include depolymerized lignins, oxidized polyphenols, lignin−carbohydrate complexes, laccase enzymes, and dead microbes, including various minerals enriched in the available form.

To write the overall macroscopic balance, it is useful to represent the substrates, products, and cells in terms of their elemental constitution. For the biochemical process considered in this work, the different substrates can be categorized into two types, namely, a carbon-rich substrate that will be represented by CH_xO_y and a nitrogen-rich substrate that will be represented by $H_lO_mN_n$. The cells convert these substrates into products, represented by CH_rO_s and $H_uO_vN_w$, liberating CO_2 and H_2O in the process. The cell material will be represented as $CH_\alpha O_\beta N_\delta$. This definition is based on 1 g of carbon atoms in the cell and is a convenient representation for a number of microorganisms.[20,21]

On the basis of Figure 3, the overall chemical reaction may be written as

$$n_1CH_\alpha O_\beta N_\delta + aCH_xO_y + bH_lO_mN_n + cO_2 \xrightarrow{k} n_2CH_\alpha O_\beta N_\delta + a'CH_rO_s + b'H_uO_vN_w + dCO_2 + eH_2O \quad (1)$$

where n_1, n_2, a, a', b, b', c, d, and e are the stoichiometric coefficients of the reaction. From eq 1, the rate of product $[CH_rO_s]$ formation follows as

$$d/dt[CH_rO_s] = k[CH_\alpha O_\beta N_\delta]^{n_1}[CH_xO_y]^a[H_lO_mN_n]^b[O_2]^c \quad (2)$$

This implies that the rate of composting varies directly as the concentration of the cell mass $[CH_\alpha O_\beta N_\delta]$, the concentration of carbon- and nitrogen-rich substrates, and most importantly, the concentration of oxygen supply $[O_2]$. Usually, the rate-determining reactant in eq 2 is oxygen, and therefore, we postulate that significant improvements in composting rates can be achieved by a better design of aeration systems for oxygen supply in the compost pile. We will validate this postulate by showing in the subsequent sections that a better designed aeration system helps in significantly accelerating the composting of coir pith.

3. Experimental Section

Two experimental programs were carried out in this study. The first experimental program involved the design and construction of an improved aeration system embedded within the heap structure of the compost and its successful demonstration in composting a pilot-scale coir pith heap. This experimental program was carried out on the premises of the Central Coir Research Institute (CCRI) in the southern state of Kerala in India. The second experimental program was a follow up to this pilot-scale demonstration in a real field study for composting a large coir pith hillock located at Thanneermukkom in the Alleppey district of Kerala, India. The design based on the pilot-scale study was scaled up for this demonstration in composting the coir pith hillock.

Our design provides a system of aeration within the multilayers of the coir-pith heap that enables the inflow of an increased quantity of oxygen to the lignolytic microorganisms. The system of aeration comprises a number of perforated polyvinyl chloride (PVC) pipes, because they are lightweight and recalcitrant to corrosion. The pipes used for the experiment were of an appropriate diameter of 100 mm and were embedded into the heap, equally spaced from each other, at a distance of 60 cm from each other. Each PVC pipe has a large number of perforations with a diameter of 6−10 mm, all over its curved surface, to allow uninterrupted free inflow of air and to provide an outlet for the carbon dioxide and dissipation of the heat generated during composting, through convection. A schematic diagram of such an aerator assembly is shown in Figure 4.

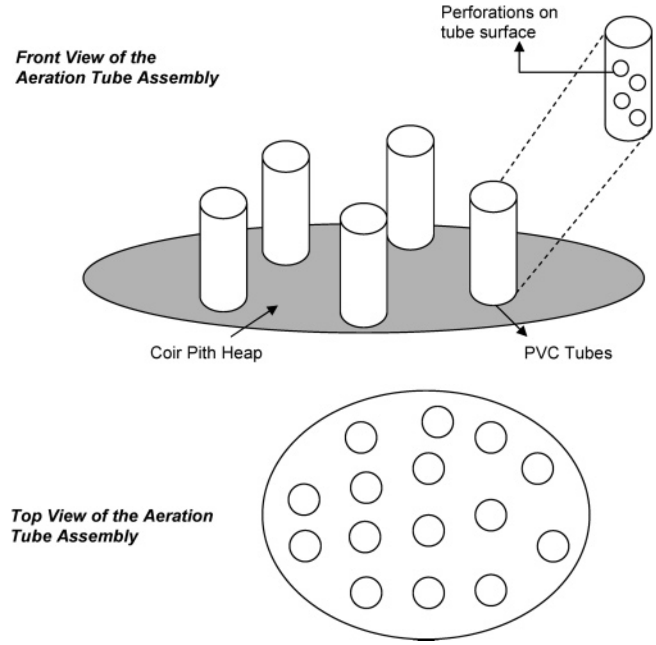

Figure 4. Schematic diagram of the aerator tube assembly.

Figure 5. Actual design of the aerator assembly.

The actual design based on the schematic diagram of Figure 4 is shown in Figure 5. It can be noticed that, in Figure 5, the composting is done on a raised platform that ensures the flow of oxygen from the bottom of the heap as well.

The raised platform is constructed with bricks laid with spaces in between and covered with a sheet of plastic fabric or sheet preferably made from the plastic PVC to avoid corrosion. The raised platform should preferably have a minimum ground clearance of 15−20 cm or more. The fabric or plastic laid on the platform has a large number of circular holes over its surface, at a spacing varying from 30 to 120 cm, preferably at a spacing of 60 cm. The space below the holes is empty and has access to air from the bottom of the platform. Above this platform, a thick fabric, preferably coir matting of a 0.5 cm thickness and having a hole pattern matching the holes in the PVC platform, can be laid. Through these holes, circular, perforated pipes, preferably of PVC, are inserted. With this arrangement, the PVC pipes are positioned at the preferred

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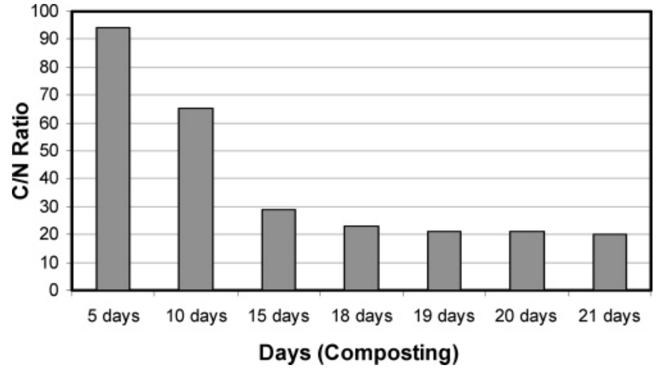
Table 1. Results of a Raised Platform Composting with an Improved Aeration System

	5 days	10 days	15 days	18 days	19 days	20 days	21 days
nitrogen (%)	0.31	0.42	0.92	1.13	1.17	1.21	1.24
phosphorus (%)	0.02	0.028	0.03	0.04	0.05	0.054	0.055
potassium (%)	0.79	0.85	0.97	1.12	1.16	1.16	1.16
organic carbon (%)	29	27.5	26.9	25.3	25.1	24.9	24.9
pH	5.9	6.1	6.3	6.3	6.3	6.5	6.5
electrical conductivity (dS/cm)	0.71	0.42	0.31	0.29	0.27	0.23	0.23
C/N ratio	94	65	29	23	21	21	20



distance of 60 cm; the pipes are positioned at each corner of a square with an area of 2 m^2. Preferably, about 20 cm of each of the pipes is below the lowest layer of heap, while about 25 cm of each of the PVC pipes extends above the top surface of the multilayered composite heap made of pith, mushroom, urea, etc., as per the layering arrangement described in Figure 2. The PVC pipes have a large number of perforations, with a diameter of about 6−10 mm, all over its curved surface. Each pipe has perforations to the extent of about 2000 holes/m^2 of the curved surface area. The four sides and the top of the heap are covered with coconut leaves to minimize the loss of moisture by evaporation.

The results of our raised platform composting method with improved aerator assembly are shown in Table 1. The table shows the rate of change of the C/N ratio in the coir pith as a function of the number of composting days. The rate of compositing is rapid during the first 5−15 days, decreasing from an initial C/N ratio of 112:1 to 29:1 at the end of 15 days, and almost follows a first-order kinetic rate. After 15 days, the rate gradually begins to plateau, with the composting becoming complete in around 21 days. The change in nitrogen, phosphorus, potassium, organic carbon, pH, and electrical conductivity are also shown during this composting period.

To contrast the rate of composting in our new design against the conventional method, a control composting experiment using the conventional method was also carried out. The layers of pith were placed in the same multilayered structure as shown previously in Figure 1. Additionally, the inoculums were supplemented with calcium carbonate to the extent of 0.5% of the weight of starting noncomposted coir pith. The conventional method has no aerator assembly and relies on natural aeration for the composting process. Further, as per the requirement of the conventional method, the height of the heap was maintained as 1 m. Table 2 presents the results of the rate of composting using the conventional method. When Table 2 is compared with Table 1, it is clear that the rate of composting is slower in the conventional method. For instance, after 15 days, the C/N ratio in the conventional method is 36:1 compared to 29:1 in our method. Most noticeably, the conventional method takes 30 days to compost compared to 21 days with our method.

Table 2. Results of a Conventional Composting Process for the Rate of Composting

	5 days	10 days	15 days	18 days	19 days	20 days	21 days	30 days
nitrogen (%)	0.28	0.34	0.78	0.82	0.87	0.93	0.93	1.06
phosphorus (%)	0.02	0.021	0.025	0.04	0.043	0.043	0.05	0.06
potassium (%)	0.74	0.79	0.81	0.91	0.93	0.94	0.94	1.2
organic carbon (%)	29.3	28.9	28	27.4	27.2	27	26.9	24.9
pH	5.6	5.9	6	6	6.1	6.1	6.1	6.5
electrical conductivity (dS/cm)	0.72	0.49	0.39	0.33	0.31	0.31	0.31	0.23
C/N ratio	105	82	36	33	31	29	29	20

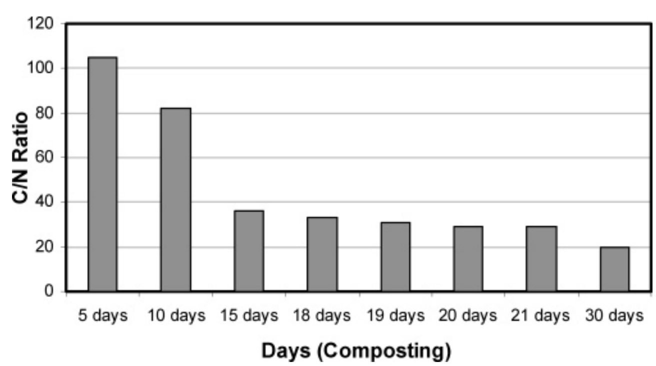


Figure 6. Initial assembly of the design of our composting assembly for coir pith.

Figure 7. Final assembly of our system at the beginning of the composting process.

4. Coir Pith Hillock Composting

After the successful demonstration of the new technology on the pilot scale, a field study on a coir pith hillock located at Thanneermukkom in the Alleppey district of Kerala, India, was conducted as a test of the new process on a large scale. In this study, the composting of coir pith was carried out *in situ* at the site where dumped mounds of coir pith lay unused. A 6-year-old heap of coir pith lying near a defibering factory was selected for composting. A pit with a diameter of 240 cm and 1 m in depth was made in the hillock by digging out the pith.

The aerator assembly used by us comprised a system of perforated horizontal pipes, which were laid on the bottom surface of the pit. These pipes were connected to vertically placed pipes through T/elbow joints. The horizontal pipes protruded outside the mound of pith in all directions, whereas about 25 cm of the vertical pipes protruded above the top surface of the multilayered heap. The ends of the pipes protruding outside the heap were covered with a plastic fabric wire mesh cap. A snapshot of the initial assembly is shown in Figure 6.

As shown, a network of PVC pipes with a diameter of 50 mm and length of 60 cm were laid horizontally. The pipes were interlinked by T/elbow joints, with one end protruding upward to hold the vertical perforated 100 mm diameter PVC pipes (total of 19) provided for aeration. Both ends of the horizontal pipeline protruded out of the pit as an air vent. The pit was refilled in 100 kg batches and overlaid alternately with PITHPLUS (400 g) supplemented with calcium carbonate (1 kg) and urea (1 kg). It was ensured that the vertical pipes extended 25 cm above the heap surface to enable air inflow and gas exchange between the heap and the atmosphere. The top of the perforated vertical pipes was covered with a polythene sheet to prevent overflooding as a result of rains that may cause the leaching of urea and other soluble beneficial materials from the heap through the laid pipes protruding outside the pit. The heap was sprinkled with water occasionally to maintain the moisture in the pith, which is essential for the composting process. The final assembly of our system at the beginning of the process is shown in Figure 7.

Similar to our pilot-scale demonstration, the composting of the pith was complete in 21 days. The composted coir pith obtained is 100% organic manure, which turns into a black mass with a reduced C/N ratio from 112:1 to 20:1. Also, as a direct consequence of compositing, there is a volume reduction of 42%. The pH increases from 5.5 to 6.5, becoming more neutral in nature, and therefore is a better soil organic manure. The electrical conductivity decreases from 0.98 to 0.23 dS/cm. Compostedpith organic manure obtained does not contain or carry weeds and undesirable pathogens. The laboratory tests were conducted for detecting the presence of any pathogens including *Salmonella* and *Escherichia coli*, which were found to be absent in all of the composted samples.

5. Conclusions

A simple and effective technology for accelerated composting of coir pith was developed in this paper that has been successfully demonstrated to biodegrade heaps of coir pith, in both pilot-scale and real field applications. The process relies on arranging the coir pith in a multilayered structure interspersed with a propriety bioformulation, PITHPLUS, and supplemented with nutrients such as urea and calcium carbonate. In addition, an aerator assembly of a network of perforated PVC pipes within this multilayered heap of coir pith is designed that ensures the successful distribution of oxygen in the heap. Using this new technology, the composting of coir pith is complete in 21 days, compared to the conventional method, which would take 30−45 days. Improved aeration also provides the added benefit of a smaller land requirement for coir pith disposal than the conventional technology. Successful implementation of this technology has already been accomplished in many parts of southern India, where coir pith disposal is a major concern. Many small coir-fiber manufacturers have adopted this simple, cost-effective method of composting, converting their agricultural waste (coir pith) into useful manure, thus generating additional income from otherwise waste byproducts. The technology is affordable because it uses locally available materials, such as PVC pipes, and also simple enough that even unskilled persons could implement it.

Coir pith, which was considered a problematic waste, has found its potential uses after converting into compost in enhancing yields of various crops.[22] The Coir Board in India has also published the recommended doses of application of composted coir pith for various plants and crops. The Kerala Agricultural University has published a code of practices for the use of coir pith compost.[23]

The process and design described in this paper have been successfully demonstrated in various places, and the results have been found to be reproducible. The extension wing of CCRI is

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popularizing the technology of heap composting by carrying out demonstrations on composting of 50 tons of coir pith at sites in the states, such as Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh. Thus far, more than 50 such demonstrations have been carried out in the continued program of extension of this technology. The technology has received favorable response from almost all of the coconut-producing states in the country, where pith has been accumulating for decades without any solution for its disposal. Some Middle East countries have also expressed interest for procuring this technology.

The design and technology presented here are scalable and relevant to many developing countries with coir industries.

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