

Review Article

Co-composting- A promising technology for the production of nutrient rich manure from coir pith waste

ABSTRACT

Coir industries in India generates around 7.5Mt of coir waste yearly, which is unsuitable for agricultural use due to its high C:N ratio, lignin, phenol, cellulose and tannin content. The accumulation of coir pith leads to adverse environmental problems due to the release of phenolic compounds, lignin, tannins etc. Biodegradation or composting is the best way to manage coir waste and thereby the environmental pollution can be avoided. Co-composting is a method of decomposing multiple organic materials, which aims to create stable humus, and overcome the limitations of composting with a single organic source. Burning coir pith releases phenolic chemicals, posing environmental hazards like fire risks and groundwater contamination. Proper disposal and recycling of coir waste can help address these issues. Co-composting in coir pith reduces the C:N ratio, lignin, cellulose content and increases the nutrient contents. In co-composting technology more than one feed stock are used for composting. Co-composting of coir-pith can be done by treating the coir pith with organic source of nutrients viz., farm yard manure or poultry manure or agro-industrial wastes or green manure crops or leguminous weeds or treating the coir pith with organic wastes and earthworms, or treating the coir pith with organic sources of nutrients and lignin degrading micro-organisms and or supplementing the coir pith with lime, rock phosphate etc. along with the organic sources of nutrients mentioned above to speed up the composting process. Co-composting of coir pith resulted in the production of nutrient rich organic manure within a short period of time. Application of coir pith compost had significant effect on the growth and yield attributes of crops. Harnessing the potential of coir pith can lead us towards a more sustainable and greener future.

Key words: Coir pith, Co-composting, Urea, Poultry manure, Earthworms, Agro-industrial wastes

INTRODUCTION

India is the largest producer and area under coconut in the world. Kerala, Tamil Nadu, Andhra Pradesh and Karnataka are the leading producing states of India and every year over 14,000 million coconut nuts are produced [1]. In India, coconut is cultivated in an area of 2.2 Mha with a production of 20,535 million nuts and productivity of 9,018 nuts ha⁻¹. In Kerala,

coconut is cultivated in an area of 0.76 M ha with the production of 5,628 millionnutsand productivity of 7402nuts ha⁻¹[2]. The total area under coconut is 2.14 M ha and production is 21.67 billion nuts. In addition to the southern states, coconut is also produced in the north-eastern and island region.It is estimated that approximately one tonne of coir pith is accumulated as waste from every 10,000 husks utilized in coir industry [1].In India, every year on an average 7.5 Mt of coir pith waste is generated from coir industries[3].

The spongy pericarp (husk) the outer shell of the coconut is used to produce coir fibre.The husk is made up of long fibres that are encircled with coir pith, a non-fibrous, light weight and fluffy material. Retting and other mechanical processes are used to remove it from the husk.The defibrillation procedure separates the pith from the coir, which constitutes up to 50 to 70 percent of the fibre. Coconut fibres are separated from the retted or un-retted husk manually by beating the husk with wooden mallets or mechanically by motorized procedures in steel drums. When disposed in nature, the high lignin and cellulose content of coir pith causes high amount of recalcitrance and the slow decomposition of the fibreswhich causes environmental issues [4].Nearly one tonne of coir pith is accumulated from every 10,000 husks utilised in the coir industry [1].

CHARACTERISTICS OF COIR PITH

Coir pithobtained from fully mature nutshad higher amounts of lignin and cellulose contentscompared to younger nuts [11]. It hasvery high moisture retention capacity (500-600%) and as high as 1100% of dry weight [12]. Due to its high moisture retention capacity of roughly 40%, coir pith has high demand in dry locations [13]. Coir pith has a high C:N ratio (>100:1), high lignin and cellulose content (about 40% each), and high polyphenol content (about 100mg/100g coir pith).The natural breakdown and mineralization rates are very slow, which makes it unsuitable for direct use in agriculture as organic manure. When raw coir pith is applied to the soil, plant nutrients become immobilized due to very high c:N ratio. The average nutritive composition of coir pith is depicted inTable 1[14]. The nutrient content of the coir pith will vary depending upon the location, maturity of the coconut and the management practices followed for the coconut.

Table 1. Average nutrient composition of raw coir pith and composted coir pith

Parameters	Raw coir pith	Composted coir pith
Lignin	30-4%	<5%

Cellulose	>25%	<10%
C:N ratio	>100:1	<24:1
Carbon	26%	24%
Nitrogen	<0.3%	>1%
Phosphorus	0.01%	0.06%
Potassium	<1%	>1%
Calcium	<0.5%	>0.50%
Magnesium	<0.4%	>0.4%
Iron	<0.07 mg kg ⁻¹	>0.09 mg kg ⁻¹
Manganese (mg kg ⁻¹)	<15 mg kg ⁻¹	>25 mg kg ⁻¹
Zinc (mg kg ⁻¹)	<10 mg kg ⁻¹	>15 mg kg ⁻¹
Copper (mg kg ⁻¹)	<5 mg kg ⁻¹	>5 mg kg ⁻¹

NEED FOR COMPOSTING

Coir pith is a lignocellulosic waste which comprises of 29-32.15% lignin, 25.1-26.40% cellulose, 29-29.5% organic carbon, 0.24-0.26% nitrogen, 0.01% phosphorus, and 0.71-0.76% potassium. It has high lignin and cellulose content leading to environmental buildup, thus forming hillocks. Lignin acts as a barrier in industrial processes also [17]. Due to the pentosan/lignin ratio of 1:0.30 and high C:N ratio of >100:1 it has slow decomposition rate and is unsuitable for use as an organic manure [18]. Over time, hillocks generated by coir pith releases harmful phenolics into water sources, thus harming the aquatic life. The direct application of coir pith leads to reduction in microbial population and immobilizes nitrogen. In order to use coir pith effectively as a manure, its lignin must be degraded. Converting coir pith in to compost by composting process is the only way to overcome the problem of coir pith waste accumulation and environmental pollution [17].

The coir pith is either burned or dumped in large hillocks on the side of the roads or area adjacent to the coir industries [19]. Due to the release of phenolic chemicals, the buildup of coir pith creates fire dangers and groundwater contamination [20]. Additionally, polyphenols and phenolic acids released from burning of coir pith can be phytotoxic and limits the plant growth [21]. The agricultural soils and irrigation canals absorb the tannins and phenols leached out from the coir pith. It also contains lot of salts, clogs the drain sand canals and accumulates in the soil, and makes agricultural fields unsuitable for cultivation.

Another major problem is that these toxic substances enter the food chain from soil and water, and undergo biomagnification which has detrimental effects to both humans and wildlife. Therefore, very essential to address the problem and develop a rapid technology for the proper conversion of coir pith waste. The best solution for the proper disposal of coir pith waste is the composting or co-composting of coir pith waste.

COMPOSTING AND CO-COMPOSTING

Composting is the process of converting organic matter into humus, which would improve the soil fertility and structure [15]. Composting is the low cost and environment friendly method for the proper disposal of agricultural waste generated. Enzymatic decomposition of coir pith has been regarded as the effective means of minimizing environmental pollution [16]. Composting refers to the process of biological decomposition of biodegradable waste in the presence of oxygen under thermophilic conditions by microorganisms (mainly bacteria and fungi). The final product of the biological decomposition of organic waste is called compost which is very stable in nature. Composting is a low cost and low investment technology which improve the value of agricultural organic waste into a nutrient rich organic manure through the biological process [5]. The composting assembly generally consists of an incubator for the biological decomposition process which transforms the organic wastes and/or agricultural byproducts (leaves, fruit, vegetables, and food wastes) into a stable humus by the action of earth worms or microorganisms in the presence of oxygen and at optimum temperature, and moisture.

Composting can be carried in the presence or absence of oxygen *i.e.* under aerobic or under anaerobic conditions. The above-ground composting systems underlies the principle aerobic composting process. Typically, aerobic composting is done in a free-standing heap or in a ventilated condition, like an open-sided bin or any container with aeration holes or chambers. If there is a constant supply of oxygen, aerobic decomposers function more quickly and effectively than anaerobic decomposers and produce final compost within a short period of time. On the other hand, anaerobic organisms require substantially lower oxygen concentrations to function, thus the majority of anaerobic processes occur deep down in pits or trenches. Anaerobic organisms work slowly and is difficult to monitor their development. It also generates methane gas during the composting process [6].

Co-composting is the process of aerobic decomposition of more than one organic waste at a time into stable humus which is rich in nutrients. It overcome the disadvantages of

composting with single organic matter[7]. The term co-composting refers to the composting of two or more raw materials simultaneously. Co-composting technology can be effectively adopted for the disposal of organic wastes to attain zero waste and sustainability. By fully utilizing a variety of waste materials, co-composting further improves the quality of the compost [8]. Co-composting is the better option for waste management than other methods like incineration and landfill. Certain physical and chemical characteristics of animal manure are not adequate for composting and limit the efficiency of the composting process. This difficulty can be overcome by addition of biodegradable waste, bulking agents, etc. and brought down the C:N ratio to a favourable range, thereby speeded up the degradation rate, and improve the quality of the final compost[9].

CO-COMPOSTING IN COIR PITH

By using a variety of chemical and biological treatment techniques, coir pith is made amenable to microbial attack and subsequent decomposition process. Addition of nitrogen fertilizers or nitrogen-rich organic resources like legume biomass, poultry manure, oil cakes, etc., the C:N ratio of the composting medium can be decreased. Lignin can also be broken down by encouraging the growth of naturally occurring lignin-degrading microbes or by artificially introducing starter cultures of effective lignin-degrading bacteria [22]. The Central Coir Research Institute (Coir Board) has developed a standardized composting method for producing organic fertilizer from coir pith, incorporating urea as a nitrogen source. The resultant manure is rich in nutrients that are necessary for plant growth, including potassium (1.20%), phosphorus (0.06%), and nitrogen (1.26%) [10].

Method of composting coir pith using Urea and *Pleurotus-sajor caju*

A technology has been developed by Coir board for composting coir pith and converting it into a nutrient rich organic manure and marketed under the trade name C-POM. C-POM is an organic manure manufactured from coir pith, made by the bioconversion of coir pith using 'PITHPLUS' a lignolytic mushroom spawn[23]. Field demonstrations in rainfed maize were conducted by Central Soil and Water Conservation Research & Training Institute (CSWCRTI) to study the effect of C-POM on rainfed maize. Results revealed that the height of the plants, cob length, and stover yield were significantly higher in the field treated with C-POM than in the control plot [24]. Providing aerators at each corner of the heap made of coir pith, *Pleurotus sajor-caju* and urea in alternate layer, 20 cm below the lowest layer and 25 cm extends over the top surface of the heap, accelerated the composting process and the coir pith

compost will be ready for application in 21 days. The final compost obtained has had a C:N ratio of 20:1, pH of 6.5, and EC of 0.23 dSm⁻¹.

Co-composting of coir pith with organic sources of N

Although composting helps to reduce the problem of pollution caused by coir pith accumulation, using urea as a source of nitrogen has several drawbacks. A high urea concentration shows the risk for burning, which will destroy the plant roots [26]. Composting of coir pith with azolla and soybean hulls in 2: 1 ratio indicated that, the mixture of Azolla and soybean hulls in a 2:1 ratio effectively facilitated lignin degradation (up to 10.15%), significantly reduced C:N ratio (20:1) and enhanced the NPK contents in biodegraded pith (1.18%, 0.051% and 1.09 respectively), and improved the biological properties of the compost [17]. Coir pith can be transformed into a potent organic fertilizer (coir-Krishimithra) through the action of the fungus *Pleurotus sajor-caju*, combined with N-rich additives such as azolla, neem cake, and fish waste, applied in a 1:1:1 ratio. Evaluation of the physicochemical properties of coir pith obtained indicated that a mixture of azolla, neem cake, and fish waste effectively promoted lignin degradation and speeded up the composting process [26]. Inclusion of nitrogen-fixing bacteria as the primary nitrogen source in coir pith composting, instead of urea resulted in significant reduction in lignin content and enhancement in NPK content. Replacing inorganic urea with biological agents enhanced the soil fertility and was cost effective [27]. Another composting technology, named Novcom was introduced in Kerala, which produces high-quality compost from coir pith waste. In this method a solution was prepared from an extract of common basil (*Ocimum basilicum*), bel (*Sida cordifolia* L), and doob grass (*Cynodon dactylon*) that has been biologically activated and potentiated. Analysis of quality parameters indicated that the Novcom composting process would be a good choice for the eco-friendly disposal of coir pith waste and for the production of high-quality organic fertilizer for organic farming [28]. The composting process can be accelerated by incorporating readily digestible organic materials, including weeds of leguminosae family, green manures, farm yard manure, poultry manure, oil cakes, biogas slurry during the preparation of compost [29][30]. The use of these organic materials during the composting process enhanced the N content of the final coir pith compost [31].

Co composting of coir-pith with poultry manure, lime and rock phosphate

Addition of lime to coir pith enhances the growth of lignin-degrading fungi. Pretreatment with lime @ 5kg t⁻¹ of coir pith significantly enhanced the degradation of

lignin[32].Lime enhances the humification of plant residues by promoting the growth and activity of microbes, and weaken the lignin structure. Also,it enhances the the quality of final compost by altering the ratio of humic to fulvic acids and by reducing the levels of bitumens and humins, which hinder the biological degradation process. Addition of rock phosphate to the coir pith also enhance the composting process. Rock phosphate, which also contains significant amounts of lime, contributes similarly. Furthermore, the phosphates and micronutrients present in rock phosphate enhanced the nutrient content of the final compost product[31].The addition of poultry manure to the coir pith accelerated the biological degradation process of the coir pith and completed the composting process in 45 days. The compostobtained from the addition of poultry manure had thephysico-chemical properties necessary for high-quality organic manure. Additionally, theC:N ratio, an indicator of compost maturity, reached to 21.42%towards the end of the process[33].NCRMI Thiruvananthapuram conducted experiment to develop an alternate composting technology, poultry manure as an alternative to inorganic urea. Three different fungi,*Pleurotus* sp., *Trichoderma harzianum* and *Phanerochaetumcrysosporium*were also tried indifferent treatment combinations along with poultry manure.The resultsrevealed that coir pith could be composted efficiently and naturally by combining poultry manure as a nitrogen source with *Trichoderma harzianum*[34]. Co-composting of coir pith with rice bran, molasses and cattle manure in 3:1:0.08:1, avoid the forced aeration during the composting process and final compost will be obtained in 21 days.The results also indicated that basic pile turning achieved efficient co-composting of coir pith even at a relatively low C:N ratioof 30:1 [35].

Co-composting with biological substrates and agro-industrial waste

The *Pleurotus*fungushad the ability to degrade coir pith. Among the various species of *Pleurotus* namely *Pleurotus citrinopileatus*, *Pleurotu platypus*, *Pleurotuflorida*, *Pleurotu sapidus*, and *Pleurotus sajor-caju* (oyster mushroom),*Pleurotu platypus*showed the highest efficiency in degrading coir pith and there was significant reduction in cellulose content (59%), and lignin content (78%) in the final compost. Significant reduction in C:Nwas also observed, C: N ration brought down from 104:1 to 18:1[36]. Treating coir pithwith Effective Microorganisms (EM) solution(EM is a liquid concentrate containing *Lactobacillus*, *Streptomyces*, and actinomycetes) significantly reduced the cellulose content, phenolic content and C: N ratio within 90 days of decomposition The decrease in phenolic content was attributed to the degradation of phenolic compounds into less toxic compounds by the microorganisms [37]. It was observed from the results that composting of coir pith with

earthworms *Eudriluseugeniaeas* bioagent significantly reduced the composting time and enhanced the recovery of the final compost compared to composting with microorganisms alone[38]. The combined effect of *Pleurotus sajor-caju* and earthworm in reduction of cellulose, hemicellulose and lignin content in coir pith compost was evaluated. The percentage reduction in cellulose, hemicellulose, and lignin content were more pronounced in coir pith treated with cowdung, *Pleurotus sajor-caju* and earthworm when compared with coir pith waste alone[39]. The impact of various white rot fungi, basidiomycetes, antagonist organisms and nitrogen fixing bacteria on the decomposition of coconut coir pith revealed that inoculation of coir pith with various organisms resulted in significant reduction in organic carbon content and an increase in total nitrogen content. The most substantial decrease in the C:N ratio, cellulose, and lignin was observed with *Pleurotudinjamor*, *Pleurotus sajor-caju*, and *Trichoderma viride*. The final coir pith compost obtained had higher levels of nitrogen, phosphorus, potassium, and calcium [40]. Final compost obtained 12 weeks after treating the coir pith with cow dung, vegetable market waste, poultry waste, and mixed microbial culture of *Trichoderma viridae* and *Pleurotus sajor-caju* had a C:N ratio of 22:1. It was also observed that the compost had higher N, P and K content and lower cellulose and lignin content[41].

Effect of coir pith compost on growth and yield attributes of crops

Coir pith compost had favourable effects in improving the soil structure and yield of crop. Coir pith compost improves the soil structure, texture, water holding capacity, hydraulic conductivity and also nutrient status of the soil. Since, the coir pith compost contains significant amount of organic matter, it improves the organic carbon content and improves the activity of microorganisms. Because of these properties, application of coir pith compost enhanced the growth and yield attributes of crop. The utilization of coir pith compost resulted in 17 per cent yield enhancement in maize compared to control without coir pith compost application. The number of grains per cob also exhibited 15 per cent increase compared to that of the control[24]. Coir pith based potting mixture (Coir krishimithra) had effects on growth of *Amaranthus* and *Groundnut* plants when compared with garden soil. Maximum plant growth, plant height at harvest, number of branches per plant at harvest and longer root and shoot were observed in plants grown in Coir KrishiMithra Coir pith + *Pleurotus Sajor-Caju* + *Azolla* + *Neem cake* + *Fish waste* [26]. A pot experiment carried out to assess the effect of organic nutrient sources on the growth and yield of barnyard millet (*Echinochloa frumentacea*) revealed that soil application of coir pith compost 10 t ha⁻¹ + bone meal powder 1 t ha⁻¹ along with foliar application of Panchagavya (3%) produced taller plants (159.7 cm),

higher number of leaves per plant (8.51 nos.), higher LAI and higher dry matter production [42]. Experiments conducted to study the effect of coir pith on the yield of onion and cassava revealed that application of 75% RDF along with coir pith +1.25% mushroom spawn +5% poultry manure resulted in the highest yield in both the crops (430 qha⁻¹ in onion and 23.5 t ha⁻¹ in cassava) [18]. Coir pith treated with *Pleurotus* and urea in alternate layers resulted in the production of compost with low C: N ratio and higher nutrient contents. This compost when applied at various rates as an organic fertilizer for sugarcane plants found to improve the root and shoot length and cane yield of sugarcane [43]. In a pot culture experiment, it was found that *Phyllanthus amaranthus* grown in pots with higher content of coir pith soil had longer shoots and roots [44]. Coir-pith compost also enhanced the growth of blackgram plants by increasing the rate and activity of nodulation [45]. In a field study conducted at CPCRI, it was observed that application of coir pith compost in combination with 50 per cent NPK resulted in an improvement in organic carbon content of the soil and a higher value of K content in coconut leaves. The nut yield obtained with the application of coir pith compost in combination with NPK was significantly higher (115 nuts per palm yr⁻¹) compared to other treatments in coconut [46]. The addition of coir pith compost not only enhances the water-holding capacity but also had positive effect on drainage, rooting of the crops, soil reconditioning, and seed germination. Field experiment was conducted to study the effect of irrigation, composted coir pith, time of N, P, K application and use of a nutrient mixture spray on the growth and yield of soybean. Results revealed that irrigating soybean at a ratio of 0.90 IW/CPE, combined with the application of composted coir pith and split doses of N, P, and K along with a nutrient mixture spray, produced taller plants, higher leaf area index, dry matter production, and grain yield [47]. Field experiment conducted with an objective to examine the residual effects of coir pith compost applied along with organic and inorganic inputs over a period of five years, results revealed that application of coir pith compost with press mud and 100 per cent recommended dose of fertilizers (RDF) resulted in significantly higher grain and straw yields of ragi crop. This treatment also significantly increased the nitrogen, phosphorus and sulphur contents of the soil [48].

CONCLUSION

In conclusion, co-composting of coir pith is a practical and sustainable solution for managing coir pith waste in countries like India where coir pith wastes create environmental issue. Compared to composting, co-composting is a low cost and environment friendly technique which rapidly convert coir pith waste into a nutrient rich organic fertilizer. Co-composting process enhanced the nutrient content of final compost. Addition of coir pith to the soil not only enhances the growth of plants but also enhances the soil health. Co-composting of coir pith not only removes the hillocks from landfills, but also helps in utilisation of a renewable resource. Hence, co-composting is an organic and eco- friendly approach for the safe disposal of coir pith waste and resulted in the production of nutrient rich manure for soil enrichment and helps in promoting sustainable agriculture. Harnessing the potential of coir pith can lead us towards a more sustainable and greener future.

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