Review Article

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

Comment [RK1]: Appropriate title "Co-composting: A Comprehensive Review of Its Potential in Transforming Coir Pith Waste into Nutrient-Rich Manure"

ABSTRACT

Coir industries in India generates around 7.5Mt of coir waste yearly, which is unsuitable for agricultural use due to its high C:Nratio, 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-pithcan 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 coirpith composthad 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.

Comment [RK2]: Abstract should be in 250 words including objective, findings and conclusion with future aspects

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

1. INTRODUCTION

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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 2.2Mha with a production of 20,535 million nutsand productivity of 9,018nuts 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].

Comment [RK4]: Very short introduction
It should be in 500-600 words
Including 15 latest references

2. CHARACTERISTICS OF COIR PITH

Coir pith obtained from fully mature nuts had higher amounts of lignin and cellulose contentscompared to younger nuts [11]. It has very 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 accumulationand 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 friendlly 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 whichimprove 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 whichtransforms

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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-sajorcaju*

Comment [RK5]: Use image

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-POMis 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 weresignificantly 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, *Pleurotussajor-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 applicationin 21 days. The final compost obtained is 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 *Pleurotussajor-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 contentand enhancement in NPK content. Replacing inorganic urea with biological agents enhancedthe soil fertility and was cost effective [27]. Another composting technology, named Novcomwas introduced in Kerala, which produces high-quality compost from coirpith waste. In this method a solution was prepared from an extract of common basil (*Ocimum bascilicum*), bel (*Sida cordifolia* L), and doob grass *(Cynodondactylon*) that has been biologically activated and potentized.Analysis of quality parameters indicated that the Novcom composting process would be a good choice for theeco-friendly disposal of coir pith waste and forthe 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 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, *Pleurotu*s 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* fungus had the ability to degrade coir pith. Among the various species of *Pleurotus* namely *Pleurotuscitrinopileatus*, *Pleurotu platypus*, *Pleurotuflorida*, *Pleurotusapidus*, and *Pleurotussajor-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 *Eudriluseugeniae*as bioagentsignificantly reduced the composting time and enhanced the recovery of the final compost compared to composting with microorganisms alone[38]. The combined effect of*Pleurotussajor-caju* and earthworm in reduction of cellulose, hemicellulose and lignin content in coir pith compostwas evaluated. The percentage reduction in cellulose, hemicellulose, and lignin content were more pronounced in coir pith treated with cowdung, *Pleurotussajor-caju* and earthworm when compared with coir pith waste alone[39].The impact of various white rot fungi, basidiomycetes, antagonist organisms and nitrogen fixing bacteriaon 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 *Pleurotudjamor*, *Pleurotusajor-caju*, and *Trichoderma viride*. The final coir pith compost obtained had higher levels of nitrogen, phosphorus, potassium, and calcium [40].Finalcompost obtained 12 weeks after treating the coir pith with cow dung, vegetable market waste, poultry waste, and mixed microbial culture of *Trichoderma viridae* and *Pleurotussajor-caju*had aC:N ratio of 22:1. It was also observed that the compost hadhigher N, P and K content and lower cellulose and lignin content[41].

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

Comment [RK6]: Use some table and figures more better illustration of info

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 alsonutrient 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 + *PleurotusSajor-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 *(Echinochloafrumentacea)* revealed that soil application of coir pith compost10 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 *Phyllanthusamaranthus* grown in pots with higher content of coir pith soil had longer shoots and roots [44]. Coir-pith compost also enhanced the growth of black gram 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 wassignificantly 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

Comment [RK7]: No need to use conclusion word, elaborate it with future aspects

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 pithto the soil not only enhances the growth of plants but also

enhancesthe 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.

REFERENCE:

1. Vetturayasudharsanan R, Manu SE, Thapa P, Sujithraj R, Kathiresan S. Assessment of soil properties from coir pith waste dump yard. In IOP Conference Series: Earth and Environmental Science. 2022; 1125(1): 012023.
2. Ministry of Agriculture & Farmers Welfare Government of India. Directorate of Economics and Statistics. Annual report 2021-2022.2021;101-102.
3. Saranraj P, Alrudainy AM, Manigandan M, Sivasakthivelan P, Vijay K. Effect of *Pleurotussajor-caju* and earthworm co-inoculation in organic matter, carbon and NPK content in coir pith compost. International Journal of Entomology Research.2022;7 (11): 104-106.
4. Nunes LA, Silva MLS, Gerber JZ, Kalid RA. Waste green coconut shells: Diagnosis of the disposal and applications for use in other products. Journal of Cleaner Production. 2020;255 (1):120-169.
5. Neves L, Ferreira V, Oliveira R. Co-composting cow manure with food waste: The influence of lipid content. World Academy of Science, Engineering and Technology. 2009;58 (2): 986-991.
6. Kacprzak M, Attard E, Lyng KA, Raclavska H, Singh B, Tesfamariam E, Vandenbulcke F. Biodegradable Waste Management in the Circular Economy. 2022; 10 : 9781119679523
7. Hidayat B, SebayangNUW, Akbar AM. Co-composting cow manure, rice straw with marine organic waste: characterization of compost quality.In IOP Conference Series: Earth and Environmental Science.2023;1182(1): 012029.
8. Fang M, Wong JWC, Ma KK, Wong MH. Co-composting of sewage sludge and coal ash: nutrient transformation. Bioresource Technology. 1999; 67: 19-24
9. Herwijnen R, Hutchings TR, Al-Tabbaa A, Moffat AJ, Johns ML, Ouki SK. Remediation of metal contaminated soil with mineral-amended composts. Environmental Pollution. 2007; 150 (3):347-354.
10. Venkatasami R. Integrated nutrient management in coconut with composted coir pith. Madras Agricultural Journal. 2003;90(1-3):54-56.
11. Joseph G. Coir pith, a money spinner. Indian Coconut Journal.1995; 26(1&2): 2-3.
12. Evans MR, Konduru S, Stamps RH. Source variation in physical and chemical properties of coconut coir dust. Horticultural Sciences. 1996;31(6):965-967.
13. Paramanandham J, Ross R, Abbiramy KS, Muthulingam M. Studies on the moisture retention capacity of coir pith, as a function of time. International Journal of Chem Tech Research. 2014;6(12):5049-5052.
14. Joshi E, Gautam P, Kumar M, Lal B. Coir compost: a source of plant nutrient in organic farming. Popular Kheti. 2013;1(4):142-145.
15. Tran HT, Lin C, Bui XT, Ngo HH, Cheruiyot NK, Hoang HG, Vu CT. Aerobic composting remediation of petroleum hydrocarbon-contaminated soil. Current and future perspectives. Science of the Total Environment. 2021;753 (1):142250.
16. Abu Qdais H, Al-Widyan M. Evaluating composting and co-composting kinetics of various agro-industrial wastes. International Journal of Recycling of Organic Waste in Agriculture. 2016;5: 273–280.
17. Radhakrishnan S, Ravindranath AD, Sarma US. Azolla & Soya Hulls-Substitutes for Urea in Coir Pith Composting Using PleurotusSajorCaju. Cod 27. 2011; 2:10-10.
18. Ganesh P, Kumar RS. Effect of coir pith compost on growth and yield attributes of onion and cassava. International Journal of Applied Research. 2016; 2(1):501-506.
19. Paramanandham J, Ross PR. Enumeration and characterization of microorganisms in raw coir pith and coir pith dumped soil. International Letters of Natural Science. 2016;53(1):34–39.
20. Ravindranath DA, Radhakrishnan S. Coir pith—wealth from waste a reference. Coir Board. Ministry of Micro, Small and Medium Enterprise, Government of India.Cochin.2016;9.
21. Wang TSC, Yang TK, Chuang TT. Soli phenolic acids as plant growth inhibitors. Soil Science. 1967;103: 239-246

22. Prabhu SR, Thomas GV. Biological conversion of coir pith into a value-added organic resource and its application in Agri-Horticulture: Current status, prospects and perspective. Journal of Plantation Crops. 2002;30 (1): 1-17.
23. Coir board. Coir Pith Wealth from Waste a Reference. Ministry of Micro Small and Medium Enterprises, Government of India. 2016;26.
24. Kannan K, Selvi V, Singh DV, Khola OPS, Mohanraj R, Murugesan A. Central Soil & Water Conservation Research and Research Centre Training Institute. Coir pith composting–an alternate source of organic manure for rainfed maize. Coir pith Compost Brouchure. 2013:1-2.
25. Ghosh PK, Sarma US, Ravindranath AD, Radhakrishnan S, Ghosh P. 2007. A novel method for accelerated composting of coir pith. Energy & fuels. 2007;21(2):822-827.
26. Radhakrishnan S, Ravindranath AD, Reghuvaran A, Geena MG. Coir-Krishimithra: An Apposite Medium for Cultivation of Vegetable/Medicinal/Ornamental Plants. Cord. 2018;34(1):9-9
27. Reghuvaran A, Ravindranath AD, Natarajan P, Augustine A. Substitution of Urea with fungi and nitrogen fixing bacteria for composting coir pith. Madras Agricultural Journal, 2009;96:144-149.
28. Antara S, Ranjan B, Anupam D, Susmita S, Chatterjee AK, Barik AK, Debashis M. Successful biodegradation of coir pith waste using Novcom composting method: a case study from Vaniampara Rubber Estate, India. Journal of Pharmaceutical and Scientific Innovation. 2015; 4(1):72-77.
29. Prabhu SR, Thomas GV. Biological conversion of coir pith into a value-added organic resource and its application in Agri-horticulture: current status, prospects and perspective. Journal of Plantation Crops. 2002;30(1):1–17
30. Elfstrand S, Bath B, Martensson A. Influence of various forms of green manure amendment on soil microbial community composition, enzyme activity and nutrient levels in leek. Applied Soil Ecology. 2007; 36(1):70–82
31. Anand H S, Suseela Devi L, Kadalli GG, TharamaniGH. Lime pre-treatment for faster degradation and humification of coir pith. Journal of Tropical Agriculture. 1999; 3:73–74.
32. Eyini M, Prema P, Jayakumar M. Cultivation trials of *Pleurotuskummer* on lime pre-treated coir waste and paddy straw. Mushroom Research. 1995; 4:77-80.
33. Thomas GV, Palaniswami C, Prabhu SR, Gopal M, Gupta A. Co-composting of coconut coir pith with solid poultry manure. Current Science. 2013;104 (2):245-250.
34. Anil KR, Soumya TV, Ansi L. Poultry manure as substitute for urea in bio composting of coir pith. International Journal of Recent Scientific Research. 2021;12 (2): 40898-40900.
35. Tripetchkul S, Pundee K, Koonsrisuk S, Akeprathumchai S. Co-composting of coir pith and cow manure: initial C/N ratio vs physico-chemical changes. International Journal of Recycling of Organic Waste in Agriculture, 2012;1:1-8.
36. Malik T, Rawat S. Microbial valorisation of coir pith for development of compost and bioethanol production. Bio-valorization of Waste: Trends and Perspectives, 2021;1-20
37. Lavanya DL, Padmaja CK. Impact of effective microorganism on the decomposition of coir pith. International Research Journal of Environmental Sciences. 2018.7(8):21–23
38. Motha K, DorajeraoAVD, Vishala S. Comparative performance of microbial cultural and earthworm in composting of tender coconut waste into high quality organic manure. International journal of current microbiology and applied sciences. 2018; 7(5):3076–3086
39. Saranraj P, Alshkarchy SS, PrasathGS, Manigandan M, Sivasakthivelan P. Combined effect of *Pleurotussajor-caju* and earthworm in reduction of physical characteristics, cellulose, hemicellulose and lignin content in coir pith compost. International Journal of Entomology Research. 2022;7(11):117-119.
40. Theradimani M, Thangeshwari S, Parthasarathy S. Biological decomposition of coconut coirpith waste. Plant Disease Research. 2018; 33 (2):142-147.
41. Muthurayar T, Dhanarajan MS. Biochemical changes during composting of coir pith waste as influenced by different agro industrial wastes. Agricultural Sciences. 2013;4(5):28.
42. Srinivasan S, Mathana T, Angayarkanni A. Effect of coir pith compost, bone meal powder and panchagavya on yield attributes, yield and harvest index of barnyard millet cv. CO_2 in sandy loam soil. Plant Achieves. 2021;21(1): 09725210.
43. Dharani A, Sarojini G. Composting of coir waste using bacteria (*Pseudomonas* and *streptococci*) and fungi (*Aspergillus* and *Rhizopus*) and their effect on sugar cane plant growth. International journal of advanced research in biological sciences. 2014;5:71-75.

44. Reghuvaran A, Ravindranath AD. Efficacy of biodegraded coir pith for cultivation of medicinal plants.2010.69(7):554-559
45. Jayakumar M, Eyini M, Velmurugan R. Effect of seed Rhizobium-pelleting treatment and addition of coir-pith compost to soil on growth and nodulation of fluoride-water-irrigated blackgram (*Phaseolus mungo*). The Indian Journal of Agricultural Sciences. 1997;67:12.
46. Upadhyay AK, Maheswarappa HP, Palaniswami C, Bhat R, Subramanian P, Thomas GV. Impact of composted coir pith on the nutrition and productivity of coconut. 2009;59(9):1-4.
47. PrabhakaranNK, Lourduraj AC. Effect of integrated management of irrigation, composted coir pith and nutrients on the growth and yield of soybean (*Glycine max* L. Merr.). Actaagronomica hungarica.2003;51(2):181-190.
48. Sushma AR, BasavarajaPK, Badrinath MS, Sridhara S. 2007. Residual effect of integrated nutrient management with coir pith compost and other organics on subsequent Ragi crop yield and chemical properties of vertisols. Journal of the Indian Society of Soil Science. 2007;55(4):500-504.