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Experimental Investigations on the Effect of Pretreatment in Anaerobic Digestion of Coir Pith Agro Waste

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ABSTRACT

The coir industry in India's southern coastal regions, especially in the state of Kerala, is becoming increasingly concerned about the environmental impact of the accumulation and incremental increase of coir pith each year. The objective of this study was to assess the effect of pretreatment on the anaerobic digestion of coir pith. The characterization study of coir pith shows high organic content, which can be anaerobically digested to produce biogas. But, the high lignin content (30.91%) makes the process slow. To overcome this, a biological pretreatment method was tried using two microbial cultures belonging to fungal genera known to be lignin decomposers, viz., *Trichoderma* and *Pleurotus*. By using *Trichoderma*, lignin content was reduced by 3.7%, and the maximum gas production was obtained in a shorter time (19 days) in comparison with the sample without any pretreatment (24 days). When *Pleurotus* was used for lignin degradation, the lignin content was reduced by 6.78%, and the maximum gas production was obtained in a much shorter time period (14 days) in comparison with the former two methods. The gas produced comprises 74 ppm of methane, which has fuel value. The sludge after digestion was tested, which indicated a marginal increase in NPK value and hence can be used as fertilizer. The results of the study appear to be quite promising in the transition towards green energy by providing scope for the process of biomethanation, with the conclusion that further research can transform coir pith into a good renewable energy resource.

INTRODUCTION

The coir industry constitutes an important aspect among traditional cottage industries in the southern coastal regions of India, where the economy and livelihood of people are largely dependent on coconut farming. These industries mainly use coconut husk as the basic raw material, from which the coir fiber is extracted (Muneeswaran & Kesavan 2022). Coir pith, an elastic cellular cork-like material forming the nonfibrous component of coconut husk, is a major agricultural waste product generated in large quantities during the extraction of coir fiber. Coir pith, thus generated, along with the process of coir retting of coconut husk, eventually results in pollution of land and water bodies to a great extent (Khadeeja et al. 2012). For every ton of fiber extracted, pith is produced to the extent of 2 tons (Narendar & Priya Dasan 2014). Coir pith left behind after processing coconut husk normally accumulates in large dumps outside the mills (Prakash et al. 2021). It is estimated that there is an accumulation of nearly 7.5 million tons of coir pith in the coconut farming states of our country (Priyadarshini et al. 2021).

Present forms of management or utilization, such as landfilling, hydroponics, manuring, etc., are not sufficient to consume the waste generated, and it continues to be a perennial problem for the nearby aquatic and terrestrial environments (Kunchikannan et al. 2007). This high quantum of production of coir pith in the defibring units faces difficulty in disposal and makes the land unfit for any other purpose or activity. When burned, it smolders, thereby emitting a large quantity of smoke for several days and causing air pollution. Other problems are the generation of leachate from the dumps in the rainy season and the fire hazard in the summer. The high lignin and cellulose content in the pith makes biodegradation difficult (Paramanandham & Ronald Ross 2015).

Further, it decomposes in the soil at a slow rate, as its pentosan-lignin ratio is less than 0.5, which is the minimum required for the slow decomposition of organic matter in the soil (Deivanai & Kasturi Bai 1995). Recently, the waste management of coir pith has become a serious social problem. A much longer matter of concern facing the world today is the energy crisis due to the depletion of fossil fuels, which are not renewable.

Several studies show that coir pith has an energy value (Kunchikannan et al. 2007). One approach to tapping this vast energy is methane production by anaerobic digestion. Agro-industrial residues such as coconut coir pith, banana waste, tea waste, cassava waste, and palm oil mill waste are generally considered the best substrates for the Solid State Fermentation processes (Karthick et al. 2015). Furthermore, a high moisture content and profusion of organic matter, methane as an alternative energy resource, and further use of the digested residue as manure are the factors that favor the technology of anaerobic digestion of coir pith (Kunchikannan et al. 2007). Various chemical treatment methods have been reported for lignin degradation. But biological treatment is always preferred over chemical means, owing to its eco-friendly nature. Since the major portion of coir pith contains lignin, aerobic microbial pre-treatments can be an option, as lignin was shown to degrade more effectively under aerobic conditions (Makela et al. 2002). Recent research regarding the lignin-degrading white rot and brown rot fungi is offering intriguing possibilities with aerobic fungal treatment followed by anaerobic digestion (Gharsallah et al. 1999).

Trichoderma fungi are commonly found on wood material (Justyna & Teresa 2020). They are known for their ability to decompose not only cellulose but also the lignin component in native plant biomass due to the simultaneous secretion of oxidoreductive enzymes (Chakroun et al. 2010). *Pleurotus* ostreatus is a species of white-rot fungus that effectively degrades lignin (Qian et al. 2020). The present study hence uses two microbial cultures, viz., *Trichoderma*, a biodecomposing agent to increase the speed of decomposition, and *Pleurotus*, an excellent delignifying microorganism to increase lignin reduction. The pretreated coir pith was further studied for anaerobic digestion.

MATERIALS AND METHODS

The sample for the present study was taken according to the standard sampling and preservation method from the coir-manufacturing center at Murukumpuzha village in Trivandrum district, Kerala. The analytical procedures described in the Standard Methods for the Examination of Water and Wastewater (APHA 1989) were followed for the characterization study. Lignin and cellulose were estimated by the method of Goering and Van Soest. For pretreatment, *Trichoderma* and *Pleurotus*, the fungal cultures prepared on PDA (Potato Dextrose Agar) slants, were collected from Kerala Agricultural University, Vellayani, Trivandrum.

Fig. 1 shows the experimental setup of an anaerobic digester. For the present study, borosilicate glass bottles of one-liter capacity were used as digesters. Three outlets were made in the digester for gas collection, sample collection, and the addition of buffer and other chemicals. One outlet is connected to the water displacement column using a rubber tube. The reading in the column directly shows the amount of gas produced during anaerobic digestion. The whole setup is perfectly sealed to maintain a complete anaerobic condition.

Experimental Studies

Optimization of pH: For the experimental study, 100 g of coir pith samples were mixed with dilution water along with a seed of 5% concentration to initiate digestion and charged into a digester of one-liter capacity. A buffer (sodium bicarbonate) was added to maintain the pH. The digester was kept at various pH levels (5, 6, 7, 8, 9), and the optimum pH was found by observing the gas production. The total solids

Fig. 1: Experimental setup.

Fig. 2: Pretreated coir pith with *Trichoderma*.

Fig. 3: Pretreated coir pith with *Pleurotus*.

and volatile solids of the samples were studied at various time intervals.

Pretreatment of coir pith using *Trichoderma*: For the pretreatment process, 10 g of *Trichoderma* was applied uniformly over 500 g of coir pith. The process was repeated by adding the microbial culture alternately with the coir pith and keeping it for thirty days for the degradation of the lignin. Proper moisture content was maintained by sprinkling water periodically. Fig. 2 shows the treatment of coir pith with *Trichoderma*. Then, the above sample was fed into the anaerobic digester, and pH 6 was maintained. The variation in gas production was noted at various time intervals.

Pretreatment of coir pith using *Pleurotus*: For the preparation of PDA slants, 40 g of PDA was accurately weighed and dissolved in one liter of distilled water. The solution was shaken well and heated to dissolve the PDA. The solution is poured into test tubes and sterilized at 1.5 $kg.cm^{-2}$ gauge pressure for 20 min. The test tubes were then kept in a slanting position in aseptic conditions to allow the medium to cool and solidify. The slants were then properly labeled and stored. The microorganism strains are subcultured on the thus-prepared PDA slants. The sub-culturing environment is maintained under aseptic conditions. The microorganism-transferring loop is sterilized on a Bunsen burner flame and allowed to cool. The microorganism is taken from the master stock with the help of the loop and inoculated on the PDA slant in a zig-zag manner to maximize growth. It is incubated at 30^{o}C for 2-3 days. After visual observation for satisfactory growth, the subcultures were stored at 5^{o}C, for further culturing and experimentation.

The coir pith collected from the site was cleaned and dried. To the 500-g batch of coir pith, 300 mL of distilled water and 1000 mL of liquid nutrient media were added for the nourishment of the microorganisms (Fig. 3). The substrate is kept in a moist state by adding distilled water every alternate day and kept for fifteen days for the degradation of the lignin. Then, the sample was fed into the anaerobic digester, and pH 6 was maintained. The variation in gas production was noted at various time intervals.

Table 1: Quality of coir pith.

Parameters	Value	Parameters	Value
pH	6.45	Total Solids [$g.L^{-1}$]	25.46
Chlorides [$mg.L^{-1}$]	163.3	Volatile Solids [$g.L^{-1}$]	22.98
Magnesium [$mg.L^{-1}$]	0.48	Alkalinity [$mg.L^{-1}$]	550
Calcium [$mg.L^{-1}$]	1.6	Inorganic Carbon [ppm]	0.1461
Sulphates [$mg.L^{-1}$]	27	Total Carbon [ppm]	390
Conductivity [$\mu s.cm^{-1}$]	64.4	Total protein [ppm]	22.94
Hardness [$mg.L^{-1}$]	6	Lignin [%]	30.91
Cellulose [%]	25.82	Total nitrogen [ppm]	3.67
TOC [ppm]	389.8	Potassium [%]	0.78
Phosphorus [%]	0.01		

RESULTS AND DISCUSSION

The characterization study of a fresh coir pith sample is shown in Table 1. From the characterization study, it can be observed that coir pith is suitable for anaerobic digestion since it possesses an appreciable amount of Total Organic Carbon and total solids and does not possess any toxic substances.

The anaerobic digester was set up with various pH values, and the variation of the gas production is shown in Fig. 4. It can be inferred that coir pith without any treatment yielded 8 mL of gas at optimum pH 6 in 24 days.

Table 2: Percentage reductions of volatile solids & total solids at various pH.

Variation in pH	Total solids	Volatile solids
pH 5	21.46%	39.25%
pH 6	24.35%	41.53%
pH 7	22.05%	38.84%
pH 8	16.57%	31.70%
pH 9	14.08%	26.96%

Table 3: Comparison of fresh and digested samples at pH 6.

Parameters	Fresh sample	Digested sample
pH	6	6
Volatile solids [$g.L^{-1}$]	20.74	12.13
Total solids [$g.L^{-1}$]	25.01	18.92
TOC [ppm]	389.8	313.2
Inorganic Carbon [ppm]	0.1461	0.101
Total Carbon [ppm]	390	313.3
Lignin [%]	30.91	30.12

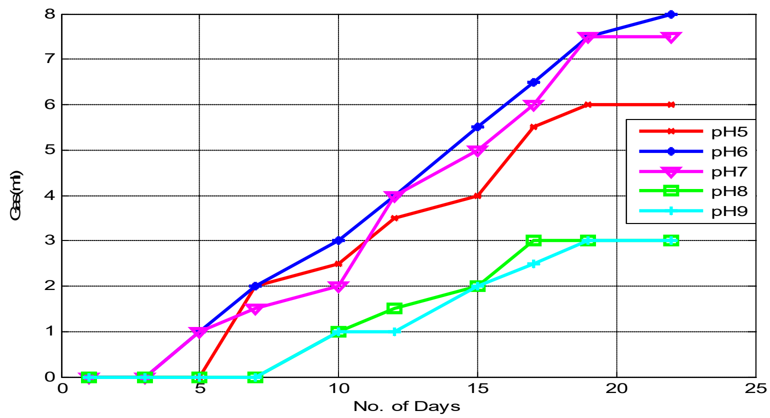

Fig. 4: Variation of gas production at various pH.

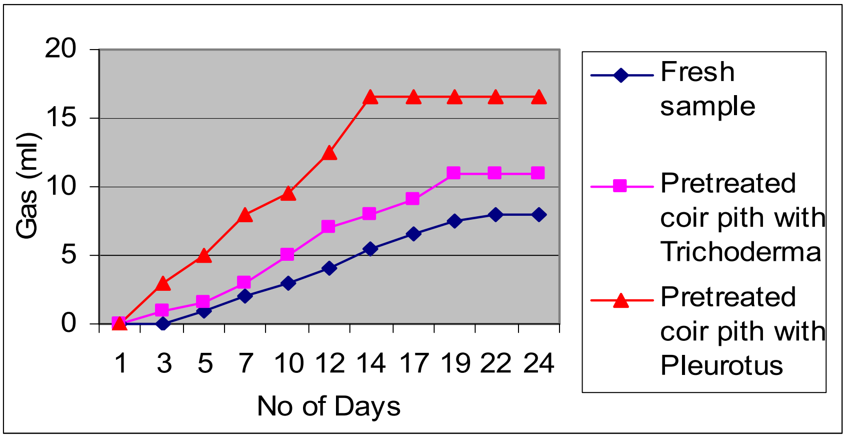

Fig. 5: Variation in gas production.

Since the maximum reduction of total solids and volatile solids was in the range of 6 to 7 (Table 2), the rest of the experiments were performed at pH 6. The characterization study for coir pith after digestion at pH 6 was done. The comparison between the fresh and digested samples of coir pith without any treatment at pH 6 is given in Table 3.

From Table 3, it can be observed that there is a gradual reduction of the parameters such as Total carbon and total solids, and also, there is yield of gas. The comparison of pretreated samples and digested samples of *Trichoderma* and *Pleurotus* and the variation in gas production are shown in Table 4. When *Trichoderma* was used, the lignin content was reduced by 3.7% after the pretreatment. There is a reduction of total solids (29.55%) and volatile solids (56.84%) during the digestion period. When *Pleurotus* was used as a delignifying agent, the lignin content was reduced

Table 4: Comparison of pretreated and digested samples using *Trichoderma* and *Pleurotus*.

Parameters	*Trichoderma*		*Pleurotus*	
	Pretreated sample	Digested sample	Pretreated sample	Digested sample
pH	6	6	6	6
Volatile solids [$g.L^{-1}$]	20.74	8.95	19.02	7.03
Total solids [$g.L^{-1}$]	23.34	16.44	22.88	14.92
TOC [ppm]	387.8	296.5	389.2	281.1
Inorganic Carbon [ppm]	0.1351	0.116	0.131	0.127
Total Carbon [ppm]	387.94	296.62	389.3	281.23
Lignin [%]	27.21	27.09	24.13	24.01

Table 5: Variation of methane content in the gas produced.

Parameters	Coir pith without pretreatment	Coir pith treated with *Trichoderma*	Coir pith treated with *Pleurotus*
Days for maximum gas production	24	17	14
Quantity of gas [mL]	8	11	16.5
Methane content [ppm]	26.9	59	74

Table 6: Characteristics of sludge after digestion.

Parameters	Coir pith without pretreatment	Coir pith treated with *Trichoderma*	Coir pith treated with *Pleurotus*
Nitrogen content [wt. %]	0.26	0.93	1.25
Phosphorus [%]	0.01	0.04	0.06
Potassium [%]	0.78	1.1	1.2
Lignin content [%]	30.91	27.09	24.01
Volatile matter [%]	43.1	44.2	43.29
Ash content [%]	25.95	24.42	26.77
Carbon content [%]	22.95	17	14.12
pH	5.67	6.2	6.28

by 6.78%, and 16.5 mL of gas was produced at an earlier time of 14 days when compared with the sample without any pretreatment (24 days). There is also a maximum reduction of total solids (34.79%) and volatile solids (63.04 %).

The gas produced was analyzed for the presence of methane using the Gas Chromatograph. The methane concentration was less than 1000 ppm, so the FID (Flame Ionization Detector) analyzer in the gas chromatograph was used for this analysis. For 2 mL of biogas, the results are shown in Table 5.

The variation in gas production of the anaerobic digesters is shown in Fig. 5. It is clear that the methane content was appreciably increased after the pretreatment of coir pith with *Pleurotus*. The quantitative and qualitative analysis of the sludge was conducted after digestion. The nitrogen content, lignin content, potassium, phosphorus, volatile matter, ash content, carbon content, and pH were studied for each digested sample, and the results are shown in Table 6.

The sludge after digestion indicates a marginal increase of 3.8%, 5%, and 0.53% in NPK value, which means it can be used as fertilizer.

CONCLUSIONS

From the experimental studies, it can be concluded that coir pith is suitable for anaerobic digestion since it possesses an appreciable amount of Total Organic Carbon, COD, total solids, and only trace amounts of calcium and magnesium. There is a considerable reduction of total solids (43.34%) and volatile solids (67.53%) during the digestion period of 24 days for the sample at pH 6 without any pretreatment of coir pith.

Pretreatment of coir pith with *Trichoderma* is found to be the effective reduction of total solids (50.52%) and volatile solids (70.32%) during the digestion period for the pretreated sample. Also, the maximum gas production was 11 mL in 19 days. The lignin content was reduced by 3.7% after the pretreatment. There is a reduction of total solids (29.55%) and volatile solids (56.84%) during the digestion period.

When *Pleurotus* was used as a delignifying agent, the lignin content was reduced by 6.78%, and 16.5 mL of gas was produced at an earlier time of 14 days when compared with the sample without any pretreatment (24 days). There is also a maximum reduction of total solids (34.79%) and volatile solids (63.04 %).

The gas produced was analyzed using a Gas chromatograph, and it was found that the methane content was 26.9 ppm, 59 ppm, and 74 ppm in three cases. The sludge after digestion indicates a marginal increase of 3.8%, 5%, and 0.53% in NPK value, which means it can be used as fertilizer. In the present work, batch digestion for a lab-scale model was made. The study of gas production with varying concentrations of coir pith, the effect of gas production with time of digestion, etc., is necessary to prepare guidelines for the actual design of a coir pith digester in the field.

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