International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 10-11-2021, Accepted: 26-11-2021, Published: 11-12-2021
Volume 6, Issue 6, 2021, Page No. 998-1004

Different physiochemical changes during composting of coir pith using specific microbial inoculants

Prakash U*, Elango R, Parthasarathi R
Department of Microbiology, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India

Abstract
Coconut, an important plantation crop is grown across the India in an area of about 1,078 million hectares and is producing 12,252 million nuts with a productivity of 6982 nuts per hectare. In Tamil Nadu, 1.7 lakh tones of coir pith accumulate every year. Coir pith is a byproduct of coir industry generated during extraction of coir fiber from coconut husk. Approximately two tons of coir pith is produced during the production of 1 ton of coir. Coir pith wastes were composted by employing the cellulolytic and lignolytic cultures of microorganism *viz.*, *Cellulomonas fimi*, *Phanerochaete chrysosporium*, and *Pleurotus sajor caju* isolated from coir pith waste. The treatment effect on changes in pH, EC, temperature, organic carbon and C: N ratio of coir pith waste during composting were recorded at periodic intervals revealed that the treatment T_7 (Triple inoculants consortium of *Cellulomonas fimi* + *Phanerochaete chrysosporium* + *Pleurotus sajor caju*) attained compost stability (C: N ratio of 37.33, pH of 6.2, EC of 0.28 mSm^{-1}) on the 45th day itself whereas dual inoculants treatments required an additional 15 days (60 days) and the single inoculant an additional 30 days (75 days) to attain stability. In the present study were, Triple inoculant (consortium) consists of *Cellulomonas fimi* + *Phanerochaete chrysosporium* + *Pleurotus sajor caju* found to be highly suitable for the development of coir pith compost.

Keywords: microbial inoculants, coir pith waste, *cellulomonas fimi, phanerochaete chrysosporium* and *pleurotus sajor caju*

Introduction

Coconut (*Cocos nucifera*) plays a significant role in the economy of India. Coconut popularly known as 'Lakshmi Phal' is the symbol of prosperity linked with religious and social activities in India, irrespective of whether the palm is grown locally or not. The coconut is known to be a rich source of raw material for a variety Coir Pith Wealth from Waste. Its nut is the most versatile of all, with its kernel of oil being widely used for edible purposes, manufacture of soaps, hair oil, cosmetics and other industrial products. The coconut husk is the raw material for the coir industry. The tender nut supplies coconut water, a popular thirst quencher of health and nutritive value.

India is the largest producer of coir in the world with a production of 5, 61, 447 metric tons, which comes to around 46.2% of world production [1]. Coir pith is a binding material in coconut husk which constitutes up to 70% of the husk and it is usually generated during the extraction of coir fibers in coconut fiber processing [2].

In Tamil Nadu, 1.7 lakh tones of coir pith accumulate every year. The actual manorial value of coir pith is very low. Coir pith will decompose in soil very slowly as its pentose lignin ratio is less than 0.5 which is the minimum requirement for decomposition of organic matter in the soil. Application of biotechnology for conversion of coir pith into useful biomass would not only solve the waste disposal problem but would also meet the growing energy crisis of developing countries.

In recent years, India has attained the top position amongst the coconut producing countries ie. About 26.1%. Indonesia, Sri Lanka and Philippines are the other major countries. In India, coconut is primarily a food crop, which produces about one-fourth of the world's 53,598 million coconuts each year, and 15% of the husk fibers are actually recovered for use.

The nut of this palm has a spongy mesocarp called husk. After the removal of the kernel from the nut, the husk is used as a raw material in coir fiber industries. The industries in turn leave elastic, cellular and cork like spongy non-fibrous tissue which is generally referred to as coir pith or coco-peat [3, 4, 5].

Coir pith has gained importance owing to its properties for use as a growth medium in Horticulture. Because of wider carbon and nitrogen ratio and lower biodegradability due to high lignin content, coir pith is still not considered as a good carbon source for use in agriculture. Coir pith is composted to reduce the wider C: N ratio, reduce the lignin and cellulose content and also to increase the manorial value of pith. Composting of coir pith reduces its bulkiness and converts plant nutrient to the available form. Coir pith is very poor in nitrogen content and C: N ratio. Rae coir pith makes the soil environment temporarily unfit to support crop growth for considerable period of time, due to high C: N ratio [5]. Coir pith is comparatively rich in potash, but low in nitrogen and phosphorous besides higher proportion of lignin, cellulose and hemicelluloses [16]. It also contains appreciable amounts of micro nutrients. The low amount of nitrogen which results in high C: N ratio makes the material refractory [6],

Coir pith can be observed that the electrical conductivity of different particle sizes of coir pith. It was high in lower grades of coir pith which gradually decreased as the size of the coir pith particle increased. The individual ion analysis made on coir pith did not show any significant change according to particle size, but potassium, sodium and chloride ions are found to be higher in amount than phosphorous, iron and calcium. Coir pith contains 87 per cent of organic matter, with a C: N ratio of 112:1 [7].

[8] Reported effective composting process resulted in the C: N ratio of 21.8:1 after 12 weeks of composting. Highest P content of 0.47 per cent and K content of 1.2 per cent and the least cellulose and lignin contents of 22.8 per cent and 10.03 per cent were recorded after a composting period of 12 weeks). The pH of the composted coir pith is close to neutral, while the pH of the natural pith is acidic. The electrical conductivity of the coir pith ranges between 2.0 to 2.3 dsm^{-1} [9].

The pH of the coir pith on 15th day of composting did not show any variation and it declined as the composting proceeds [10, 11]. The pH of the composted coir pith is close to neutral, while the pH of the natural pith is acidic. The electrical conductivity of the coir pith ranges between 2.0 to 2.3 dsm^{-1}. [12].

Carbon and nitrogen ratio projects the digestion rate of the organic waste by microorganisms and it is observed that the C: N ratio obtained in compost is more favorable for the suppression of plant pathogen [13, 14, 15, 16, 17, 18]. Turning the materials is the most common method of aeration. Turning is often cited as the primary mechanism of aeration and temperature regulation during composting [19]. Turning frequency is commonly believed to be a factor which affects the rate of composting, time required to reach full maturation and the elimination of phototoxicity as well as compost quality [20, 21, 22].

[23] Reported that the effects of turning on the composting and noted that during composting, turning enhance microbial consortia load and the degradation of organic matter.

The true maturity of compost can be assessed by measuring the maturity indices such as C: N ratio, lignin, cellulose, humus composition, phenol contents and quality of major nutrients, secondary nutrients and micronutrients during the period of composting [24, 25, 26].

Materials and Methods

Physico-Chemical and Biochemical Characterization of Coirpith

Collection of coir pith waste

Coir pith collected from Sri Kamachi Amman coir industries, Cumbum, Theni district, Tamil Nadu state.

Composting of Coir Pith Waste

Composting experiment was conducted in the backyard of Department of Microbiology, Faculty of Agriculture, Annamalai University, Tamil Nadu. The Samples were withdrawn at periodic intervals for analyzing the physio-chemical parameters, nutrient content and the population dynamics of microbes.

Coir pith wastes were composted by employing the cellulolytic and lignolytic cultures of microorganism *viz.*, *Cellulomonas fimi*, *Phanerochaete chrysosporium*, and *Pleurotus sajor caju* isolated from coir pith waste. These cultures of considered as potential coir pith compost makers. They were store and maintained at culture collection Unit and Department of Agricultural Microbiology, Faculty of Agriculture. Annamalai University. Based on their activity. The following treatments were drawn for making the coir pith compost. The treatment details are as follows:

Treatment details

T_1 - *Cellulomonas fimi*
T_2 - *Phanerochaete chrysosporium*
T_3 - *Pleurotus sajor caju*
T_4 - *Cellulomonas fimi + Phanerochaete chrysosporium*
T_5 - *Cellulomonas fimi + Pleurotus sajor caju*
T_6 - *Phanerochaete chrysosporium + Pleurotus sajor caju*
T_7 - Cellulomonas *fimi + P. chrysosporium+ Pleurotus sajor caju*
T_8 - Control (Uninoculate)

Randomized block design (RBD) was followed with three Replications.

Composting of coir Pith Waste

Coir pith was collected without any fiber. The fiber was removed from the source itself and the Coir pith alone transported to experimental site.

Single, dual, and triple inoculants were added separately @ 500 ml of broth culture per 100 kg of coir pith (1x $l0^9$cfu ml^{-1}). Moisture level of 55-60 percent was maintained uniformly by sprinkling water at regular intervals. Turnings of the compost pile were given at fortnight intervals.

Collection and Analysis

The samples were collected periodically at an interval of 20 days up to 90 days. Sampling of compost was done by following the method described by Faure and Deschamps (1990). Samples were air dried, powdered and used for analyzing the physio-chemical properties.

The coir pith compost that obtained after treating with respective inoculants, and effective treatment were taken for the study. The performance of microbial coir pith compost at different doses was assessed and recorded using standard procedures.

Table 1: Physio-chemical and microbial analysis of coir pith compost

S. No	Parameters	Method	Reference
1	Temperature	Using thermometer	Bhoyar *et al.*, (1979)
2	pH	Compost water suspension at 1:10 ratio by using pH meter	Falcon *et al.*, (1987)
3	Electrical Conductivity	Compost water suspension at 1:10 ratio by using conductivity bridge	Falcon *et al.*, (1987)
4	Nitrogen	Microkjeldhal's method	Humphries (1956)
5	Phosphorus	Vanadomolybdate yellow color method	Jackson (1973)
6	Potassium	Flame photometer	Jackson (1973)
7	Organic carbon	Chromic acid wet digestion method	Walkey and Black (1934)
8	Compost maturity	Germination test, C:N ratio	Lossin (1970),

Statistical analysis

The experimental data were processed statistically by applying the technique of analysis of variance in Randomized Block Design [33].

Result and Discusstion

Coir pith collected from Sri Kamachi Amman Coir industries, Cumbum, Theni dist, Tamil Nadu state. They were analyzed and recorded for their physic-chemical and biological properties presented in Table 2. The coir pith waste was slightly acidic (6.46) with EC of 2.15 dSm^{-1} and recorded appreciable number of macronutrients like N, P and K and secondary nutrients like Ca, Mg, Fe and Cu. The biochemical constituents like cellulose (36.28), hemicelluloses (20.10) and lignin (43.10) were also recorded on sizeable proportions with an organic carbon content of 33.85 per cent. Similar results were reported by [34] who reported a pH of 6.5 and organic carbon content of 38.10 per cent in coir pith. Also, the similar reports by the earlier workers [34, 35, 36, 37, 38, 39] lend support to the present findings.

Table 2: Physico-Chemical and biological properties of coir pith waste

S.No	Parameter	Concentration
1.	Colour	Brown
2.	Ph	6.46
3.	EC (dSm^{-1})	2.15
4.	Organic carbon (%)	33.85
5.	Nitrogen (%)	0.40
6.	Phosphorus (%)	0.10
7.	Potassium (%)	0.49
8.	C:N ratio	89.38
9.	Calcium (%)	0.40
10.	Zinc (mg/kg^{-1})	7.50
11.	Magnesium (%)	0.30
12.	Iron (mg/kg^{-1})	2.00
13.	Manganese (mg/kg^{-1})	12.50
14.	Copper (mg/kg^{-1})	3.10
15.	Total sulphur (%)	0.20
16.	Cellulose (%)	36.28
17.	Hemi cellulose (%)	20.10
18.	Lignin (%)	43.10
19.	Bacteria ($x10^6$ cfu g^{-1})	9.16
20.	Fungi ($x10^3$ cfu g^{-1})	12.00
21.	Actinomycetes ($x10^4$ cfu g^{-1})	4.00

The hydrogen ion concentration plays an important role in determining the microbial diversity. The effect of pH on the activity of any substrata is influenced by even a small change in pH and may lead to entirely diversified microbial population. In the present study, an attempt was made to record changes in pH of the compost sample over a period of 90 days and the results are presented in Table 3.

The triple inoculants treatment T_7 attained pH stability on the 45^{th} day itself whereas in dual inoculants on the 60^{th} day followed by the single inoculant on the 75^{th} day. The pH started to increase from the 15^{th} day onwards in consortium. The treatment T_7 recorded pH of 6.4 on the 45^{th} day thereafter there was slightly change in pH upto 90 days of composting. The uninoculated control (T_8) pH of 5.6 was attained only on the 90 days of composting. The initial pH of 5.0 was increased gradually and attained a stability state at the end of the composting.

The composting process involved the organic acid and ammonia production which decrease and increase the pH level. Both the process took place in compost pile simultaneously and results in a neutral pH. This is in conformation with [40] and synthesis of some phenolic compounds or evolution of ammonia may increase the pH during composting [41, 42, 43] previous researchers have recorded similar finagling and stated about the stability of pH in composting process.

Table 3: Effect of Change in pH during the coir pith composting period

Tr. No.	Treatments	pH						
		Composting period (In days)						
		0	15	30	45	60	75	90
T_1	*Cellulomonas fimi* (CPB3)	5.5	5.5	5.5	5.5	5.6	6.0	6.2
T_2	*Phanerocheate chrysosporium* (CPF7)	5.5	5.5	5.5	5.5	5.6	5.8	6.1
T_3	*Pleurotus sajor caju* (CPF13)	5.5	5.5	5.5	5.5	5.6	6.0	6.2
T_4	*Cellulomonas fimi* (CPB3) + *P.chrysosporium* (CPF7)	5.5	5.5	5.5	5.6	5.6	6.1	6.3
T_5	*Cellulomonas fimi* (CPB3) + *Pleurotus sajor caju* (CPF13)	5.5	5.5	5.7	6.0	6.0	6.4	6.5
T_6	*Pleurotus sajor caju*(CPF13) + *P.chrysosporium* (CPF7)	5.5	5.5	5.5	6.0	6.0	6.2	6.4
T_7	*Cellulomonas fimi* (CPB3) + *P. Chrysosporium* (CPF13) + *Pleurotus sajor caju* (CPF13)	5.5	5.6	5.9	6.4	6.5	6.6	6.6
T_8	Control	5.5	5.5	5.5	5.5	5.6	5.6	5.8
SED		-	0.01	0.01	0.02	0.01	0.02	0.03
CD (p=0.05)		NS	0.02	0.03	0.04	0.03	0.04	0.07

NS: Non-Significant

Electrical conductivity (EC) is largely influenced by the chemical constituents present in the substance. Free ions greatly influence on the breakdown of any molecules resulting in changes in the molecular structure. Coir pith, when composted, releases free ions for exchange and the microbial development. The individual inoculants treatment attained stability in electrical conductivity on 60th day of composting, whereas the dual inoculants treatments attained stability on 75th day. The triple inoculants treatment showed drastic reduction in EC on 30th day itself (0.36 mSm^{-1}), on 45th day, the EC was (0.32 mSm^{-1}) and on 60th day, the EC was (0.24 mSm^{-1}). In general, electrical conductivity of all the treatments decreased significantly during the composting process (Table 4).

Table 4: Effects of Changes in Electrical Conductivity during the Coir Pith Composting period

Tr. No.	Treatments	EC						
		Composting period (In days)						
		0	15	30	45	60	75	90
T_1	*Cellulomonas fimi* (CPB3)	0.40	0.40	0.40	0.38	0.38	0.36	0.26
T_2	*Phanerocheate chrysosporium* (CPF7)	0.40	0.40	0.40	0.38	0.38	0.36	0.26
T_3	*Pleurotus sajor caju* (CPF13)	0.40	0.40	0.38	0.38	0.32	0.30	0.25
T_4	*Cellulomonas fimi* (CPB3) + *P.chrysosporium* (CPF7)	0.40	0.40	0.40	0.38	0.36	0.26	0.24
T_5	*Cellulomonas fimi* (CPB3) + *Pleurotus sajor caju* (CPF13)	0.40	0.40	0.34	0.30	0.28	0.24	0.22
T_6	*Pleurotus sajor caju*(CPF13) + *P.chrysosporium* (CPF7)	0.40	0.40	0.34	0.32	0.30	0.25	0.23
T_7	*Cellulomonas fimi* (CPB3) + *P. Chrysosporium* (CPF13) + *Pleurotus sajor caju* (CPF13)	0.40	0.40	0.36	0.32	0.24	0.22	0.22
T_8	Control	0.40	0.40	0.40	0.39	0.36	0.33	0.33
SED		-	-	0.01	0.01	0.01	0.01	0.01
CD (p=0.05)		NS	NS	0.02	0.02	0.02	0.02	0.02

NS; Non-Significant

Table 5: Effects of Changes in organic carbon content during composting period of Coir pith

Tr. No.	Treatments	Organic carbon (%)						
		Composting period (In days)						
		0	15	30	45	60	75	90
T_1	*Cellulomonas fimi* (CPB3)	36.80	35.23	32.62	29.73	28.96	28.00	27.56
T_2	*Phanerocheate chrysosporium* (CPF7)	36.80	35.66	35.28	32.39	29.22	28.75	28.18
T_3	*Pleurotus sajor caju* (CPF13)	36.80	35.42	34.96	33.29	30.66	27.29	24.88
T_4	*Cellulomonas fimi* (CPB3) + *P.chrysosporium* (CPF7)	36.80	35.21	32.63	30.72	29.52	27.51	23.96
T_5	*Cellulomonas fimi* (CPB3) + *Pleurotus sajor caju* (CPF13)	36.80	36.02	33.09	30.01	27.29	24.12	22.99
T_6	*Pleurotus sajor caju*(CPF13) + *P.chrysosporium* (CPF7)	36.80	35.91	34.27	30.63	27.17	23.69	23.21
T_7	*Cellulomonas fimi* (CPB3) + *P. Chrysosporium* (CPF13) + *Pleurotus sajor caju* (CPF13)	36.80	35.40	31.72	28.00	26.32	24.59	22.88
T_8	Control	36.80	36.23	36.01	35.73	33.11	32.30	30.00
SED		-	1.19	1.16	1.15	1.10	1.10	1.09
CD (p=0.05)		NS	2.24	2.27	2.21	2.21	2.19	2.05

NS: Non-Significant

Since, the compost prepared using coir pith waste had an EC of less than 1.8 dSm^{-1}, it can be safely used for crop production [44]. This was supported by the earlier workers [45, 46, 47, 48].

During the composting process, the organic carbon content showed a decreasing trend (Table 5). The initial organic carbon content of 36.80 per cent decreased to 26.32 per cent on the 60th day in the treatment T_7. The dual inoculants treatments required 75 days to attain less than per cent reduction and the single inoculant treatments required 90 days to attain 30 per cent reduction. On the 90th day of composting, T_8 showed the maximum of 30.00 per cent organic carbon whereas rest of the treatments showed reduction in organic carbon lies between 28.18 per cent to 22.88 per cent.

This reduction of organic carbon content could be solely attributed to the efficient utilization of the substrate by the microbial inoculants as observed by [49] who reported that the reduction in organic carbon might be due to the utilization of organic carbon as an energy source to build up protoplasm. The reduction in organic carbon was due to the release of CO_2 through the breakdown of carbon by microorganisms during composting process [50, 51] of carbon for microbial physiology by microorganism will automatically reduce the organic carbon level in compost

The C: N ratio of the substrate narrowed down during composting

(Table 6). The initial C: N ratio of the coir pith was 76.50. The decrease in C: N ratio was proportional to with increase in the sampling period. On 60th day, T_7 attained a C: N ratio of 26.32 and thereafter got stabilized. The dual inoculants treatments required 75 days of composting to attain a C: N ratio of 26.12 to 27.51. On the other hand, single inoculant treatments T_1, T_2 and T_3 required 90 days to attain the C: N ratio of 24.88 to 27.56.

The reduction in C: N ratio was faster up to 75 days of composting and it might due to the presence of high amount of nitrogen and also due to the prevalence of thermophilic conditions with increased microbial activity [52, 53]. Slow reduction rate is due to the high lignin content in the coir pith waste [54, 55, 56].

Table 6: Effect of Changes in C: N ratio during coir pith composting period

Tr. No.	Treatments	C:N ratio						
		Composting period (in days)						
		0	15	30	45	60	75	90
T_1	*Cellulomonas fimi* (CPB3)	76.50	71.89	63.96	50.38	41.97	40.57	39.37
T_2	*Phanerocheate chrysosporium* (CPF7)	76.50	72.77	66.56	54.89	40.02	39.38	38.08
T_3	*Pleurotus sajor caju* (CPF13)	76.50	72.28	64.74	60.52	41.43	38.43	36.81
T_4	*Cellulomonas fimi* (CPB3) + *P.chrysosporium* (CPF7)	76.50	73.35	61.56	55.85	31.74	27.51	22.18
T_5	*Cellulomonas fimi* (CPB3) + *Pleurotus sajor caju* (CPF13)	76.50	73.51	61.27	55.57	34.98	22.75	20.90
T_6	*Pleurotus sajor caju*(CPF13) + *P.chrysosporium* (CPF7)	76.50	71.82	56.18	50.12	29.85	22.35	21.29
T_7	*Cellulomonas fimi* (CPB3) + *P. Chrysosporium* (CPF13) + *Pleurotus sajor caju* (CPF13)	76.50	69.41	50.34	37.33	29.36	20.78	19.89
T_8	Control	76.50	72.49	67.94	62.68	55.18	52.09	48.38
SED		-	0.82	0.71	0.66	0.58	0.56	0.52
CD (p=0.05)		NS	1.68	1.47	1.23	1.16	1.10	1.08

NS: Non-Significant

Conclusion

The present study was undertaken to develop the agro industrial waste coir pith were composted using their related isolates as single, dual and triple inoculums. Various parameters like pH, Electrical conductivity, C: N ratio, organic carbon content revealed the usage of triple inoculants fastens the composting process. The single and dual inoculants treatment required at least 90 days for composting where us the triple inoculants require 75 days only for composting. Reduction with number days for effective composting reduction labour cost and meaningful handling and the coir pith for further value addition.

Reference

1. Banerjee PK. Handbook of Natural Fibers, In: Kozłowski, R. M. Kozłowski and M. Mackiewicz-Talarczyk, M. (eds), imprint: woodhead publishing, United Kingdom,2020:2:621-651.
2. Reddy, N. 2019. *Sustainable applications of coir and other coconut by-products*. Switzerland: Springer International Publishing.
3. Abbiramy KS, Ronald Ross P. Efficacy of vermi composted coir pith on the growth physiology of *Abelmoschus Esculentus*. International Journal of Environmental Biology,2012:2(3):153-155.
4. Sivaramakrishnan G. Studies on the Microbial Composting of Coir Pith Waste and Its effect on Sunflower crop. M. Sc thesis, Annamalai University, Tamil Nadu, India, 2017.
5. Krishnakumar S, Jawahar D. Coir pith compost. Journal of Kissan World,2001:28(3):41-47.
6. Prabha DS, Karthikeyan K, Navanietha krishnaraj R, Akila B, Hemnth S, Harikrishnan R. Effect of phenolic compounds released degradation of coir pith by *Osillatoria annae* on Albino rat (*Rattus norvegicus*). J. App. Sci. Environ. Manage,2009:13(4):87-90.
7. Raghuvaran A. Process improvement of coir pith degradation involving white rot fungi by substitution of urea with nitrogen fixing bacteria and application of bio degraded coir pith as plant growth medium. Journal of Scientific and Industrial Research,2014:69:554-559.
8. Jose SL, Mishra G Basu, kumar samanta A. A Study on Reuse of Coconut Fiber Chemical Retting Bath. Recovery and Characterization of Lignin. Journal Of Natural Fibres,2017:21(5):2-9.
9. Lodolini EM. Pica F, Massetani F, Neri D. Physical, chemical and biological properties of some alternative growing substrates. International Journal of Soil Science,2018:12:32-38.
10. Abesh Reghuvaran, K. Kala, Jacob and Anita Das Ravindranath. Isolation and characterization of nitrogen fixing bacteria from raw coir pith. African Journal of Biotechnology,2012:11(27):7063-7071.
11. Azim. k., B. Soudi, S. Boukhari, C.Perissoi, S.Roussos and I. Thami Alami. 2017. Composting parameters and compost quality. Organic Agriculture,2012:8(2):141-158.
12. Lodolini EM, Pica F, Massetani F, Neri D. Physical, chemical and biological properties of some alternative growing substrates. International Journal of Soil Science,2018:12:32-38.
13. Taiwo LB, Oso BA. Influence of composting techniques on microbial succession, temperature and pH in a composting municipal solid waste. African J. biotechnoL,2004:3(4):239-243.
14. Pramanik P, Ghosh GK, Ghosal PK, Banik P. Changes in organic C, N, P and K and enzyme activities in vermicompost of biodegradable organic wastes under liming microbial inoculants. Biores. Technol,2007:98:2485-2494.
15. Fabrizio A, Tambone F, Genevini P. Effect of compost application rate on carbon degradation and retention in soils. Waste Management,2009:29:174-179.
16. Sudarut Tripetchkul, Kanokwan Pundee, Songpon Koonsrisuk ans Saengchi Akeprathumchai. Co-Composting of coir pith and cow manure: Initial C/N ratio vs Physical- Chemical changes. International journal of recycling of organic waste in agriculture,2012:1:15.
17. Anwar Z, Irshad M, Fareed I, Saleem A. Characterization and recycling of organic waste after co-composting-A review. Journal of Agricultural Science,2015:7(4):68.
18. Ansi L. Comparative studies of the effect of different microorganisms on coir pith composting. Indian Journal of Life Sciences,2017:6 (1):55.
19. Michel FC, Forney LJ, Huang AJF, Drew S, Czupenshi M, Lindeberg JD *et al*. Effects of tarring frequency, leaves to grass mix basis and windrow Vs pile configuration on the composting of yard trimmings. Compost Sci. UtiL,1996:4(1):26-43.
20. Tiquia SM, NFY Tam, Hodghills IJ. Effect of composting on phytotoxicity of the spent pig manure saw dust like. Environ. Pollut,1996:93:249-256.

21. Neklyadav AD, Fedotov GN, lyankin AN. Aerobic processing of organic waste into composts. Appl. Biochem. Microbiol,2006:42(4):341-353.
22. Londra P, Paraskevopoulou A, Psychogiou M. Hydrological behavior of peat- and coir- based substrates and their effect on begonia growth. Water,2018:10:722.
23. Elango R, Parthasarathi R, Mugilan L. Microbial technology for the management and effective utilization of coirpith wastes. 6th International Conference on Chemical Agricultural, Biological and Environmental Sciences, 2017, 10-12.
24. Preethu DC, Bhanu BNUH, Prakash CA. Srinivasamurthy and B.G. Vasanthi. Maturity indices as an index to evaluate the quality of compost of coir waste blended with other organic wastes. In: International Conference on sustainable solid waste management, 5-7, Chennai, India, 2007, 270-275.
25. Sanjaigandhi P, Divakaran J. Effect of microbial consortium on the composting of coir pith waste. Journal of Applicable Chemistry,2014:3(2):739-742.
26. Ansi L. Comparitive studies of the effect of different microorganisms on coir pith composting.Indian Journal of Life Sciences,2017:6(1):55.
27. Bhoyar RV, Olaniya MS, Bhide AD. Effect of temperature on mineralization of nitrogen during aerobic composting. Indian J. Environ. Health,1979:21(1):23-34.
28. Falcon MA, Corominas E, Perez MC, Perestelu F. Aerobic bacterial population and environmental factors involved in the composting of agriculture. Biol. Wastes,1987:20:89-99.
29. Humphries EC. Oil content analysis. In: Peach, K. and M.V. Tracey (Eds.) Modern, 1956.
30. Jackson ML. Soil chemical analysis. Prentice Hall of India Pvt. Ltd, New Delhi, India, 1973, 498.
31. Walkley A, Black CA. An examination of the Degtjarett method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Sci,1934:37:29-39.
32. Lossin RD. Compost studies, Part – I. Compost Sci,1970:11:16.
33. Panse VG, Sukhatme SV. Statistical Methods for Agricultural. residues. Biomass Bioener,1978:26:361-385.
34. Taiwo LB, Oso BA. Influence of composting techniques on microbial succession, temperature and pH in a composting municipal solid waste. African J. biotechnoL,2004:3(4):239-243.
35. Krishnasamy R, Somasundaram J, Savithri P. Sewage sludge - Coir pith pellets: A source of organic manure. 17th World Congress of Soil Science,2002:344:1-11.
36. Mak ATY, Yeh DM. Nitrogen nutrition of Spathiphyllum sensation grown in Sphagrium peat and Coir based media with two irrigation methods. Hort. Science,2001:36(4):46-48.
37. Rao PS, Devi LS, Kadalli GG. Effect of micronutrient enrichment on chelation in Coir dust-based composts. Curr. Res,2001:30:144-146.
38. Ganesh P, Kumar RS. Effect of coir pith compost on growth and yield attributes of onion and cassava. Indian Journal of Agricultural Research,2016:2(1):501-506.
39. Gaur AC, Sadasivam KV. Theory and practical considerations of composting organic wastes. In: Organics in soil health and crop production (Ed.) P.K. Thampan. Peekay Tree Crops Development Foundation, Cochin, 1993, 1-22.
40. Jose SL, Mishra G, Basu, kumar samanta A. A Study on Reuse of Coconut Fiber Chemical Retting Bath. Recovery and Characterization of Lignin. Journal Of Natural Fibres,2017:21(5):2-9.
41. Mahimairaja S, Bolan NS, Hedley MJ, MacGregor AN. Losses and transformation of nitrogen during composting of poultry manure with different amendments. An incubation experiments. Biores. Technol,1994.:47:265-273.
42. Tiquia SM, Tam NFY, Hodgkiss IJ. Effect of turning frequency on composting of spent pig-manure sawdust litter. Biores. Technol,1997:55:201-206.
43. Satisha GC. Devarajan L. Effects of amendments on windrow composting of sugar industry pressmud. Waste Manage,2007:27(9):1083-1091.
44. Beuno P, Tapias R, Lopez F, Dias MJ. Optimizing composting parameters for nitrogen conservation in composting. Biores. Technol,2008:99:5069-5077.
45. Subasree A. Microbial conversion of agro industrial wastes. M. Sc thesis, Annamalai University, Tamil Nadu, India, 2007.
46. Garcia C, Hernandez TL, Costa F, Pascal JA. Phytotoxicity due to the agricultural use of urban wastes: Germination experiments. J. Sci. Food Agric,1992:59:313-319.
47. Prasanta K, Ghosh US, Sarma, Anita Das Ravindranath, S. Radha Krishnan, Prasenject Ghosh. A Novel method for Accelerated composting of coir pith. Energy & Fuels, 2007, 822-827.
48. Ghosh PK, Sharma US, Ravindranath AD, Radhakrishnan S. A novel method for accelerating composting of coir pith, *Energy fuels*,2007:21:822-827.
49. Dhanapal R, Tayade AS, Bhaskaran A, Geetha P. Efficient water management in sugarcane with composted coir pith and sugarcane trash under tropical Indian conditions. Sugar Tech, 2018, 1-9.
50. Gaur AC, Sadasivam KV. Theory and practical considerations of composting organic wastes. In: Organics in soil health and crop production (Ed.) P.K. Thampan. Peekay Tree Crops Development Foundation, Cochin, 1993, 1-22.
51. Borkar DK, Deshmukh ES, Bhoyar VS. Manurial values of FYM and composts as influenced by raw materials used methods and period of decomposition. *J. Soil and Crops*,1991:1:117-119.
52. Diaz MJ, Madejon E, Ariza J, Lopez R, Cabrera F. Composting of Beet Vinasse and Grape Marc in windrows and static pile systems. *Compost Sci. Utili*,2002:10(3):258-269.Bioresource technology. 274: 173-179.
53. Belso MC, Villan MC, Cananeiro A, Carballas M, Gonzalez-Prieto SJ, Carballas T. Carbon and nitrogen mineralization in an acid soil fertilized with composted urban refuse. *Biores. Technol*,1993:45:123-129.
54. Riggs CE, Hobbie SE, Bach EM, Hofmockel kS, Kazanski CE. Nitrogen addition changes grassland soil organic matter decomposition. Biogeochemistry,2015:125(2):203-219.
55. El-Houssein M, Fahmy Soheir S, Allam EH. *Co-compost production from agricultural wastes and sewage sludge.* 17th WCSS, Thailand, 2002, 1755-14.

56. Vighnesh Kumar M, Vijay G, Vijaya bharathi M, Ramesh D. An experimental study on bio-degradation of organic waste by using composting. Inter. J. of latest Eng. Research and Application,2017:2(3):41-48.
57. Theradimani M, Thangaeshwari S, Parthasarathy S. Biological decomposition of coconut coir pith waste. PL. Dis. Res,2018:33(2):142-147.