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Surface morphology and structural characteristics of rice husk, its biochar and vermicompost

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ABSTRACT

Production of biochar and composting of the residue are the effective and proven residue management strategies that have high potential to improve soil properties and crop productivity. The milling of paddy yields large amount of husk. As a part of the present investigation, both biochar as well as vermicompost were prepared from the rice husk. Surface morphology and structural characteristics of rice husk, biochar and vermicompost were examined using Scanning Electron Microscope (SEM) and Fourier Transform Infra-Red (FTIR) spectrometer equipped with Attenuated Total Reflectance. SEM image of rice husk exhibited well-arranged micro-bumps on the surface. Whereas, the SEM image of biochar was porous, fragmented and heterogeneous. In the micrograph of vermicompost, undecomposed rice husk structure was visible. It indicated that technology of composting rice husk using earthworms was not much suitable. Each peak in FTIR was assigned with corresponding functional groups and it clearly explained the presence of C, H, O, N and Si in the rice husk and products. The FTIR spectra of rice husk and vermicompost were almost similar whereas characteristic differences were noted in biochar spectrum. FTIR spectra of rice husk biochar revealed its aromatic and recalcitrant nature. Pyrolysis process created more recalcitrant character by increasing aromatic compounds, and thus could help in sequestering carbon in soil.

Keywords: Rice husk, biochar, vermicompost, SEM, FTIR

INTRODUCTION

Rice is the most important food crop of the developing world, the staple food of more than half of the world's population, and an important residue producing crop in Asia. India ranks second in rice production after China, covering 43.79 million ha, with a production of 112.91 million tones and productivity of 2578 kg ha^{-1} in 2018-19 (GOI, 2019). The area, production and productivity of rice in Kerala is 1.98 lakh ha, 5.78 lakh tones and 2920 kg ha^{-1}, respectively in 2018-19 (GOK, 2019).

Rice husk, also called as rice hull, is the by-product generated in abundance from rice milling units. The richness in terms of lignin and cellulose makes difficult for its degradation under natural conditions. Their disposal in land-fill or open fields and also its burning is truly dangerous as it would cause serious environmental and human health related problems. Globally, 153.95 million tonnes of rice husk are produced. In India, husk production is 33.70 million tonnes (FAO, 2017). Many a times, the crop residues are looked upon as waste materials that calls for disposal, but it has been increasingly realized that they are important organic resources and not wastes. Appropriate management of crop residues for agricultural use is of great significance and relevance. One of the best management options is the recycling of crop residues, which converts the surplus farm waste into useful products that meets nutrient requirement of crops. The richness in terms of lignin and cellulose in rice husk makes it difficult for its degradation under natural conditions. Despite claims that rice residues are rich in silica and potential sources of plant nutrients, they are not widely used as source of plant nutrients, mainly because of the wide C: N ratio that prolongs the decomposition, limiting its benefit to the current crop. Direct application also hinders the intercultural operations, thus necessitating an alternative waste management strategy for the disposal of rice residues.

Composting is an excellent waste management strategy, which yields a biologically stable organic matter. Crop residues contain nutrients in their recalcitrant forms, which, on composting get transformed into humified matter through the activity of soil biota. The process of vermicomposting has emerged as an environment friendly waste management method. The intestine of earthworms contains a wide range of microorganisms, enzymes and hormones, which aid in the rapid decomposition of partially digested material, transforming them into vermicompost in a short time. Worm casts/ vermicast is the organic form of fertilizer, also known as worm manure produced by earthworms. Worm cast is a resource that can be used in agriculture due to their effects on soil property enhancement and nutrient dynamics.

On the other hand, Biochar is a carbon rich material produced through thermal decomposition of organic material or biomass through a process of carbonisation, and is a novel technology for improving agricultural productivity. It is also a resource to combat climate change and global warming via sequestration of atmospheric CO_2. The most prominent benefit of biochar is its longevity, since it can remain in the soil for many years. Accordingly, biochar application helps to reduce the repeated addition of soil amendments and minimise the possibility of new contaminants reaching the soil through addition of synthetic soil amendments. Application of biochar is a good soil management practice because of its potential to improve soil fertility and soil pH, increase the cation exchange capacity, enhance soil carbon, mitigate soil green-house gas emissions, reduce leaching of nutrients and chemicals, increase fertilizer use efficiency, and enhance agriculture productivity (Cheng *et al*., 2006; Lehmann and Rondon (2006); Dainy *et al*., 2015; Rajakumar, 2019). In this perspective biochar and vermicompost were produced from rice husk.

MATERIAL AND METHODS

Biochar and vermicompost required for the investigation were produced from the rice husk using the methodology furnished underneath.

Production of biochar

The charcoal like material obtained on burning organic residues from agricultural and forestry wastes resorting to a controlled burning process called pyrolysis would yield biochar. This stable solid material rich in carbon is capable of capturing carbon and locking it into the soil. The utilization of biochar as a soil amendment both for sequestering carbon and soil health benefits are extensively researched upon.

The biochar used in the present study was produced from rice husk utilising kilns specially designed and fabricated using a drum with 87 cm height and 57 cm diameter. Rice husk was loaded to the inlet on the top and the process of pyrolysis was initiated using a little diesel. With the reduction in intensity of smoke produced, closed the inlet to slow down air entry thus preventing the material getting converted into ash. After 2.5hr duration the kiln was allowed to cool and the finished product 'rice husk biochar' was collected from the outlet located towards the bottom side. The collected biochar was crushed using wooden mallet and sieved and stored in laboratory for further analysis.

Production of vermicompost

Rice husk compost as an alternative organic manure has been experimented successfully in many crops to enhance productivity. Vermicomposting of the rice husk was carried out in the vermi unit attached to the Department of Soil Science and Agricultural Chemistry in ferrocement tanks of one meter diameter, 0.3m height and 300 kg capacity. The bottom portion of the tank up to one foot height was filled with a layer of coconut husk, position with their concave side facing upwards. Rice husk and cowdung was mixed in 6:1 ratio and this mixture was transferred into the ferrocement tank to form a layer of 30-45 cm thickness. Cowdung slurry was sprinkled over this layer. This process was continued till the tanks were filled to their fullest capacity maintaining a top layer of cowdung slurry and it was covered using moistant gunny bag. The material was left as such to allow partial decomposition with occasional turning at weekly interval followed by cowdung slurry application to ensure proper aeration and moisture content. After two months, the composting worm *Eisenia foetida* was introduced into the tank @ 2000 Nos. per tank. Turning was done once in five days to maintain homogeneity. Care was taken to ensure an optimum moisture content of 40-50 per cent by sprinkling water. The material achieved the maturity by 128 days as evidenced by the change in appearance, colour and odour. Sprinkling of water was stopped at this point to enable the worm to migrate down and cling to the vermi bed. Composted material was collected from the top portion of the ferrocement tank without disturbing the vermi bed and kept in shade for two days. The composted rice husk was sieved and stored in laboratory for further analysis.

Surface morphology

The information on surface composition and topography of the rice husk and its products were studied using Scanning Electron Microscope (SEM) that enabled for creating a high-resolution image. The samples were smeared on a small piece of adhesive carbon tape which was fixed on a brass stub. The samples then subjected to gold coating using sputtering unit for 10 seconds at 10 mA of current. The gold coated samples were placed in the chamber of SEM (Model: TESCANVEGA-3-LMU) and secondary electron or back scattered electron images are recorded.

Structural chemistry

The structural chemistry of rice husk and their products were characterized using Fourier Transform Infra-Red spectrometer equipped with Attenuated Total Reflectance (FTIR-ATR) containing diamond crystal (Model: Perkin Elmer spectrum 100 FTIR spectrometer with ATR). The methodology included transferring samples to the small crystal area located on the ATR top plate, followed by positioning the pressure over crystal/ sample area and applying force till the pressure gauge registered force sufficient enough to push the sample on the diamond surface. An infra-red (IR) beam with a high refractive index was then directed at a certain angle onto the optically dense diamond crystal. This reflectance helped to create an evanescent wave that extended beyond the surface of the crystal on to the sample held in contact with it. The evanescent wave got alternated in those regions of the IR spectrum where the sample absorbed energy. These alienated-beam then returned to the crystal, exist via opposite side of the crystal and got directed to the detector in the IR spectrometer. The detector recorded the alienated IR beam as an interferogram signal which could be used to generate an IR spectrum.

RESULTS AND DISCUSSION

Surface morphology

The changes in surface morphology of rice husk during pyrolysis and vermicomposting were examined using scanning electron microscope (SEM). SEM image of rice husk exhibited well-arranged micro-bumps on the surface. Outer epidermis was uneven and appeared to be highly ridged structure with protrusion (Fig. 1, Plate 1). The results are in accordance with the findings of Thiyageshwari *et al*. (2018).

The SEM image of biochar (Fig. 1, Plate 2) exhibited a highly fragmented and heterogenous structure. Pyrolysis process changed the external morphology of rice husk into porous, fragmented and heterogenous structure. This might be due to the release of volatile compounds released during the pyrolysis process. Similar findings were also reported by Phuong *et al*. (2015).

Disaggregated or fragmented structure was observed in SEM micrograph of vermicompost and also, part of the undecomposed or initial rice husk structure containing epidermis was clearly noted in the image (Fig. 1, Plate 3). This might be due to the incomplete decomposition of husk during

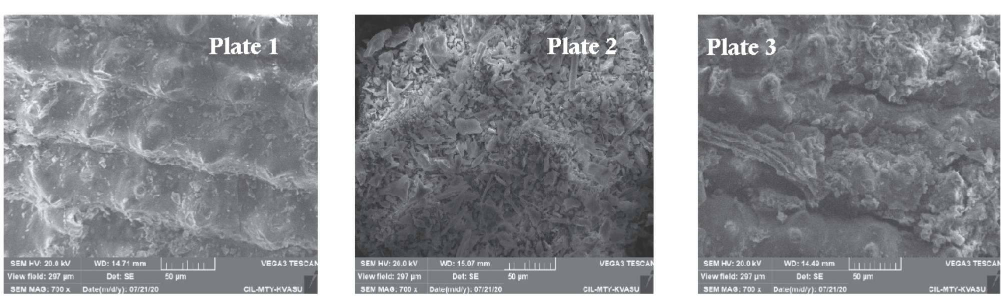

Fig. 1. Scanning electron microscope (SEM) images of rice husk (Plate 1), biochar (Plate 2), and vermicompost (Plate 3)

vermicomposting because of its high lignin content and C: N ratio.

Structural chemistry

Structural chemistry of rice husk (Fig. 2), biochar (Fig. 3) and vermicompost (Fig. 4) were characterized using FTIR. Each peak in FTIR spectrum is assigned with corresponding functional groups (Table 1, 2, and 3). The three spectra clearly showed the presence of carbon, hydrogen, oxygen and nitrogen in rice husk (Table 1), biochar (Table 2) and vermicompost (Table 3). In FTIR spectrum, presence of silicon is illustrated by Si-O-Si and Si-H bond. In the present study such bonds were identifiable in both the rice husk and their products. Silicon is a major component in chemical structure of rice material, and is typical of its recalcitrant property (Jindo *et al.*, 2014).

Stretching or broadening of peaks in spectrum of biochar and vermicompost was mainly due to

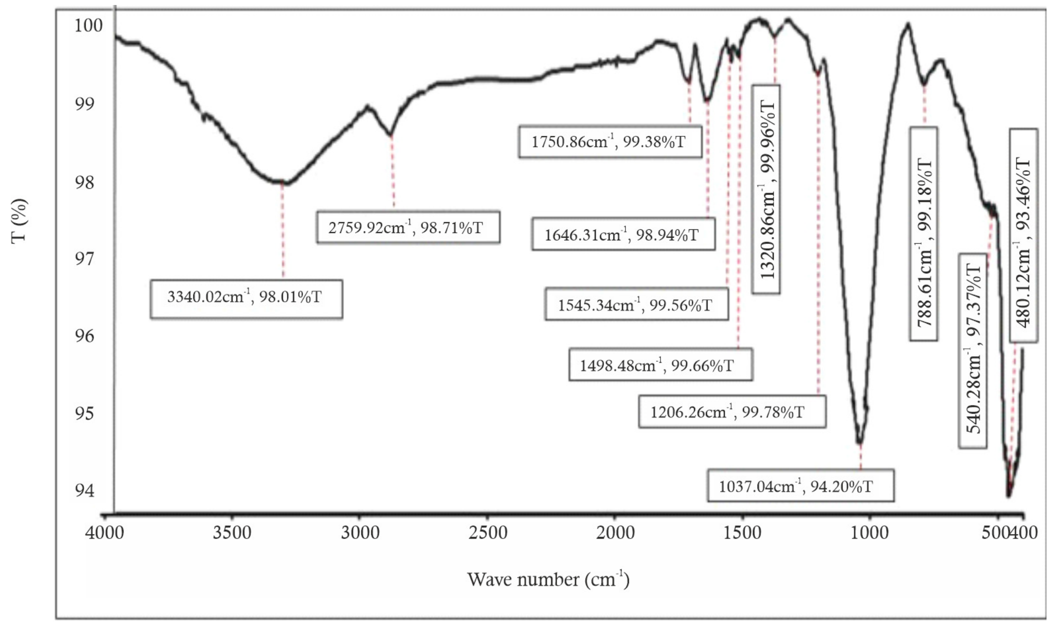

Fig. 2. FTIR spectrum of rice husk

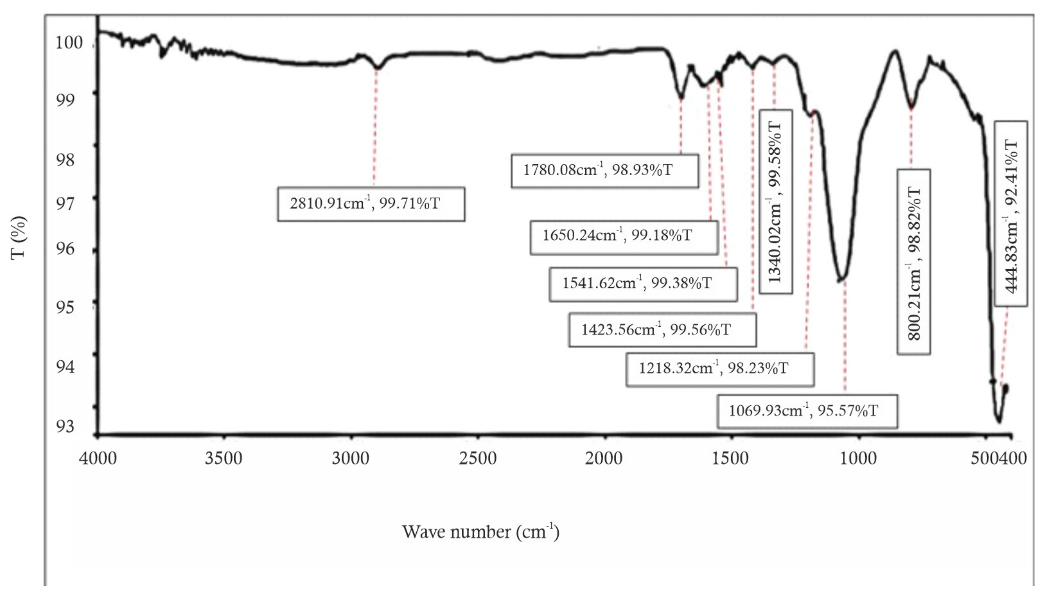

Fig. 3. FTIR spectrum of biochar

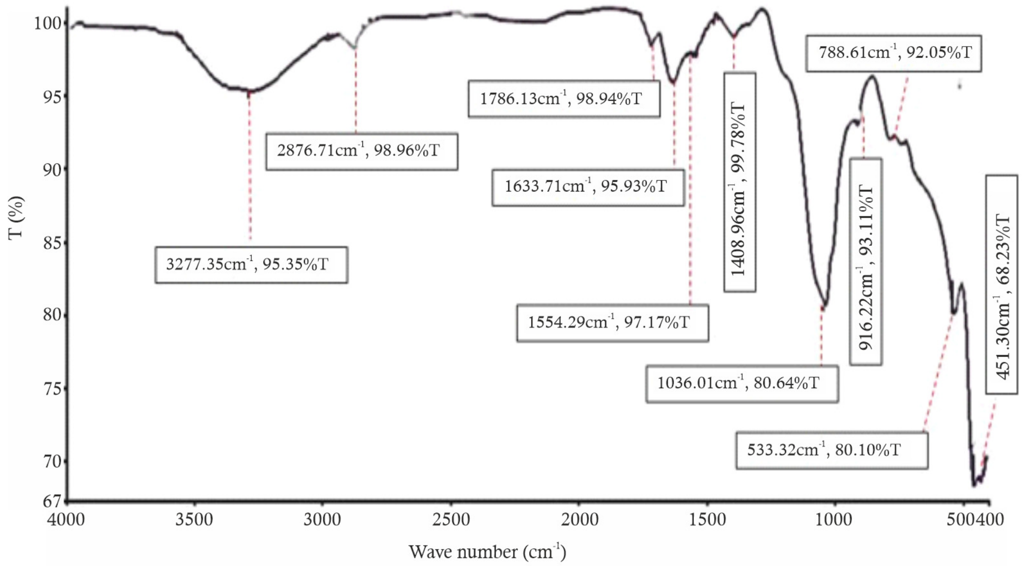

Fig. 4. FTIR spectrum of vermicompost

Table 1. Functional groups in the FT-IR spectrum of rice husk

Wave number (cm^{-1})	Functional group
3340.02	O-H / N-H stretch
2759.92	Aliphatic C-H
1750.86	C=O bond
1646.31	C=C alkene bond
1545.34, 1498.48	C=C aromatic
1206.26	C-O-C stretch
1037.04	Si-O-Si stretch
788.61	Si-H stretch
540.28, 480.12	C-H stretch

Table 2. Functional groups in the FT-IR spectrum of biochar

Wave number (cm^{-1})	Functional group
2810.91	Aliphatic C-H stretch
1780.08	C=O stretch
1650.24	C=C alkene stretch
1541.62 ,1423.56	C=C aromatic stretch
1340.02	C-H stretch
1218.32	C-O-C stretch
1069.93	Si-O-Si stretch
800.21	Si-H stretch
444.83	C-H stretch

chemical alteration during its production process. Compared to the FTIR spectrum of husk (Fig. 2), characteristic differences were observed in the spectra of rice husk biochar (Fig. 1). The complete disappearance of O-H/N-H stretching (>3000 cm^{-1}) and almost disappearance of aliphatic C-H stretching (3000-2500 cm^{-1}) was noted in the spectrum of biochar. While, peaks arising from the aromatic

Table 3. Functional groups in the FT-IR spectrum of vermicompost

Wave number (cm^{-1})	Functional group
3277.35	O-H / N-H stretch
2876.71	Aliphatic C-H
1786.13	C=O bond
1633.71	C=C alkene bond
1554.29 ,1408.96	C=C aromatic
1036.01	Si-O-Si stretch
788.61	Si-H stretch
916.22, 533.32, 451.30	C-H stretch

stretching became more apparent. This implies that greater dehydration and increased aromatization occurred during pyrolysis process. Lee *et al.* (2010) reported that charring temperature modifies the functional groups, and thus aliphatic carbon groups decreases but aromatic carbon increases. Pyrolysis process created more recalcitrant character by increasing aromatic compounds, and is thus suitable for carbon sequestration.

CONCLUSIONS

Biochar production process or pyrolysis created more recalcitrant character by increasing aromatic compounds as evident from FTIR spectrum of biochar and its porous nature was visible in SEM image of biochar, and thus its application was suitable for soil carbon sequestration and integration of biochar with nutrients will be useful for enhancing soil health as well as crop productivity. The SEM and FTIR analysis showed that, there was not much morphological as well as structural changes were visible in vermicompost compared to rice husk. And it indicates that technology of composting rice husk using earth worm was not much suitable. So, the best residue management option in case of rice husk is production of biochar that have potential to improve soil health.

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