



Enhanced bio-composting of rice straw using agricultural residues: an alternate to burning

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Abstract

Purpose Rice straw which predominantly contains cellulose, hemicellulose and lignin, can be converted into value-added product such as bio-compost. The present study was planned to carry out rice straw degradation, added with agricultural residues like rice bran and fruit waste in different combinations, with standard fungal culture of *Trichoderma harzianum* MTCC 8230.

Methods Rice straw added with fruit waste and rice bran was moistened with sterilized water in five different proportions. The experimental trays were inoculated with spore suspension (1×10^8 spores/ml) of *T. harzianum*. The trays were observed for change in pH, appearance and chemical fibres (acid detergent fibre, neutral detergent fibre, and acid detergent lignin).

Results A continuous increase in bulk density accompanied with a decrease in volume was observed in all the experimental trays including the control. There was an initial increase in pH from 7 to 9 which stabilized to 8 after 12 days of incubation. The crystalline structure of rice straw was transformed into amorphous one in a time frame of 28 days, with a significant decrease in lignin from 20–25% to 13–15% and an increase in crude protein from 5–17%.

Conclusion The crystalline rice straw was reduced to a brown crumpled and compact value-added composted biofertilizer with a high carbon and crude protein content.

Keywords Rice straw · Rice bran · Fruit waste · Bio-compost · *Trichoderma harzianum*

Introduction

Amongst the different lignocellulosic crop residues in India, rice straw constitutes the largest proportion, with a production of 112 million metric tons per annum (Sukumaran et al. 2010). However, a vast proportion of this rice straw is subjected to open-field burning which is hazardous for the environment. Rice straw possess various several characteristics that make it an ideal feedstock for value-added products such as animal feed, bioethanol, lignocellulose enzyme, and bio-compost. The rice straw is chiefly composed of cellulose (32–47%), hemicellulose (19–27%) and lignin (5–24%) (Garrote et al. 2002). Therefore, the hidden value of rice

straw can be explored by biological conversion of polysaccharides into aforementioned value-added products.

Composting is a bio-oxidative process which involves the conversion of organic waste to a stabilized final product free of phytotoxicity and pathogens, by the process of mineralization and partial humification (Inckel et al. 1996). It can be made on the farm at very low cost and can be used as organic fertilizer (Zuconi et al. 1981). Therefore, the rationale of the present study was to convert rice straw into organic fertilizer to mitigate its open-field burning.

Methodology

Collection of rice straw and fungal culture

Rice straw was collected from School of Renewable Energy Engineering, Punjab Agricultural University (PAU), Ludhiana. The rice straw was washed thoroughly with tap water, chopped and sieved to 30 mesh size. Rice bran and fruit waste were collected from the local market. The materials

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were stored in clean plastic bags at room temperature for further analysis and treatment. The fungal culture *Trichoderma harzianum* MTCC 8230 was procured from department of Microbiology, PAU, Ludhiana.

Experimental design

Ten clean and dried plastic trays were taken for the experimentation and 50 g (each) of rice straw was added in them. Fruit waste and rice bran were supplemented along with sterilized water in five different proportions (Table 1). The contents were mixed thoroughly and inoculated with spore suspension (1×10^8 spores/ml) of *Trichoderma harzianum* @ 10% (v/v). The trays were covered with muslin cloth and incubated at 30 °C in a BOD incubator. The trays were observed every 48 h for change in physical appearance and sprinkled with water to prevent surface drying. The contents were weighed and their volumes were noted in a 1.0 L capacity measuring cylinder after every 4th day till their bulk densities became constant. The data were used to calculate bulk density by the following method:

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{Weigh of contents (g)}}{\text{Volume (cm}^3\text{)}}$$

The pHs of the contents were also recorded by using a pH paper strip of range 3–10. The contents were replenished in trays that were placed in BOD incubator maintained at 30 °C.

Chemical fibre analysis

To evaluate the biodegradation rate, the samples were analyzed for acid detergent fibre (ADF), neutral detergent fibre (NDF) and acid detergent lignin (ADL) by the method of Goering and Van Soest (1970). The crude fibre protein determination was carried out with the help of department of

Animal nutrition, Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana.

Statistical analysis

All experiments were carried out in triplicates and all the values are mean \pm standard error (SE), calculated using the MS excel program.

Results and discussion

Changes in bulk density, pH, and physical parameters

The results presented in Fig. 1 revealed a continuous increase in bulk density in all the trays including the control, though there was more increase in the first 12 days. The increase in bulk density represented the compactness of rice straw which is due to decrease in volume. The volume decrease was also accompanied with decrease in weight due to reduction in moisture level and volatile solids. The reduced weight and stability of compost facilitates its storage and transportation to faraway nursery and residential value-added markets (NRAES 2001). The pH of the compost showed an initial increase from 7 to 9 which stabilized to 8 after 12 days of incubation. A previous study on composting of cow manure and rice straw with cow urine addition (pile A) and cow manure and rice straw without cow urine addition (pile B) reported a rise in pH with start of composting and a final pH of 7.8 for pile A and 6.7 for pile B (Phong and Quynh 2018). Dewes (1996) reported pH of 7.0–8.5 to be optimum range for composting that could reduce volatilization speed of ammonia and the nitrogen losses. Smars (2002) found that composting is inhibited at pH below 6. Sundberg and Jonsson (2008) reported faster decomposition in biowaste and more stable compost product at higher pH condition.

The morphological appearance of the composting rice straw depicted change in color, structure, and odor. The color changes of the compost help in evaluation of compost maturity in the field in a swift and convenient manner. As observed in the present study, the rice straw compost turned dark brown from an initial yellow color and on 15th day, a profuse growth of fungal mycelium became apparent. A change in texture to crumpled and crusty was observed from an initial smooth texture (Table 2, Fig. 2). The degrading material had putrid odor during 12–15 days of incubation and was pleasant earthy at the end of the composting process (28 days). A previous study also recorded similar physical characteristic features of rice straw and sewage sludge compost. The color of the blend at the start of the composting process was observed to be yellowish grey while that at the end was

Table 1 Experimental plan of rice straw bio-composting

Treatment no.	Rice straw (g)	Fruit waste (g)	Rice bran (g)	Water (ml)
1	50	-	12.5	175
2	50	12.5	25.0	262
3	50	25.0	12.5	175
4	50	12.5	25.0	175
5	50	25.0	12.5	262

Inoculum of *T. harzianum* added @ 10% (v/v)

Treatment no. 1 is control



Fig. 1 Change in bulk density and pH during bio-composting. The graph displays error bars with SE

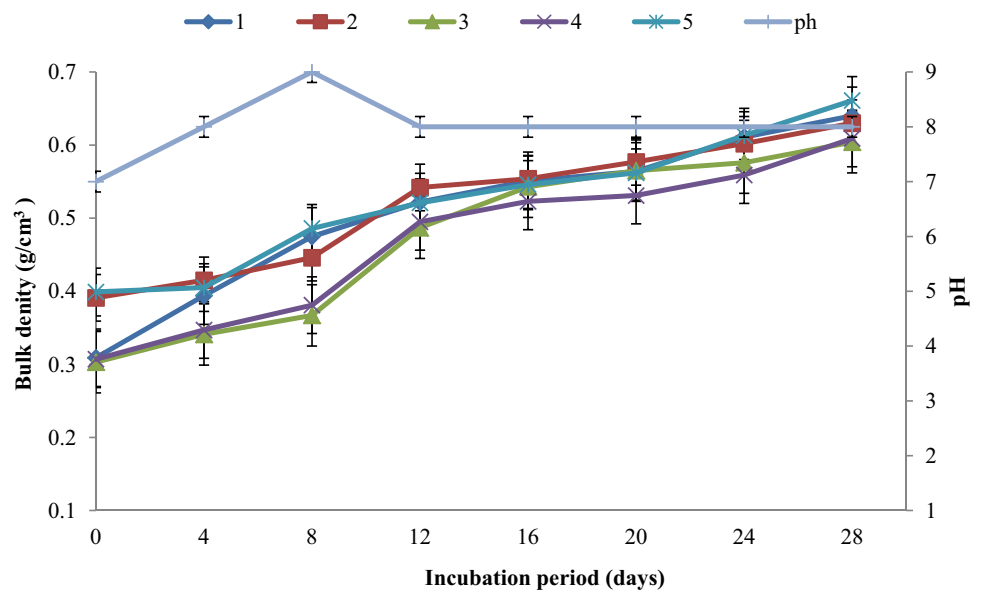


Table 2 Physical appearance of rice straw during and after bio-composting

Physical parameters	0 day	15 day	28 day
Color	Yellow	Light brown	Dark brown
Texture	Fragile, smooth textured	Non fragile, rough textured	Non fragile, crumpled, crust textured
Odor	No odor	Putrid	Pleasant earthy
Fungal growth	No growth	White fungal mycelium visible	No visible growth

The readings are mean values of experiments carried out in triplicate trays; control was devoid of fruit waste

Fig. 2 Change in physical appearance of rice straw after bio-composting

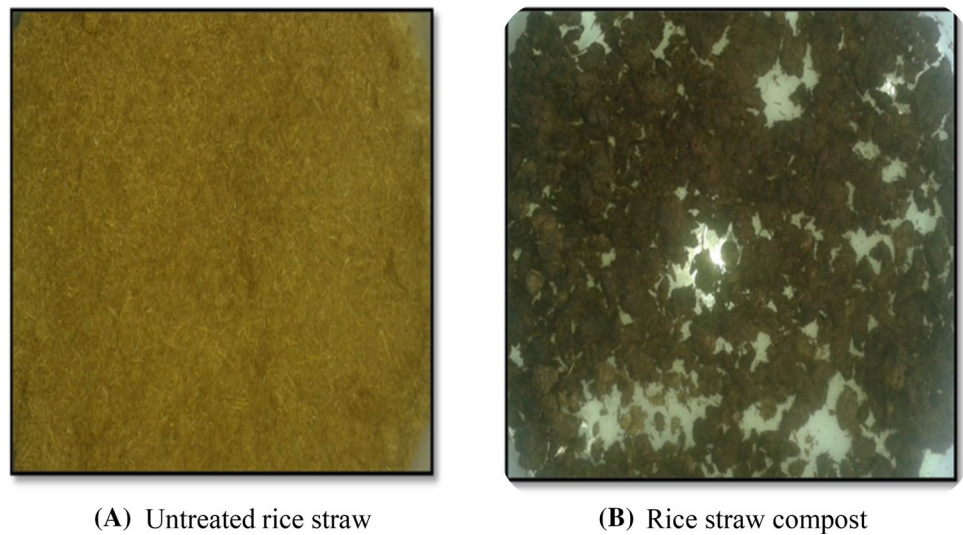


Table 3 Chemical composition of rice straw during and after bio-composting

Components	Treated rice straw ^a		
	0 day	15 day	28 day
Cellulose (%)	40 ± 1.2	43 ± 1.4	43 ± 1.4
Hemicellulose (%)	22 ± 0.7	18 ± 0.6	16 ± 0.5
Lignin (%)	24 ± 0.8	18 ± 0.6	15 ± 0.5
Crude protein (%)	5 ± 0.2	10 ± 0.3	17 ± 0.5

^a50 g rice straw added with 12.5 g rice bran and 25 g fruit waste. The values are expressed as mean ± SE

a consistent dark brown to brownish black with a cloddy structure and pleasant odor resembling that of wet forest soil (Roca-Pérez et al. 2009). Lee et al. (2002) attributed the dark-brown coloration of compost to microbial decomposition of organic materials with a long composting time, which may be due to the occurrence of underlying complex reactions such as Maillard reaction.

Changes in chemical characteristics of compost.

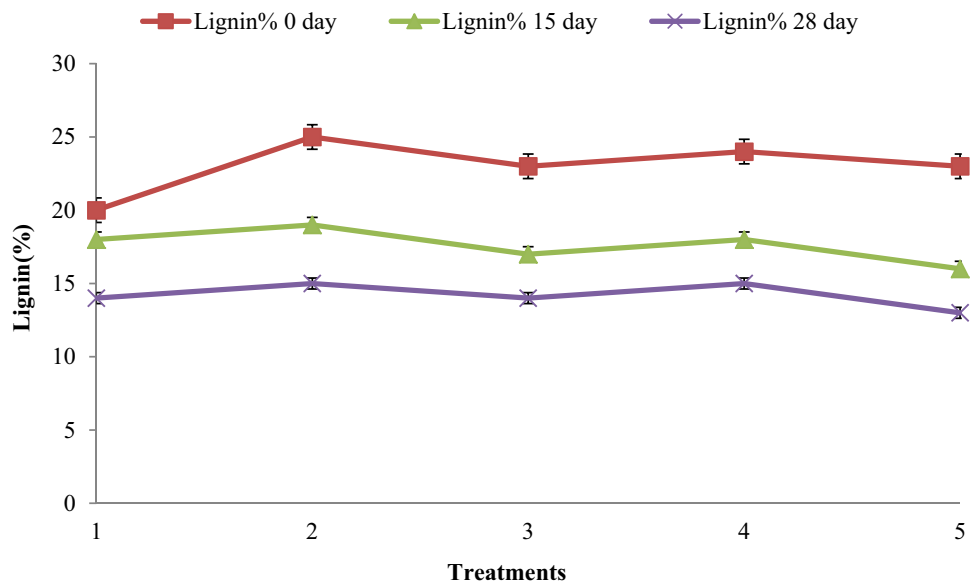
The recalcitrant nature of rice straw is due to the presence of crystalline cellulose with a high degree of polymerization and branched low-molecular weight hemicelluloses, which are laminated partly, by a lignin matrix. The lignin component of the rice straw is decomposed into fulvic acid

and humic acids by lignocellulolytic fungi, by humification process, which finally makes the substantial proportion of soil organic matter (Huang et al. 2008). These humic substances serve to provide energy for microbial growth and help in the regulation of carbon cycle (Veeken et al. 2000). The compost material in the present study depicted change in composition of rice straw during 28 days of experiment. The crystallinity of rice straw was transformed into amorphous with a significant decrease in lignin from 20–25% to 13–15%, thus making cellulose and hemicelluloses available for microbial degradation. The maximum reduction in lignin was observed in treatment number 5 that had high fruit waste addition and moisture level (Table 3, Fig. 3). The crude protein also increased to 17% in the compost material which was as low as 5% at the start of the experiment (Table 3).

Conclusion

The crystalline rice straw with a low bulk density, which occupied a large volume was reduced to a brown, crumpled and compact value-added composted biofertilizer. The said biofertilizer possessed a high carbon and crude protein content that can help provide a green technique for the improvement of soil health by supplementing the C and N pool of the soil and thus alleviate the farming cost.

Fig. 3 Percent change in lignin during bio-composting. The graph displays error bars with SE



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References

- Dewes T (1996) Effect pH, temperature, amount of litter and storage density on ammonia emission from stable manure. *J Agric Sci* 127:501–509. <https://doi.org/10.1017/S0021859600078722>
- Garrote G, Dominguez H, Parajo JC (2002) Autohydrolysis of corncob: study of non-isothermal operation for xylooligosaccharide production. *J Food Eng* 52:211–218. [https://doi.org/10.1016/S0260-8774\(01\)00108X](https://doi.org/10.1016/S0260-8774(01)00108X)
- Goering H K, Van Soest P J (1970) Forage fiber analyses (apparatus, reagents, procedures, and some applications), *Agriculture handbook no. 379*, Agriculture Research Service USDA, Washington (DC), USA, pp 20
- Huang H L, Zeng G M, Tang L, Yu H.Y, Xi H M, Chen Z M, Huang G H (2008) Effect of biodelignification of rice straw on humification and humus quality by *Phanerochaete chrysosporium* and *Streptomyces badius*. *Int Biodeter Biodegrad* 61:331–336. DOI.10.1016/j.ibiod.2007.06.014.
- Inckel MP, Smet D, Tersmette T, Veldkamp T (1996) The preparation and use of compost, 4th edn. E.W.M. Verheij, Wageningen, The Netherlands, Trans, p 28
- Lee BI, Kim PJ, Chang WK (2002) Evaluation of stability of compost prepared with Korean food waste. *Soil Sci Plant Nutr* 48:1–8. <https://doi.org/10.1080/00380768.2002.10409164>
- NRAES (2001) Proceedings from, dairy manure systems—equipment and technology, Rochester, New York, March 20–22. Agriculture, and Engineering Service, Cooperative Extension, Ithaca, New York, Natural Resource, p 424
- Phong NT, Quynh NTN (2018) Composting of cow manure and rice straw with cow urine and its influence on compost quality. *J Viet Env* 9(2):61–66. <https://doi.org/10.13141/jve>
- Roca-Pérez L, Martínez C, Marcilla P, Boluda R (2009) Composting rice straw with sewage sludge and compost effects on the soil-plant system. *Chemosphere* 75:781–787
- Smars S (2002) Influence of different temperature and aeration regulation strategies on respiration in composting of organic household waste, Department of Agricultural Engineering, Swedish University of Agricultural Sciences: Doctoral thesis, Agraria 324. Uppsala, Sweden
- Sukumaran RK, Surender VJ, Sindhu R, Binod P, Janu KU, Sajna KV, Rajasree KP, Pandey A (2010) Lignocellulosic ethanol in India: prospects, challenges and feedstock availability. *Biore-sour Technol* 101:4826–4883. <https://doi.org/10.1016/j.biortech.2009.11.049>
- Sundberg C, Jonsson H (2008) Higher pH and faster decomposition in biowaste composting by increased aeration. *J Waste Management* 28:518–526
- Veeken A, Nierop K, De Wilde V, Hamelers B (2000) Characterization of NaOH-extracted humic acid during composting of a biowaste. *Biore-sour Technol* 72:33–41. [https://doi.org/10.1016/S0960-8524\(99\)90096-2](https://doi.org/10.1016/S0960-8524(99)90096-2)
- Zucconi F, Pera A, Forte M, De Bertoldi M (1981) Evaluating toxicity of immature compost. *Biocycle* 22:54–57

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