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Assessment of Changes in Physico-chemical Parameters in Paddy Straw during Fungal-based Decomposition

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ABSTRACT

The degradation of paddy straw is an extremely important process in managing agricultural waste. This study aimed at examining the physico-chemical changes that might occur during the fungal-based decomposition of paddy straw. This study included different treatment with paddy straw alone and paddy straw with a microbial consortium. The maximum bulk density achieved after treatment with a lignocellulolytic fungal consortium was 0.85 g/cm^3. The SEM analysis showed a modification in the surface structure of paddy straw after the decomposition process. The treated paddy straw showed maximum changes in bulk density, colour, odour, pH, EC and moisture per cent. The significant reduction in C:N ratio (75.44 to 29.82) was observed after 30 days of treatment with a microbial consortium, which indicated the enhancement of decomposition by the intervention of microorganisms. These modifications affected the stability and possible uses of degraded paddy straw in various agricultural and environmental conditions. The goal to examine these differences was to learn more about the efficacy of degradation techniques and how they relate to sustainable waste management.

Key words: Paddy straw, bulk density (BD), SEM (scanning electron microscopy), C:N ratio

INTRODUCTION

Rice production in India ranks second globally, and paddy is one of the most important crops world-wide after corn. In the 2018-19 growing season, rice and wheat were cultivated on 1.45-2.55 million hectares in Haryana, resulting in total production of 4.52 and 12.75 million tonnes, as well as productivity of 3121 and 4925 kg/ha, respectively (Anonymous, 2019). The Ministry of New and Renewable Energy estimates that 500 metric tonnes of crop residues are produced annually. Major crop residues are generated by frequent use of combine harvester when conventional methods are not followed. Burning rice straw causes the loss of the soil organic carbon and plant nutrients, which negatively affects the properties of the soil and their flora and fauna. It also contributes approximately 0.05% of India's total greenhouse gas emissions (Sarkar *et al*., 2020). However, rice straw composting is gaining popularity as a secure solution that permits reusing the residue's nutrients (Kumar and Singh, 2021). Understanding the possible effects on the environment and applications requires investigating the physico-chemical changes in paddy straw during *ex-situ* degradation. Numerous factors, including nutrient content, structural integrity and chemical composition, can alter during degradation. By investigating these variations, the current study aims at gaining insights into the effectiveness of degradation methods and their implications for sustainable waste management.

In past years, attempts have been made in the development of an effective microbial consortium for the degradation of rice straw in order to speed up the process (Nevita *et al*., 2018; Chen *et al.,* 2019; Dash *et al.,* 2022), to encourage efficient recycling of nutrients, and enhance the nutrient status of the soil. The current study involved the use of lignocellulolytic fungal consortium for the degradation of paddy straw in flask experiments. Since the paddy straw has a C:N ratio of about 76:1, and to speed up the

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decomposition process, a microbial inoculants and a basal dose of urea were added.

Therefore, the goal of the current study was to examine the effects of the fungal consortium in order to evaluate their effects on the physico-chemical parameters of paddy straw degradation. One key consideration was the breakdown of complex organic compounds present in paddy straw. Furthermore, the straw's structural integrity modifications may affect its physical characteristics, including density and porosity. These physico-chemical variations are essential for optimizing degradation techniques and developing strategies for efficient degradation of paddy straw. Moreover, it contributes to the broader discourse on sustainable agricultural practices and waste management, especially in the context of addressing environmental concerns associated with crop residues.

MATERIALS AND METHODS

Paddy straw (1121) was collected from farmers' fields in Ghirai, a village of Hisar, Haryana, India. The rice straw was thoroughly cleaned with tap water before being cut into pieces. The paddy straws were chopped into 2 to 3 cm long pieces using a blender. The material was stored in sterile plastic bags for additional analysis and treatment at room temperature. Ten grams of rice straw were added to each 250-ml flask, cleaned, dried and prepared for experimentation (Table 1). The contents were thoroughly mixed before being inoculated in triplicate with spore suspension (1×10^8 spores/ml). The flasks were incubated at room temperature and covered with muslin cloth. To keep the flasks moist and avoid surface drying, sprayed with water and checked every 48 h for physical changes. Once their bulk densities stabilized, the contents of flask were weighed every seven days, and their volumes were recorded in a measuring cylinder. The bulk density was calculated as:

Bulk density (g/cm^3) = Weight of contents (g)/Volume (cm^3)

Table 1. Experimental set-up plan for rice straw degradation

Treatments	Isolates
T_1	Control
T_2	JLB
T_3	GD2
T_4	GKH3
T_5	GHR4
T_6	MC
T_7	JLB+GD2
T_8	JLB+GKH2
T_9	JLB+GHR4
T_{10}	GD2+GKH2
T_{11}	GD2+GHR4
T_{12}	GKH2+GHR4

Morphological characteristics, such as texture, colour and odour of paddy straw were observed during the decomposition process.

The structural changes in lignocellulosic substrates were observed using scanning electron microscopy. The physical differences between treated and untreated straw were seen in SEM images. Using Jeol, a high-resolution field emission scanning electron microscope with EDS (FESEM) operating in SE imaging mode at an acceleration voltage of 3-15 kV, the surface morphology of treated and untreated residues was investigated. The samples were sputter coated with gold palladium, dried using a critical point drier (EMS-850, Japan) and examined at various magnifications.

The variation in different physical-chemical parameters (Table 2) was observed before and after treatments with paddy straw.

Table 2. Analytical methods used to assess the physico-chemical characteristics of paddy straw degradation

S. No.	Parameters	Instrument and methods
1.	Temperature	Thermometer (°C)
2.	pH	pH meter
3.	Electrical conductivity	Conductivity meter (mS/cm)
4.	Total carbon	Walkley and Black method
5.	Total nitrogen	Kjeldahl method
6.	C:N ratio	Total carbon/Total nitrogen

RESULTS AND DISCUSSION

Paddy straw was subjected to different physical and chemical parameters during degradation. The microbial consortium-treated paddy straw was compared to the control for its morphological appearance, bulk density, scanning electron microscopy and chemical properties (pH, moisture content, electrical conductivity and C:N ratio).

The morphological characteristics, such as

Table 3. Morphological appearance of paddy straw during the degradation process

Treatments	Physical parameters															
	Colour				Texture				Odour				Fungal growth			
	0 day	15 day	30 day	60 day	0 day	15 day	30 day	60 day	0 day	15 day	30 day	60 day	0 day	15 day	30 day	60 day
PS alone (Control)	Yellow	Light brown	Dark brown	Light dark	Smooth, fragile	Smooth, fragrile	Rough, non-fragile	Crust, non-fragile, crumpled	No odour	No odour	Slight smell	Less putrid	No growth	No growth	No growth	No growth
PS+JLB	Yellow	Light brown	Light dark	Light dark	Smooth, fragile	Rough, non-fragile	Crust, non-fragile, crumpled	Non-fragile, crumpled	No odour	Less putrid	Putrid	Slight earthy	No growth	White mycelium of fungi with spores are visible	Visible growth	Not visible
PS+GKH3	Yellow	Light brown	Black brown	Light dark	Smooth, fragile	Rough, non-fragile	Crust, non-fragile, crumpled	Non-fragile, crumpled	No odour	Less putrid	Putrid	Slight earthy	No growth	Black spore visible	Full black growth,	Not visible
PS+GHR4	Yellow	Light brown	Light brown	Light dark	Smooth, fragile	Rough, non-fragile	Crust, non-fragile, crumpled	Non-fragile, crumpled	No odour	No odour	No odour	Slight earthy	No growth	Mycelium of fungi with spores are visible	No growth	Not visible
PS+GD2	Yellow	Brown	Brown	Light dark	Smooth, fragile	Rough, non-fragile	Crust, non-fragile, crumpled	Non-fragile, crumpled	No odour	Less putrid	Putrid	Slight earthy	No growth	Less growth of black spores	Faint growth of black spores	Not visible
PS+MC	Yellow	Light brown	Dark brown	Dark	Smooth, fragile	Rough, non-fragile	Crust, non-fragile, crumpled	Non-fragile, crumpled	No odour	Putrid	Slight earthy	Earthy pleasant	No growth	Visible growth	Not visible	Not visible

texture, colour and odour of paddy straw during degradation and fungal growth, were observed at different time intervals (Table 3).

The morphological alterations in the paddy straw's appearance revealed colour, structure and smell shift. The colour shift makes it easy and quick to assess the degradation process. The paddy straw in this study turned from yellow to dark brown, and on the fifteenth day, a noticeable proliferation of fungal mycelium was seen. The texture changed from smooth to crumple and crusty (Table 3). The degrading material smelled foul for the first ten to thirteen days of decomposition. However, it became pleasant and earthy after the 60th day. In a related study, the blend was observed to be yellowish-grey at the start of the process. But in the end, it had a uniform colour ranging from dark brown to brownish-black, a cloddy structure, and a pleasant scent similar to damp forest soil. According to Pourmazaheri *et al.* (2015) and Kaur *et al.* (2019) it can thus be regarded as the cause of the compost's dark-brown colour and a crucial indicator of compost maturity.

The bulk density increased steadily in all the flasks, including the control (Fig. 1). An increase in bulk density was observed after 30 days of treatment. This increase indicated the compactness of paddy straw, which resulted from decreased volume. A decrease in weight also accompanied the volume decrease due to a reduction in moisture level and volatile solids. The initial bulk density ranged from 0.47 to 0.59 g/cm^3, and an increase (0.85 g/cm^3) in bulk density was observed in treatment containing a lignocellulolytic microbial consortium of fungi as compared to control (without microbial consortium). As degradation progresses, microorganisms in paddy straw break down complex organic compounds. The breakdown of organic matter causes gases to be released and organic structures to disintegrate; decreasing overall volume. The decrease in moisture content and volatile solids in the paddy straw is directly linked to the reduction in bulk density. Increased bulk density resulted from the elevated microbial activity, which also raised BD and shrunk the size of the rice straw's raw components. The breakdown of lignocellulosic structures in the paddy straw contributes to changes in its physical integrity. When the fibrous components break down into smaller particles,

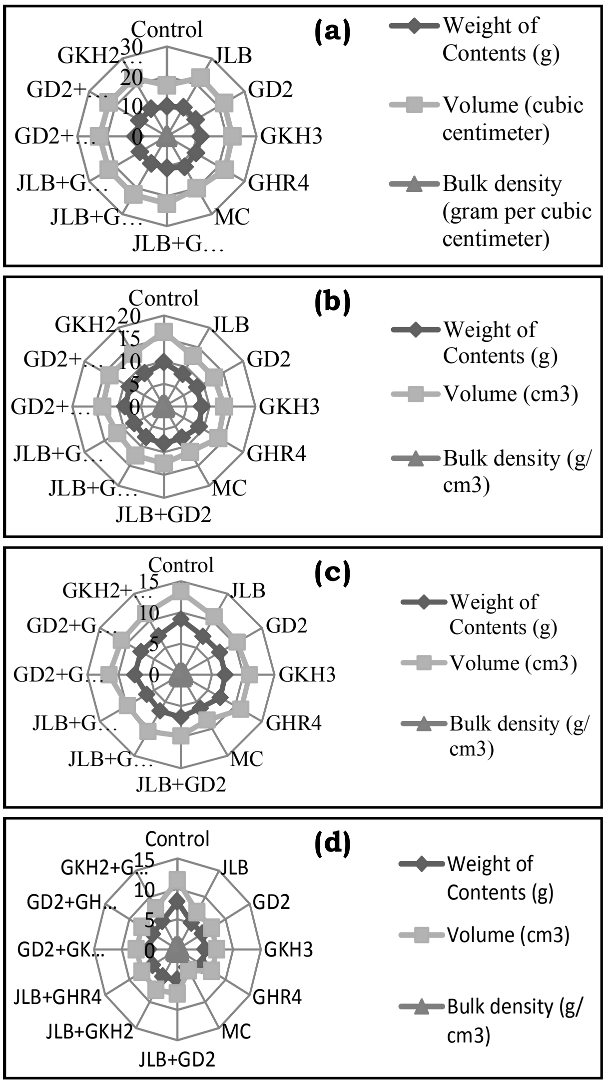

Fig. 1. Change in bulk density at different intervals of time. A representation of the (a) seventh-day, (b) fourteenth-day, (c) twenty-first-day and (d) after thirty days.

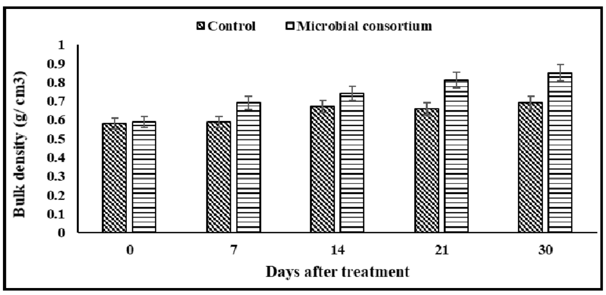

Fig. 2. Changes in the bulk density during decomposition of rice straw.

this could result in a denser and more compact material. Particles generated during degradation may settle within the flask, contributing to increased bulk density. Furthermore, because of increased biodegradation and frequent turning, BD increased over time as the particle size decreased. This settling effect may be more pronounced in the initial stages of degradation, explaining the observed trend in the first 30 days. The treatment containing a microbial consortium of fungi had a more pronounced effect than the other treatments (Fig. 2).

Evaluating the ability to retain nutrients is essential to comprehend the possible agricultural uses of the degraded paddy straw. The material's use in agriculture may be affected by variations in bulk density and related changes in the material's physical structure. To maximize soil conditioning properties, one must comprehend these changes.

SEM images observed physical changes in paddy straw during decomposition and differences between untreated and treated with the microbial consortium (Fig. 3A). A correlation was found between the degraded fibre bundles and the control straw. According to the SEM analysis some surface structure modifications were observed in the treated rice straw (Fig. 3). The surface of the rice straw was compact and regular before enzymatic treatment. The surface of the rice straw became hollowed out, chapped and cracked following the microbial consortium treatment. Sruthy *et al.* (2023) found that the three fungi (*Aspergillus terreus, Aspergillus fumigatus* and *Alternaria* sp.) successfully colonised rice stubble and efficiently degraded it. The modifications in the structure were caused by enzymatic activity. The microbial consortium produces lignocellulolytic enzymes that aid in the hydrolysis of rice straw. The enzymes act synergistically to degrade celluloses, hemicelluloses and lignin completely.

The changes in physico-chemical parameters during the decomposition increased pH of the treated rice straw from 6.6 to 7.7 (Tables 4 and 5). The previous study demonstrated that the microbial breakdown of nitrogen-containing substances, like ammonia, which is released and accumulated in the composting treatments, may be responsible for the pH increase (Wan *et al.*, 2020). The process of ammonification and the biodegradation of short-chain fatty acids could be the cause of the pH increase. The consistent rise in pH was observed when the rice straw decomposed over the course of the degradation process (Kaur and Katyal, 2021).

The treated paddy straw's electrical conductivity (EC) increased from 2.5 to 3.1 mS/cm compared to the control. However, the high EC would lead to more salinity and phyto-inhibitory effects in the soils and plants (Wan *et al.*, 2020).

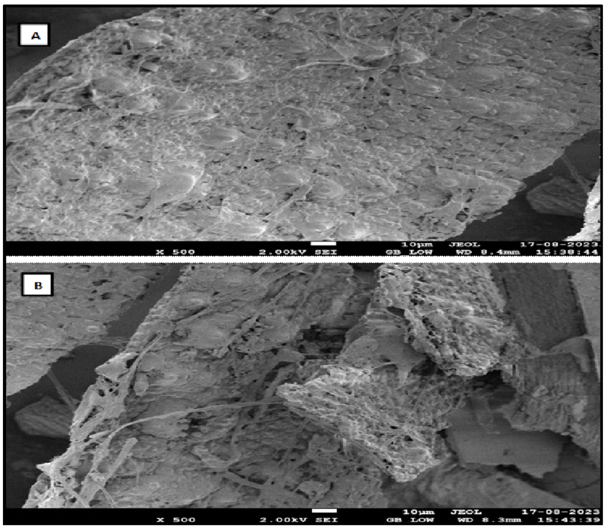

Fig. 3. Surface structure of rice straw at 500X resolution before (A) and after (B) treatment with the microbial consortium.

Table 4. Physico-chemical analysis of rice straw during microbial degradation

S. No.	Instrument and methods	Initial parameters
1.	Moisture content (%)	59.7
2.	pH	6.5
3.	Electrical conductivity meter (mS/cm)	2.5
4.	Total carbon (%)	46.02
5.	Total nitrogen (%)	0.61
6.	C:N ratio	75.44:1

Table 5. Changes in physico-chemical analysis of rice straw during degradation of paddy straw

S. No.	Treatments	Days after treatment (DAT)			
		0 (DAT)		30 (DAT)	
		pH	Electrical conductivity meter (mS/cm)	pH	Electrical conductivity meter (mS/cm)
1.	Paddy straw alone	6.5	2.3	6.7	2.4
2.	Paddy straw+MC	6.6	2.5	7.7	3.1

Table 6. Changes in C:N ratio (%) during degradation of paddy straw

S. No.	Treatments	Days after treatment (DAT)					
		0 (DAT)			30 (DAT)		
		C	N	C:N	C	N	C:N
1.	Paddy straw alone	48.48	0.59	82.16:1	46.02	0.61	75.44:1
2.	Paddy straw alone+MC	46.40	0.62	74.83:1	36.68	1.23	29.82:1

After 30 days of incubation, the pH of the treated paddy straw increased from 6.6 to 7.7, while the pH of the control increased from 6.5 to 6.7 (Table 5).

The degradation of crop residues mainly depends on the raw materials C:N ratio. The decrease in the C:N ratio indicates the decomposition of rice straw. A high C:N ratio indicates the presence of unutilized complex N and C, whereas a complete breakdown of these materials is indicated by a low C:N ratio. In the present study, total nitrogen observed after 0 and 30 days of application of microbial consortium was 0.62 and 1.23%, respectively, and the total organic carbon was 46.4 and 36.68% (Table 6) compared to the control. So, the results revealed that the C:N ratio of the paddy straw reduced from 75.44 to 29.82, which indicates the decomposition of the paddy straw. Sarma *et al.* (2022) studied that addition of lignocellulolytic novel consortium reduced the C:N ratio from 54.25 to 17.66% on the 20th day. The decreases in the C:N ratio are mainly due to the rapid loss of C in the straw samples, which may be due to the addition of lingo cellulolytic microbial consortium leading to increased loss of carbon in the form of CO_2 emissions (Abdel-Rahman *et al.*, 2016).

CONCLUSION

In conclusion, microbial activity, structural deterioration and moisture content variations were the reasons behind the bulk density changes observed in the flask experiment. These changes practically impact the stability and potential applications of degraded paddy straw in various agricultural and environmental contexts. The surface structure of the rice straw had changed after the treatment, according to the results of the SEM analysis. Enzymatic activity was the source of this modification. The microbial consortium had lignocellulolytic enzymes that catalyzed the hydrolysis of rice straw. The enzymes act synergistically to degrade celluloses, hemicelluloses and lignin completely. Thus, in this case, catalytic enzyme enhanced the delignification process of rice straw. Although the incorporated straw's enhanced chemical and biological qualities suggesting better decomposition, but this study did not evaluate the changes in the soil's physical conditions. Further investigations could be required to ascertain these characteristics, as this data would benefit the field operations for the subsequent cropping season, which involves preparing the soil and the seedbed. There is a way to shorten the decomposition period even more. In that case, it might be tested by adding more amendments, like manure and organic fertilizers, or by carrying out more field operation tasks.

REFERENCES

Abdel-Rahman, M. A., El-Din, M. N., Refaat, B. M., Abdel-Shakour, E. H., Ewais, E. E. D. and Alrefaey, H. M. (2016). Biotechnological application of thermotolerant cellulose-decomposing bacteria in composting of rice straw. *Ann. Agric. Sci.* **61**: 135-143.

Anonymous (2019). Ministry of Agriculture and Farmers' Welfare. Directorate of Economics and Statistics, Government of India. p. 314.

Chen, K. J., Tang, J. C., Xu, B. H., Lan, S. L. and Cao, Y. (2019). Degradation enhancement of rice straw by co-culture of *Phanerochaete chrysosporium* and *Trichoderma viride*. *Sci. Rep.* **9**: 19708-19713.

Dash, P. K., Padhy, S. R., Bhattacharyya, P., Pattanayak, A., Routray, S., Panneerselvam, P. and Pathak, H. (2022). Efficient lignin decomposing microbial consortium to hasten rice-straw composting with moderate GHGs fluxes. *Waste Biomass Valorization* **13**: 481-496.

Kaur, A. and Katyal, P. (2021). Microbial interventions for composting of organic and lignocellulose waste. *Appl. Biochem. Microbiol.* **57**: 127-132.

Kaur, P., Singh Kocher, G. and Sachdeva Taggar, M. (2019). Enhanced bio-composting of rice straw using agricultural residues: An alternate to burning. *Int. J. Recycling Organic Waste Agric.* **8**: 479-483.

Kumar, P. and Singh, R. K. (2021). Selection of sustainable solutions for crop residue burning: An environmental issue in north-western states of India. *Environ. Develop. Sustain.* **23**: 3696-3730.

Nevita, T., Sharma, G. D. and Pandey, P. (2018). Composting of rice-residues using lignocellulolytic plant-probiotic *Stenotrophomonas maltophilia* and its evaluation for growth enhancement of *Oryza sativa* L. *Environ. Sustain.* **1**: 185-196.

Pourmazaheri, H., Jouzani, G. S., Karimi, E., Nekouei, S. M. K., Tabatabaei, M. and Amiri, R. M. (2015). Development of a bioprocess for fast production of enriched biocompost from municipal solid wastes. *Int. J. Biodeterioration Biodegradation* **104**: 482-489.

Sarkar, S., Skalicky, M., Hossain, A., Brestic, M., Saha, S., Garai, S. and Brahmachari, K. (2020). Management of crop residues for improving input use efficiency and agricultural sustainability. *Sustainab.* **12**: 9808-9831.

Sarma, S., Patel, N., Patel, A., Desai, C., Sharma, S., Dedania, S. and Narra, M. (2022). Rapid decomposition of rice straw by application of a novel microbial consortium and study its microbial community dynamics. *World J. Microbiol. Biotech.* **38**: 212-226.

Sruthy, K. S., Shukla, L., Kundu, A., Singh, S. K., Abdulrahman Alodaini, H., Hatamleh, A. A. and Kumar, A. (2023). Effect of microbial consortium constructed with lignolytic ascomycetes fungi on degradation of rice stubble. *J. Fungi* **9**: 567-581.

Wan, L., Wang, X., Cong, C., Li, J., Xu, Y., Li, X. and Wang, L. (2020). Effect of inoculating microorganisms in chicken manure composting with maize straw. *Bioresource Tech.* **301**: 122730-122736.