Food and Scientific Reports
ISSN 2582-5437
foodandscientificreports.com

Rapid decomposition of paddy straw: An overview

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ABSTRACT

The burning of paddy straw causes deterioration of soil, air, and human health. The consortium of bacterial and fungal microorganisms degrades the complex polymer by the action of their microbial enzymes. Thus, paddy straw can be converted into compost using microbial inoculants developed by different ICAR or government.

Keywords: burning paddy straw, rapid decomposition

Over 502 million tonnes of agricultural residue are produced in India annually, of which cereal residue contributes to 70% of total crop residues, out of which paddy residue contributes 34% (MNRE, 2009). Most of the paddy straw in Punjab and Haryana, and Uttar Pradesh is harvested using a combine harvester, and paddy crop residues are left in the field. For sowing rabi crop, i.e., mainly wheat and potato, the time available for preparatory tillage is only 2-3 weeks. Crop residue burning after rice harvest, especially in a north-western region like Punjab and Haryana, and Uttar Pradesh, is critical for deteriorating air quality, soil health, and human health.

Deterioration of Soil health

Residue burning has an adverse effect on soil carbon storage, soil quality, crop yield and leads to greenhouse gas emission. The paddy straw burning leads to loss of nitrogen completely, phosphorus (25%), and sulfur (5-60%) (Doberman and Fairhurst, 2002). The burning of approximately 23 million tons of paddy residue in north-western India causes losses of CO_2 equivalent of approximately 34 million tonnes and 1.4 X 10^5tonnes of nitrogen annually.

Deterioration of air quality

Burning paddy straw leads to loss of 70%, 7%, and 0.66% carbon as carbon dioxide, carbon monoxide, and methane, respectively, and 2.1% N as N_2O, are causing global warming. Approximately one tonne of paddy residue on burning emits 13 Kg particulate matter, 60 Kg carbon monoxide, 1460 Kg of carbon dioxide, 3.5 Kg NOx, 0.2 Kg sulfur dioxide. Furthermore, the aerosol creates health problems for humans and animals, particularly respiratory and eye problems among the local population. Paddy residue burning increases the top soil temperature, which negatively affects the carbon-nitrogen equilibrium of the soil (Kumar *et al.*, 2015). The raised soil temperature kills the beneficial micro flora and fauna of the soil, causing loss of biodiversity and adverse impact on soil health.

Loss to economy

About 35 million tonnes of straw are burned, and considering the economics and health losses, this amounts to 1.5 times the health and education budget of India. The ultimate consequence of an increase in air PM 2.5 level causing Acute Respiratory Infection (ARI) among children and about USD 30 billion losses every year in monetary terms (Chakrabarti *et al.*, 2019).

Management of Paddy Straw

Keeping the burning of paddy straw in view, recycling of these wastes is an ecological necessity, but, in a country like India, it is an economic compulsion. Composting agri- residue has been an eco-friendly and economical way of recycling agri-residues as the final product of composting is humus-rich, stable, pathogens, and plant seeds free. Thus, it can be beneficially applied to the land to improve soil fertility and health (Singh and Nain, 2014). Instead of burning, we can utilize paddy straw in different ways, as shown in (Figure.1). Here, we have discussed some microbial consortium developed by different Indian Council of Agriculture Research (ICAR) institutions for rapid degradation of agricultural residue, including paddy straw. Farmers can prepare compost on their farm and can replenish soil fertility and soil quality for sustainable agriculture.

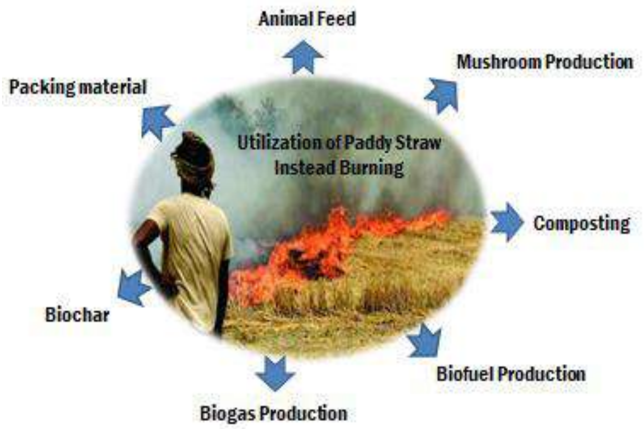

Figure 1: Utilization of paddy straw instead of burning.

Consortium for enhanced degradation of lignocellulosic plant residue

Paddy straw is composed mainly of cellulose (36%), hemicellulose (24%), lignin (15%), and starch. These plant residues can be degraded at a faster rate by microbial formulation.The consortium of lignocellulolytic microbes consisting of *Aspergillus* sp. *Bacillus* sp. and *Streptomyces* sp. degrade paddy straw quickly and improve soil quality (Shrivastava *et al.*, 2018). Similarly, efficient microorganisms consisting of *Candida tropicalis* (Y6), *Lactobacillus* sp., *Streptomyces globisporous* (C3), *Phanerochaete chrysosporium* (VV18), and Pusa compost inoculum have shown rapid decomposition of paddy straw (Sharma *et al.*, 2014).

Some formulation made by ICAR based institutions are as follows

- Recently the Division of Microbiology, IARI, New Delhi, has developed a microbial capsule-based consortium for the decomposition of paddy straw with a short duration of time named Pusa Decomposer.
- Similarly, another ICAR institute ICAR-NBAIM, Mau developed under the name of biocompost, which consists of *Trichoderma viride, Aspergillus niger, Pleurotus florida* and *Phanerochaete chryso-sporium* (http://nbaim.org.in/)
- On the same line, ICAR-TNAU also developed the TNAU Biomineralizer consortium, which consists of bacteria, fungi, and actinomycetes for composting (Department of Microbiology, TNAU website).
- ICAR-IISS, Bhopal recommended Phospho-Sulpho-Nitro-Compost (PSNC). Here microbial consortia comprise cellulose decomposer (*Aspergillus awamori* and *Paecilomyces fusisporus*), P-solubilizers (*Pseudomonas striata* and *Bacillus polymyxa*), and N-fixer (*Azotobacter chroococcum*). This consortium decomposes and enriches the nutrient status of the soil. They suggested rapid decomposition could be done by mixing chopped plant residue, cellulose-decomposer fungus *Trichoderma harzianum*, and weeds/grasses or subabul tree leaves. They also suggested the possible combination for rapid paddy straw degradation (ICAR-IISS technology folder).
- ICAR-AAU, Jorhat suggested bio-enriched compost. In this, final compost amended with rock phosphate (1%) and microorganisms like phosphorus-solubilizer, *Azospirillum / Azotobacter*. It minimizes the nitrogenous and phosphatic fertilizer to about 50% for the rice-wheat cropping system (ICAR agriculture commercialized technology manual).
- ICAR-IARI, New Delhi, recommended mixing low-grade rock phosphate (1%) and waste mica. For one ton, enriched compost requires one-ton crop residue, 200 kg low-grade rock phosphate, and 200 kg waste mica. (ICAR agriculture commercialized technology manual).
- ICAR-NRRI, Cuttack has also tried with three consortia for rapid ex-situ degradation *Aspergillus* + *Streptomyces* + Bacteria, *Aspergillus* + *Streptomyces*, *Trichoderma* + *Streptomyces* (ICAR-NRRI, annual report 2017-18).

Methods of composting preparation for paddy straw

The paddy straw can be degraded In-situ as well as ex-situ. Composting can be done in closed pits, perforated pits, or heap method. Harvested paddy straw should be chopped into (3-5) cm pieces and mixed with poultry dropping or legume or grass leaves to narrow down the C: N ratio desirable for rapid decomposition. The different combination suggested by ICAR-IISS, Bhopal should be used. Similarly, Crop residue mixed with poultry manure (8:1) or urea 0.5% to get a desirable C: N ratio. The rock phosphate (1%) or nitrogen fixer, or phosphorus solubilizer may be added to enrich the compost quality. The chopped paddy straw is mixed with lignocellulosic microbial consortium procured from ICAR institutions/government agencies may be inoculated. The compost-pit should be preferably in shadow, well-drained, and level sites.

Microorganisms involved in the composting process:

Phases of Composting	Temperature	Moisture	Microorganisms Involved
Mesophilic	< 45 °c	55%	*Aspergillus awamori, Paciliomycis variotii, Phanerochaetechrysosporium, Trichoderma viride, B.subtilis,* and *B. pumilus*
Thermophilic	55-60°c	50%	*Sporotrichum thermophile, Thermoascus aurantiacus, B. stearothermophilus,* and *B. licheniformis, Aspergillus fumigatus*
Maturing/Curing	45-50°c	45%	*Actinomycete ssp., Trichoderma viride*

Enzymes involved in the decomposition process

Lignocellulosic biomass is made up of cellulose, hemicellulose, and lignin. Due to their recalcitrant crystalline structure, it is very difficult to degrade, but most fungi produce an extracellular enzyme that easily breaks the recalcitrant structure of lignocellulosic biomass. Some hydrolytic enzymes that are responsible for degradation are cellobiohydrolase, β-glucosidase, endoglucanase, and laccase.

Important factors for decomposition

- C: N ratio: A ratio of 30-35:1 is best for rapid degradation, and the wider the ratio, the more resistant to degradation. In broader C: N crop residue, the crop residue having higher in nitrogen like legume stalk green leaves and biogas slurry are added to lower the level.
- Crops residue should be shredded less than 5 cm to increase the surface area.
- The optimum moisture should be 45-60% for aerobic composting. Excess and low moisture hinder microbial growth and, thereby, the decomposition process.
- Ideal pH for composting is 6.5-8.0
- Temperature: Due to hydrolysis of crop residue by microorganisms, temperature of the pile increases up to 55-60°c. Thus, a succession of microflora occurs, and mesophilic microbes like bacilli are replaced with thermophilic bacteria, actinomycetes, and fungi. The faster decomposition is seen under the thermophilic range of temperature 60°c.

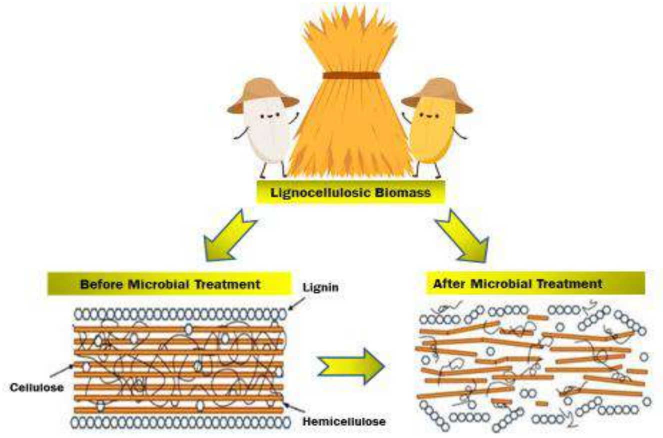

Figure 2: Microbial degradation of ligno-cellulosic material.

Advantages of rapid degradation

- Recalcitrant lignocellulosic agro-material may be converted into compost for supplementing plant nutrients.
- Recycling of humus and nutrients in the soil.
- It improves the physical, biological, and chemical properties of soil.
- Composting is safe for use because of free from weed, pathogen, and pest propagules.

Conclusion

The paddy straw left after harvesting paddy in northwestern and other parts of India may be converted into compost by using ligno-cellulosic microbial inoculants developed by ICAR institutions or government agencies.

Disclaimer

The content of this article is a personal opinion and experience of the authors, not necessarily an endorsement or suggestion of the institute where they are associated with.

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