Accelerating Stubble Decomposition: A Bio-Enzyme Approach

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***Abstract*—Stubble burning remains a critical environmental concern in Northern India, contributing significantly to deteriorating air quality and public health hazards. This study evaluates the potential of bio-enzymes as a cost-effective, scalable, and eco-friendly alternative for rapid stubble decomposition. Using a combination of expert interviews, field visits, and controlled experiments with three distinct enzyme compositions, we observed that increased concentrations of jaggery and yeast significantly enhanced microbial activity and accelerated decomposition. The research advocates a multi-pronged solution combining bio-enzymes, technological interventions, and policy support to eliminate the need for stubble burning.**

Keywords—stubble burning, bio-enzyme, decomposition, environmental issues, agriculture

I. Introduction

Stubble burning is deeply entrenched in India's agricultural practices, driven by tight cropping schedules due to mechanized harvesting and the push for double cropping. Farmers, constrained by time and lacking viable alternatives, often resort to open-field burning of crop residue—particularly in Punjab, Haryana, and Uttar Pradesh during the winter season.

This practice emits large volumes of carbon dioxide, methane, nitrous oxide, carbon monoxide, and particulate matter, resulting in severe smog conditions. The environmental fallout is compounded by public health issues such as respiratory disorders, eye irritation, and increased hospitalizations, particularly among vulnerable groups.

Despite efforts like fines, subsidies for machinery, and awareness campaigns, adoption of sustainable practices remains low. This research focuses on bio-enzymes as a practical alternative, capable of breaking down stubble organically and reducing the need for burning.

II. Alternatives to Stubble Burning

This section outlines various alternatives that have been explored to address the stubble burning crisis by effectively disposing of crop residue in a sustainable manner. While promising, each comes with its own set of logistical, economic, or behavioral challenges that limit widespread adoption.

A. *Waterlogging for decomposition*

Maintaining standing water in paddy fields post-harvest promotes anaerobic microbial activity, which naturally decomposes organic matter like stubble.

Challenges

- Requires proper field bunding and drainage systems
- Risk of soil salinization and nutrient leaching
- Time-consuming and not suitable for tight sowing schedules

B. *Happy seeder*

This machine cuts and lifts straw while simultaneously sowing seeds, allowing farmers to prepare fields without removing or burning stubble.

Challenges

- High initial cost of machinery
- Requires specific soil moisture conditions
- Limited availability and adoption among smallholder farmers

C. *Biomass Briquettes*

Crop residue is compressed into briquettes and used as a cleaner fuel alternative to coal.

Challenges

- Requires infrastructure for collection, transport, and processing
- Limited market linkages and demand in rural areas

D. *Composting with Bio-Enzymes (e.g., PUSA Decomposer)*

Enzymes such as PUSA facilitate the rapid decomposition of crop residue, transforming it into nutrient-rich manure. This not only improves soil fertility but also supports sustainable farming practices.

Challenges

- Requires consistent training and follow-up with farmers
- Takes time to show visible benefits

E. *Fodder for Livestock*

Residue can be repurposed as cattle feed where feasible.

Challenges

- Not all stubble types are suitable or nutritious for fodder
- Limited cattle population per household
- High volume of stubble far exceeds demand

F. *Sale to Biofuel Plants:*

Excess stubble can be sold to biofuel and alcohol distilleries, creating an additional income stream for farmers.

Challenges

- Requires organized supply chains and aggregation mechanisms
- Transportation costs are often prohibitive
- Biofuel units are not uniformly distributed across regions

III. Research Methodology

A. Expert insight

In an interview with environmentalist Mr. Neeraj Gulati, key insights emerged regarding the policy and economic context of stubble burning. He noted that government procurement policies, particularly the Minimum Support Price (MSP) for rice, have intensified paddy cultivation in water-deficient regions—leading to surplus stubble.

While many farmers are aware of decomposition techniques, adoption is hindered by high enzyme costs, irregular availability, and lack of infrastructure. Mr. Gulati emphasized that financial incentives alone are insufficient without systemic changes including farmer education, infrastructure development, and policy reform.

B. Field study

A field investigation in Kalyana village highlighted similar challenges. Farmers reported that mechanized harvesters leave behind stubble that is uneven and difficult to remove, especially in waterlogged fields. A noteworthy suggestion was to equip harvesters with spraying mechanisms for simultaneous enzyme application—an idea that informed our proposed engineering solution.

C. Approach followed

The approach combined:

- Qualitative Data: Field visits and expert interviews
- Literature Review: Scientific and technical resources
- Experimental Validation: Testing of three enzyme compositions over 30 days

Changes in mass, microbial activity (LUX meter), temperature, and pH, were tracked allowing for a holistic understanding of enzyme effectiveness.

IV. Experiment Design

A. Objective

To identify the most effective bio-enzyme formulation (comprising cow dung, jaggery, yeast, water, and soil) for accelerating wheat stubble decomposition.

B. Hypothesis

Higher concentrations of jaggery and yeast will stimulate microbial activity, expediting decomposition.

C. Materials

- 1 kg wheat stubble
- Three enzyme compositions
- LUX meter, pH meter, thermometer, digital scale, timer
- Containers for fermentation

D. Variables

- Independent Variable: The quantity of cow manure, jaggery, yeast, and water used.
- Dependent Variable: The time taken for stubble to decompose.
- Controlled Variables: Amount of stubble used, temperature, and type of stubble (wheat stubble in this case).

E. Bio-enzyme compositions

TABLE I. Bio-enzyme compositions

Composition	***Jaggery***	***Yeast***	***Cow Manure***	***Water***	***Soil***
Comp1	25g	5g	500g	1 Litre	100g
Comp2	50g	10g	500g	1 Litre	100g
Comp3	75g	20g	500g	1 Litre	100g

F. Procedure

Each bio-enzyme mixture was fermented separately and 1 kg of wheat stubble was fully submerged in the solution. Parameters were tracked daily over 30 days, with each trial repeated thrice to ensure data reliability. This is explained in ensuing paragraphs.

1) Preparation Phase: Three fermentation containers were set up, each corresponding to one of the three bio-enzyme compositions. Each container was filled with the specific ratio of cow manure, jaggery, yeast, water, and soil.

2) Stubble Immersion: One kilogram of wheat stubble was added to each container, ensuring full submersion in the bio-enzyme solution.

3) Monitoring Parameters:

- Daily recording of mass loss to track decomposition rate.
- Measurement of temperature and pH to monitor environmental conditions inside the container.
- Use of a LUX light meter to assess microbial activity through light absorption.

4) Duration: The experiment was conducted for 30 days or until stubble mass was reduced by at least 80%, indicating substantial decomposition.

5) Repetition and Data Logging: Each composition was tested in triplicate to ensure data accuracy and reproducibility. Results were recorded in tabular form for comparative analysis.

V. Results

A. Temperature trend during decomposition

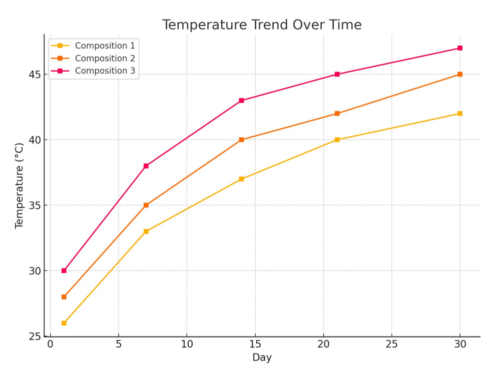

Figure 1: Temperature trend during decomposition

B. pH trend during decomposition

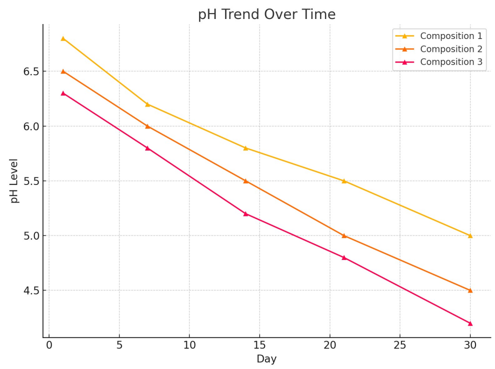

Figure 2: pH trend during decomposition

C. Mass loss

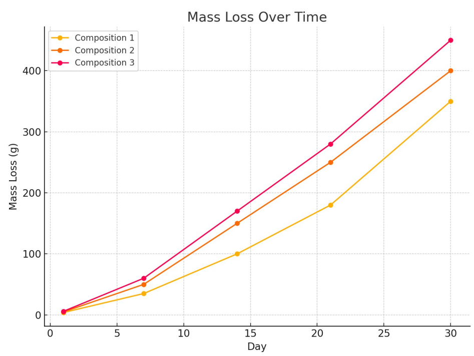

Figure 3: Mass loss trend during decomposition

D. Key observations

- Composition 3 which contained the highest amounts of jaggery and yeast achieved the fastest and most complete decomposition, with 45% greater mass reduction than Composition 1 by Day 30.
- The increased sugar content from jaggery and elevated yeast levels enhanced microbial activity, significantly accelerating the fermentation and breakdown process.
- Composition 1 was the least effective due to lower nutrient content.

VI. Way Forward

A. Engineering integration

To support large-scale implementation of bio-enzyme use, we propose modifying harvesters as follows:

- Storage tank, pump & nozzles to ensure even distribution during harvesting.
- Control systems to maintain consistent flow.
- GPS-quadrat mapping to divide field into spray zones.
- Sensors and data logging for moisture control and performance tracking.

B. Improvement suggestions

- Include more temperature controls to monitor the effect of temperature on enzyme efficiency.
- Use larger quantities of stubble to simulate real-life applications more effectively.
- Explore variations in pH to determine if acidic or alkaline conditions further enhance decomposition rates.

C. Other recommendations

- Equip harvesters with enzyme sprayers
- Encourage community-level decomposer production
- Conduct awareness drives via gram panchayats
- Launch pilot programs with government backing
- Adjust crop calendars to allow for natural breakdown

Acknowledgment

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