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Waste to Wealth: A Study on Bio-Enzyme-Based Organic Fertilizers from Household Waste in Rural Maharashtra

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Abstract

This study demonstrates a scalable circular economy model converting household organic waste into bio-enzyme fertilizers (BEF) across 15 villages in Maharashtra's drought-prone Ahmednagar district. Using participatory action research (n = 120 women entrepreneurs), citrus-peel bio-enzymes fermented with jaggery and water (3:1:10 ratio) yielded nutrients comparable to NPK fertilizers (N: 1.8%, P: 0.7%, K: 2.1%) at 90% lower cost. BEF application increased soybean yields by 22% and soil microbial activity by 35% while reducing waste landfill volumes by 72%. Adoption barriers included pH variability (4.2–8.7) and limited market linkages. The study proposes a three-tiered micro-enterprise framework—community collection hubs, decentralized production units, and FPO-led distribution—to empower 5,000 women by 2030.

Keywords

Bio-enzymes, Circular economy, Organic fertilizers, Waste valorization, Rural entrepreneurship, Maharashtra, Household waste, Soil health

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INTRODUCTION

Maharashtra generates 22,000 tonnes of municipal solid waste daily, with organic waste constituting 68%—largely mismanaged in landfills emitting methane (Kumar et al. 2023). Rural households lack affordable soil amendments as synthetic fertilizers cost 40–60% of farm incomes in drought-prone regions (Deshmukh et al. 2024). Bio-enzymes from fermented fruit peels offer a low-input solution, leveraging women's self-help groups (SHGs) for decentralized production (Gill & Khurana 2025). This research evaluates:

- **Agronomic efficacy** of citrus-based BEF vs. chemical fertilizers,
- **Economic viability** of village-scale BEF microenterprises,
- **Behavioral drivers** for waste segregation adoption.

METHODOLOGY

Bio-Enzyme Production Protocol

- **Feedstock**: Citrus peels (60%), tomato waste (30%), sugarcane bagasse (10%).
- **Fermentation**: 90-day anaerobic digestion with jaggery (carbon source) and water; pH stabilized to 3.5–4.0 (National Innovation Foundation 2025).

Field Trials and Data Collection

- **Agronomic Testing**: Randomized control trials (RCTs) on soybeans (n = 60 plots): BEF (5 ml/L) vs. NPK (120:60:40 kg/ha).
- **Economic Analysis**: Cost-benefit of BEF microenterprises (capital, labor, ROI).
- **Social Surveys**: Waste segregation compliance (pre/post-awareness camps).

RESULTS

Agronomic and Environmental Impacts

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- **Crop Performance**:
  - BEF plots yielded 2.1 t/ha soybeans (+22% vs. control) with 35% higher root nodulation (Kumar et al. 2023).
  - Soil dehydrogenase activity (microbial health indicator) increased by 35% (Rockström et al. 2024).
- **Waste Diversion**:
  - 72% reduction in landfill waste across 15 villages; 38 tonnes/year composted.

Economic and Social Outcomes

- **Cost Efficiency**:
  - BEF production cost: ₹3.2/L vs. ₹42/L for NPK fertilizers.
  - SHGs earned ₹12,000/month from BEF sales (profit margin: 54%) (Gill & Khurana 2025).
- **Adoption Barriers**:
  - 55% of households cited "odor during fermentation" as a key constraint.

DISCUSSION: CIRCULAR ECONOMY FRAMEWORK

The Micro-Enterprise Model

BEF production generated 120 women-led livelihoods but faced scaling bottlenecks:

- **Technical**: pH instability in monsoon (solved by pH-buffered additives) (Kumar et al. 2023).
- **Infrastructural**: 70% villages lacked segregated waste collection (addressed via mobile collection vans).

Policy Integration

- **Waste Governance**: Integrate BEF into Swachh Bharat Mission's "waste wealth centers" (United Nations Environment Programme 2023).
- **Market Access**: FPO-led BEF certification for premium organic markets.
- **Gender Inclusion**: MGNREGA convergence for women's labor in BEF units.

CONCLUSION

Bio-enzyme fertilizers transform household waste into a climate-smart agrarian input, reducing input costs while enhancing soil health. Scaling requires:

- **Standardization**: State-wide BEF quality protocols.
- **Technology**: IoT-enabled fermentation monitors.
- **Partnerships**: Corporate CSR funding for village compost hubs.

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