Utilizing Wheat and Rice Straw for High-Yield Mushroom Cultivation: A Solution to Stubble Burning

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ABSTRACT

Agricultural stubble burning in rice-wheat growing regions generates 7,300 kg CO_2 emissions per hectare while severely degrading air quality and soil health. This article examines wheat and rice straw utilization for oyster mushroom (*Pleurotus* species) cultivation as a sustainable alternative. Evidence demonstrates biological efficiencies of 60-85% when substrates are supplemented with nitrogen-rich materials, generating gross revenues of 120,000-250,000 Indian Rupees per 100 m² annually for smallholder farmers. Spent mushroom substrate application enhances soil health through nutrient recycling and organic matter addition. This integrated approach simultaneously addresses environmental degradation, food security, farmer income, and climate change mitigation across major cereal-producing regions.

INTRODUCTION

Stubble burning represents a critical agricultural and environmental challenge affecting Asia's major cereal-producing regions. India generates approximately 126.6 million tonnes of rice straw annually, with significant portions disposed through open-field burning rather than value-added utilization. This practice releases greenhouse gas emissions equivalent to 7,300 kg Co2 per hectare, increases $PM_{2.5}$ concentrations by 50-75%, destroys soil microorganisms, and depletes essential nutrients from agricultural ecosystems (Dey *et al.*, 2020). Despite policy interventions and mechanized alternatives, farmer adoption remains limited due to high machinery costs and inadequate market structures for alternative residue products (Singh *et al.*, 2025).

Mushroom cultivation on cereal crop residues offers a multifaceted solution. Oyster mushrooms (*Pleurotus* species) possess remarkable capacity to decompose lignocellulosic materials, achieving biological efficiencies of 60-85% on properly supplemented wheat and rice straw substrates (Yang *et al.*, 2013). This converts agricultural waste into high-value protein-rich food while simultaneously mitigating environmental degradation. The spent mushroom substrate (SMS) remaining after harvest generates secondary benefits through soil application, improving soil fertility and organic matter content.

Substrate Characteristics and Preparation Optimization

Wheat and rice straw present distinct chemical compositions influencing mushroom cultivation outcomes. Rice straw contains approximately 40-50% cellulose, 25-30% hemicellulose, 10-15% lignin, and elevated silicon concentrations, while wheat straw exhibits 35-40% cellulose, 20-25% hemicellulose, and 15-20% lignin (Han *et al.*, 2024). Both materials exhibit high carbon-to-nitrogen (C/N) ratios of 80-120:1, substantially exceeding the optimal 30-50:1 range for mushroom cultivation. Comparative studies demonstrate that rice straw substrates generate yields of approximately 600 grams per kilogram dry weight, substantially exceeding corn husk or rice husk alternatives (Akcay *et al.*, 2023).

Nitrogen supplementation represents the critical optimization strategy. Addition of cotton seed hull (15-30% by weight) to rice straw increases yields by 20% and enhances fruiting body quality, while supplementation with wheat bran (10-20% by weight) increases protein content from 15.52% to 22.09% (Sharma *et al.*, 2013). Optimal substrate formulations combining rice straw (60%), cotton seed hull (30%), and wheat bran (10%) achieve yields of 470-475 grams per kilogram, substantially exceeding non-supplemented straw performance.

Substrate sterilization through pressure cooking at 121°C for 60-90 minutes or pasteurization at 65°C for 6-8 hours eliminates competing microorganisms essential for successful cultivation (Hoa *et al.*, 2015). While sterilization increases production costs and equipment requirements, pasteurization provides a farmer-accessible alternative with results comparable to sterilization when coupled with adequate spawn inoculation rates (10-15% by dry weight).

Mushroom Cultivation Performance and Yield Optimization

Oyster mushroom (*Pleurotus*) species demonstrate variable performance on cereal residues. Comparative analysis reveals that *Pleurotus florida* achieves highest yields of 872 grams per kilogram (87.22% biological efficiency), followed by *Pleurotus sajor-caju* (78.43%), *Pleurotus ostreatus* (72.04%), and *Pleurotus fossulatus* (71.35%) (Obodai & Vowotor, 2003). Species selection should align with regional climatic conditions and market preferences.

Spawn production and inoculation protocols establish the biological foundation for cultivation success. Quality spawn developed from pure cultures requires aseptic technique and grain-based substrates (wheat grain, millet, or sorghum) sterilized at 15 PSI for 60-90 minutes. Complete grain colonization typically requires 10-20 days at 23-25°C before use as inoculum. Spawn at 10-15% of the dry weight of the substrate ensures adequate mycelial biomass for competitive substrate colonisation (Prasad *et al*., 2024).

Colonization occurs at 20-25°C in darkness for 15-30 days, with complete colonization evidenced by uniform white mycelial coverage. Fruiting induction follows through environmental modification: 6-12 hours light exposure daily, temperature reduction to 16-20°C, humidity maintenance at 80-90%, and increased air exchange. Pin formation occurs within 3-10 days, with harvest-ready fruiting bodies developing within 7-14 days post-pinning. Multiple flushes extend over 6-8 weeks, with first flush typically generating 50-60% of total yield (Gebru *et al*., 2024). Commercial yields of 800-1,000 kg fresh mushrooms annually per 100 m² support gross revenues of 120,000-250,000 Indian Rupees at farm gate prices of 150-250 Rupees per kilogram.

Environmental Benefits and Socioeconomic Implications

The substitution of straw burning with mushroom cultivation generates substantial environmental and climate benefits. Complete elimination of field burning removes 7,300 kg CO_2e emissions per hectare, while spent mushroom substrate (SMS) application further reduces net Global Warming Potential by 2.46-3.22 times through soil carbon sequestration and reduced chemical fertilizer requirements (Martin *et al*., 2023). Air quality improvements reduce $PM_{2.5}$ concentrations by 30-50%, preventing approximately 40,000-80,000 annual premature deaths across affected regions while reducing respiratory disease morbidity.

Spent mushroom substrate application at 100 tonnes per hectare increases crop yields by 50% while enhancing soil phosphorus (2.3-fold increase), organic carbon (40% improvement), nitrogen (28% increase), and essential minerals (3× increase in calcium, potassium, magnesium) (Zhang *et al*., 2002). Water retention capacity improvements prove critical for drought-prone regions, supporting agricultural resilience to climate variability.

Mushroom cultivation creates particular opportunities for women's economic empowerment and rural employment generation. The activity demands lower physical labor compared to field cultivation, proves compatible with household management schedules, and generates year-round income through 12-15 harvest cycles annually. Capital requirements of 50,000-100,000 Indian Rupees prove accessible to resource-limited smallholders, substantially lower than mechanization alternatives requiring 200,000-500,000 Rupees investment.

Policy recommendations for scaling adoption include: (1) institutional capacity building through agricultural university curricula development and farmer training centers; (2) spawn production center establishment providing quality spawn at subsidized rates; (3) farmer cooperative development for collective marketing and value-added processing; (4) rural infrastructure investment in electricity access and cold storage; (5) financial incentive programs including input subsidies and carbon credit monetization; (6) research prioritization on region-specific species selection and processing value-added product development.

CONCLUSION

Mushroom cultivation on wheat and rice straw represents a genuinely transformative solution addressing simultaneously the environmental, economic, and social dimensions of the agricultural stubble burning crisis. Biological efficiencies of 60-85% convert agricultural residues into nutritious protein-rich food while eliminating direct combustion emissions, improving air quality, restoring soil microbial communities, and generating farmer income substantially exceeding conventional field crop returns. Integration of spent mushroom substrate application creates circular agricultural systems where residues support food production, enabling soil regeneration supporting enhanced subsequent crop yields.

Scaling this sustainable practice requires coordinated policy action, institutional capacity building, infrastructure investment, and knowledge system transformation. With appropriate support structures, mushroom-based residue management can transition from marginal adoption to mainstream practice across major rice-wheat producing regions, delivering comprehensive sustainability benefits across environmental, food security, and livelihood dimensions.

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