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Oyster Mushroom production using locally available agricultural residues: A farm-level waste to wealth evaluation and village-based production model in Anjaw district, Arunachal Pradesh

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Abstract

The study evaluated the potential of locally available agricultural residues, including millet straw, paddy straw, large cardamom residue and banana psuedostem, for oyster mushroom production under the farming conditions of Anjaw district, Arunachal Pradesh. The findings demonstrated that locally available residues can serve as practical alternatives to conventional mushroom substrates, with variations in biological performance and economic suitability. Particular attention is given to large cardamom residue because of its abundance in the district and its potential to convert an underutilized agricultural by-product into a value-added product. The study further highlights opportunities for developing decentralized, cluster-based mushroom production involving farmers, women Self-Help Groups and rural youth. Integration of residue utilization, mushroom production, collective marketing and recycling of the remaining substrate as compost could contribute to livelihood diversification, improved agricultural waste to wealth management and resource-efficient farming system in the remote hill areas of Anjaw.

Keywords: Agricultural residues; Large cardamom, Millet, Banana; Paddy; Substrate utilization; Farm-level economics, Waste to Wealth

Introduction

Large quantities of agricultural residues like paddy straw, millet straw, banana residues and large cardamom biomass remains after crop production. In many farming systems, these residues have limited direct economic value and are left to decompose, discarded or used only for a few traditional purposes. Productive utilization of these residues can provide an opportunity to obtain additional value regenerated from already available farm resources. Oyster mushroom (*Pleurotus sajor-caju*) cultivation provides a practical means of converting such agricultural wastes into a commercially important on-farm products by relatively using simple production practices (Sánchez, 2010; Grimm and Wosten, 2018).

The situation is particularly pertinent in Anjaw district of Arunachal Pradesh, where the availability of agricultural residue varies significantly by location and farming systems (Mody *et al.*, 2012; Singh *et al.*, 2023, Singh *et al.*, 2026). Although paddy straw is a commonly used substrate for oyster mushroom cultivation, its availability in the district is relatively scares as compared to millet straw, banana psuedostem and large cardamom residue. Therefore, paddy straw was taken as a reference substrate to evaluate the performance in comparison with locally available alternative substrates. Of all these alternatives, large cardamom residue has been given significance importance in the hill farming system and its cultivation produces substantial quantities of biomass. The potential utilization of this residue as a mushroom substrate provides an opportunity to convert underused agricultural by-product into a value-added product. Utilization of such residues can reduce reliance on conventional substrates and keep more value within the local farming system.

Utilization of agricultural residues in mushrooms production also represents a simple waste-to-wealth approach. Rather than seeing crop residues as waste, farmers can thus deploy them as an input for other enterprises, creating additional ecological and economic value, without necessitating any additional cultivable land. This may contribute to farm-income diversification especially with respect to households residing in remote hilly areas. Substrates diversification, thus, stood as important factor where conventional mushroom substrates are not easily available. A substrate that performs well under local conditions is easily available and requires minimal expenditure for collection and transportation may possess greater practical utility to farmers than a conventional substrate that needs to be purchased or imported from outside the production area (Pandya *et al.*, 2024).

Against this background, a comparative farm-level demonstration was conducted to evaluate paddy straw, millet straw, large cardamom residue and banana psuedostem as substrates for oyster mushroom cultivation. The experiment monitored spawning date, pinhead initiation and mushrooms production over three successive flushes.

Substrates evaluated

The study evaluated four different agricultural residues that are already available in the local farming system namely, millet, paddy, large cardamom and banana psuedostem. Paddy straw was considered as reference substrate based on its established use (Ragunathan *et al.*, 1996; Obodai *et al.*, 2003) in oyster mushroom production, although its availability in the district is very limited. Millet, large cardamom and banana psuedostem were included because of their higher local availability and potential for alternatives utilization. All four substrates were spawned and evaluated under the same production process. Their subsequent growth and development were monitored until pinhead initiation and harvesting.

Spawning and pinhead formation

The spawning date was identical for all four substrates, but the time required for pinhead initiation differed slightly. The paddy straw recorded the earliest pinhead initiation, approximately 17 days after spawning. Large cardamom residue and banana straw-initiated pinheads after approximately 19 days, while millet straw required approximately 20 days. The difference in pinhead initiation among the substrates was therefore relatively small. Importantly, all four substrates supported fruiting and produced mushrooms over successive harvests (Adedokun and George-David, 2016; John *et al.*, 2023). Mushroom production was recorded during three successive flushes.

The three-flush production differed across the four substrates. Millet straw observed the highest cumulative production followed by paddy straw, large cardamom and banana psuedostem. Despite the lowest cumulative yield recorded in banana psuedostem residue among the four substrates, its capability to support mushroom production across successive flushes revealed it potentiality to utilize as an alternate substrate considering its local availability and limited alternative use.

Table 1. Estimated production and economics of oyster mushroom cultivation using different substrates

Particular	Millet	Paddy	L. Cardamom	Banana psuedostem
Yield/15 bags of 5 kg each)	14.26	13.74	13.90	10.12
Gross return (₹)	4278	4122	4176	3036
Total cost (₹)	1800	1800	1800	1800
B: C ratio	2.37	2.29	2.32	1.68

Note: Miscellaneous expenditure of ₹1,200 was incurred on firewood, plastic bags and bamboo required for the mushroom cultivation. And selling price @300/kg

Table 1 represents the comparative economic performance of oyster mushroom cultivation using millet straw, paddy straw, large cardamom residue and banana psuedostem. Millet straw realized the highest overall productivity and economic performance followed by large cardamom residue and paddy straw whereas, banana psuedostem reported lower production and returns. The result reflects that substrate type can have an impact not only on mushroom yield but also on the overall economic return of the production system.

Importantly, large cardamom residue showed significant economic potential even though it was not the most productive substrate. Its performance is particularly pertinent in Anjaw because the residue is available within the local farming system. All four substrates produced positive returns the prevailing cost and selling price, indicating that locally available agricultural residues can provide economically feasible options for oyster mushroom production while creating opportunities for additional value generation from farm biomass.

Yield is not just the only measure of a good substrate

Although millet straw recorded the highest yield in this demonstration, substrate selection at farm level should not be based on solely biological yield. Farmers also need to consider the local availability of the substrate whether it has to be purchased, transportation cost and labour requirements for collection and preparation, seasonal availability, competition use of agricultural residue and prevailing market price of mushrooms. These factors are particularly important in far-flung areas like

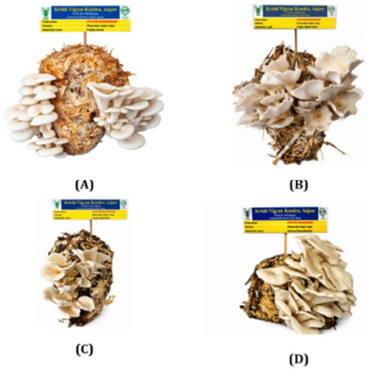

Figure 1. Oyster mushroom (Pleurotus sajor-caju) production on different agricultural residue substrates: (A) paddy straw (B) millet straw (C) large cardamom residue and (D) banana psuedostem.

Anjaw, where transportation and accessibility can greatly leverage the cost of agricultural inputs. As an example, paddy straw is a widely established substrate for oyster mushroom cultivation, its limited availability in Anjaw may reduce its practically feasible compared to agricultural residues that are already available within the local farming system.

Thus, a locally available substrates with slightly lower biological performance may however represents a more practical and economically feasible option when its acquisition, transportation and preparation costs are relatively low. Such wider consideration of substrate availability, accessibility and cost is thus required for identifying substrates that not only just biologically productive, but also suitable for farm-level mushroom production in remote and resource-limited environment.

Circular economy and zero-waste farming

The results of the present demonstration are not just limited to the comparative yield of mushroom of each of the four substrates. It demonstrates the feasibility of constructing a circular resource-use system where agricultural residues produce from crop production can be re-directed to mushroom production and then back to farming systems as an organic resource. The cycle demonstrated in figure 2 represents the transition from a conventional linear system of crop production → residue generation → disposal towards a more circular system crop production → agricultural residues→ mushroom substrate→ sale → remaining mushroom substrate → compost/organic manure → crop production. This approach is particularly relevant to Anjaw district where the availability of conventional substrate such as paddy straw is relatively scarce while, residues of millet, banana and large cardamom are locally available. The present demonstration indicates that all four

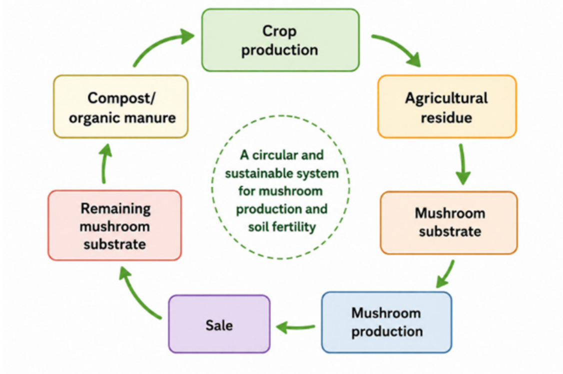

Figure 2. Circular system for agricultural residue utilization in mushroom production

materials were capable of supporting oyster mushroom production though their yield differs. The relatively good performance of large cardamom residue is important from resource utilization point of view. Its yield slightly differs to that of millet straw and paddy straw, suggesting that locally available residue with few alternative uses can replace a more conventional substrate.

More importantly, the finding is the value that can be added to the residue. Most of agricultural biomass has little or no direct market value at the point of generation. But when it is transformed into mushroom substrate, the same biomass becomes an input for a product that is saleable. Thus, the economic value of the residue is increased without necessitating additional agricultural land. In this context of large cardamom production, this provides an additional opportunity for using crop biomass and diversifies farm incomes.

Value addition of mushroom produce product promotion through SHGs/FIGs and FPOs

Fresh oyster mushroom is highly perishable due to its short shelf life that can results in post-harvest losses, more particularly in this remote district where transportation and market access are hindered. Therefore, value addition would be the best support for shelf-life extension, transport facilitation so as to reduce loss and economic viability of mushroom production. Instead of marketing the entire harvest as fresh mushrooms, surplus or unsold produce can be processed into products with longer storage potential, such as dried mushroom, pickle, chutney, powder form and other locally suitable processed products. Fresh mushrooms can also be cleaned, graded and properly packaged to improve their quality, appearance and marketability in higher-value retail and institutional markets.

For Anjaw, value addition could be particularly useful for women SHGs, FIGs and FPOs, which can conduct collective processing, packaging, branding and marketing of mushroom products at the village or cluster level (Mishra, 2012). Such collective activities could reduce processing and packaging costs, improve product consistency and create opportunities for small-scale rural enterprises. The value-addition pathway can therefore be represented as:

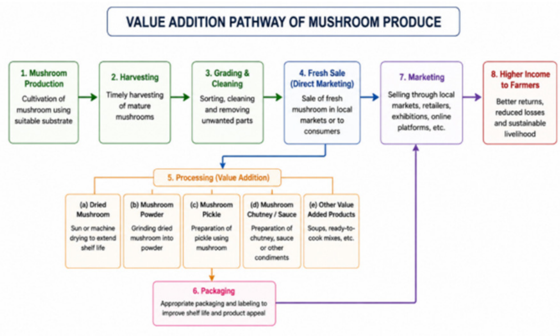

Figure 3. Value addition and marketing pathway for mushroom produce

Development of a Village-Level Model

The study sets a foundation for establishing cluster-based model village on mushroom production utilizing locally available millet straw, large cardamom straw and banana psuedostem in the district. Specifically mentioning that the approach is particularly pertinent in the district as mushroom cultivation has already been introduced in some villages utilizing large cardamom residues as a substrate, especially among women SHG members showing great interest in expanding mushroom production units through the utilization of these locally available resources. Such initiatives would provide a practical basis for development of coordinated, farmer-led production system where locally available agricultural residues can be utilized collectively for preparation of substrate, its production, accumulation and marketing. Development of such model would facilitate an effective utilization of agricultural biomass, minimizing dependency on imported substrates and creation of additional livelihood opportunities whilst promoting a circular and efficient farming system. A simple village-level model can be represented as:

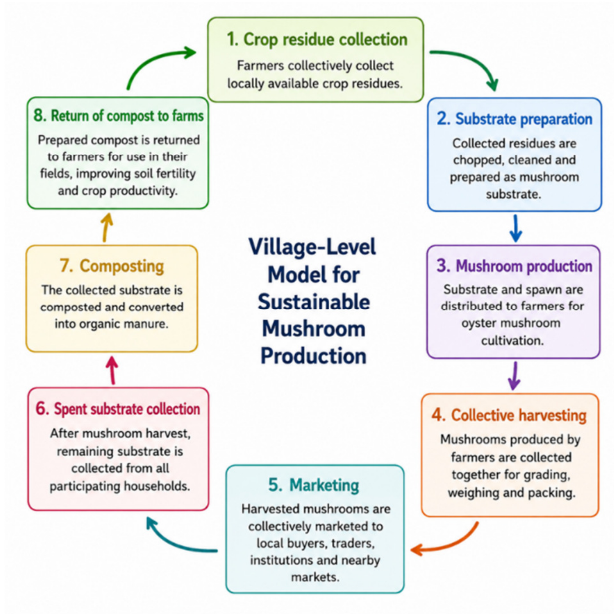

Figure 4. Proposed village-level circular model for sustainable mushroom production

For Anjaw, this model could be particularly relevant in large cardamom growing villages, where its residue is produced locally and can potentially be marketed. The model could also be expanded to millet and banana growing areas depending on the availability and suitability of these residues, By linking residue availability with decentralized mushroom production and group marketing, this approach would enable to reduce reliance on substrates that are scarce or to be imported from outside the production areas. This would also create additional livelihood opportunities for farmers, women SHGs including rural youths. Most importantly, recycling the remaining mushroom substrate as compost or organic manure could contribute to a circular, resource-efficient and locally integrated farming system that would retain more economic value (Paula *et al.*, 2017; Owaid *et al.*, 2017; Leong *et al.*, 2022).

Table 4. Key constraints, strategies and institutional roles for village-level mushroom development in Anjaw district

Specific constraint	**Practical strategy**	**Responsible institution /Organization**
Remote and scattered villages	Develop small village/cluster units rather than a centralized production centre	District Administration, KVK, Dept. of Horticulture
High transportation cost	Prioritize locally available crop residues and prepare substrates within or near the village	KVK, Dept. of Agriculture & Horticulture
Difficult in selling of fresh mushrooms	Promote local/nearby markets, collective aggregation and linkages with institutional buyers or promote immediate drying if marketing is not feasible	SHGs/FPOs /FIGs
Limited access to inputs such as spawn	Establishment of spawn production unit at village and block level	KVK, Agriculture & Horticulture Dept., SHGs/FPOs

Seasonal road disruption/landslides	Maintain small stocks of substrate, bags and spawn before difficult weather periods arises	District Administration, KVK, farmer groups
Limited suitable production infrastructure	Promote low-cost mushroom units using locally available materials instead of expensive permanent structures	KVK, Agriculture & Horticulture Dept.
Limited market volume from individual farmers	Introduce collective harvesting, grading, packing and scheduled marketing days	SHGs/FPOs, Horticulture, DIC
Limited opportunities for disposal/recycling of substrate	Establish village-level composting pits/units among SHGs or PLF members	KVK, Agriculture, Gram Panchayats
Limited financial resources for new units	Link SHGs and farmer groups with credit and suitable livelihood improvement schemes	Banks, NABARD, Rural Development, DIC
Difficult extension coverage across remote villages	Use a lead & active farmer/SHG-member to train within their village	KVK, Agriculture & Horticulture Dept.
Fragmented institutional support	Establish a district-level convergence mechanism with clearly assigned responsibilities	District Administration

**** DIC: District Industries Centre, PFL- Primary Level Federation, FPOs- Farmers Producer Organization, FIGs- Farmers Interest Group, SHG- Self-Help Group*

Future ahead

The findings provide a basis for further development of **decentralized, cluster-based mushroom production systems** in the district. Future efforts should focus on multi-season and farmer field-level validation of locally available substrates, particularly large cardamom, millet and banana residues along with improved access to quality spawn, low-cost production units and local market linkages. Strengthening women SHGs, farmer groups and rural youth as local mushroom entrepreneurs could support expansion of the enterprises, while collective marketing and village-level composting could also improve economic viability and resource recycling. With appropriate institutional convergence and consistent technical support, mushroom cultivation could emerge as a **locally adapted livelihood option that converts agricultural residues into value-added products while strengthening circular and sustainable farming systems in the district.**

Conclusion

The present demonstration indicates that locally available agricultural residues can serve as viable substrates for oyster mushroom production under the agro-climatic conditions of Anjaw district. Millet straw recorded the highest mushroom yield, while large cardamom residue also showed considerable potential, producing a yield comparable to the conventional substrates evaluated. The utilization of large cardamom residue is particularly relevant because the crop is widely cultivated in the district and generates substantial biomass that can otherwise remain underutilized (Mane *et al.*, 2007; Singh *et al.*, 2026). Although substrate performance varied, the findings demonstrate that substrate selection should consider not only yield but also local availability, transportation requirements, production cost and market conditions.

The result therefore, provides a practical basis for promoting a decentralized, cluster-based mushroom production model involving farmers, women SHGs and rural youth. Such model can integrate locally available crop residues, mushroom production, collective marketing and recycling of the remaining mushroom substrate as compost or organic manure. With appropriate technical support, institutional convergence and farmer-level validation, mushroom cultivation has the potential to contribute to agricultural residue management, additional livelihood generation and circular resource use in the remote farming systems of the district.

With sound technical backstopping and institutional convergence and validation at farmer-level, mushroom production can substantially contribute to agricultural residues management, livelihood diversification and resource cycling in the remote farming systems of the district. It can also improve access to nutritious food source rich in protein, dietary fibre, vitamins and minerals, thereby supporting dietary diversity and household nutrition. Thus, integrating mushroom production into local farming systems can provide both economic and nutritional benefits to rural farmers of the remotely located district.

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