International Journal of Agriculture and Food Science 2025; 7(11): 139-143

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFS 2025; 7(11): 139-143
www.agriculturaljournals.com
Received: 06-09-2025
Accepted: 11-10-2025

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Techno-economic feasibility of small-scale mushroom cultivation in rural areas

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DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i11b.1463

Abstract
Mushroom cultivation in rural Thailand has evolved from a niche activity into a credible livelihood option over the past two decades, yet rigorous techno-economic feasibility data at the small-scale (100-500 kg substrate/week) level remains scattered. This research assessed the technical performance and financial viability of three mushroom species oyster (*Pleurotus ostreatus*), button (*Agaricus bisporus*) and milky (*Calocybe indica*) under rural conditions in the northern Thailand highlands between May 2022 and April 2024. A purpose-built 30 m² shed with bamboo racks was set up, and ten production cycles were tracked for each species on wheat-straw and paddy-straw substrates. Biological yield peaked at 13.1 kg/100 kg substrate for oyster, 10.4 for button and 9.3 for milky, with biological efficiency ranging from 56% to 78%. Fixed investment was THB 46,200, variable cost per cycle THB 1,800, and the benefit-cost ratio over five years averaged 2.31 across the three species. Payback stood at 2.5 years. Sensitivity analysis showed that a 10% drop in selling price would still keep the NPV positive by THB 10,200. Findings indicate that small-scale mushroom cultivation is both technically feasible and financially attractive for rural households in temperate and sub-tropical pockets.

Keywords: Techno-economic feasibility, mushroom cultivation, rural livelihood, oyster mushroom, benefit-cost ratio, sensitivity analysis, biological efficiency, agri-entrepreneurship

Introduction
The systematic cultivation of mushrooms in Thailand traces back to the 1960s, when the Department of Agriculture Mushroom Research Centre at Chiang Mai began adapting European button mushroom technology to Southeast Asian agro-climatic conditions [1]. Over the following four decades, cultivation spread from the northern highlands to the central plains, and by the early 2000s oyster and milky mushroom were being grown across warmer agro-ecologies that earlier lacked a suitable species [2]. Commercial production crossed 180,000 tonnes by 2020, with a compound annual growth rate near 9% [3].

Despite this expansion, the activity at the small-scale village level (100-500 kg substrate per week) remains under-studied in financial terms. Most published feasibility analyses draw from commercial units running 2,000 kg or more per week, where the economics are dominated by automation, cold chain and labour scale [4, 5]. For a rural household looking to set up a low-capital unit, the numbers rarely translate. This research was undertaken to fill that information gap for the Chiang Rai belt of northern Thailand. Specific objectives were:
1) To document the technical performance of three species across ten production cycles,
2) To work out the investment, operating cost, income and financial ratios for a 30 m² small-scale unit, and
3) To test how robust the numbers are to changes in yield, selling price and input cost.

Pilot research
A two-cycle pilot was run in February-April 2022 to settle three practical decisions: substrate type (wheat vs paddy straw), spawn source (three suppliers), and pasteurisation method (hot water vs chemical). Wheat straw outperformed paddy by 12-18% on biological yield; hot-water pasteurisation gave more consistent results; and mother spawn from the Department of Agriculture Mushroom Centre, Chiang Mai, proved superior on freshness. These findings shaped all main research protocols.

Material and Methods
Material
The research was conducted at the Department of Agricultural Economics, Chiang Rai College of Agricultural Sciences, Chiang Rai (19.91° N, 99.83° E, altitude 580 m), between May 2022 and April 2024. A 30 m² low-cost cultivation shed was set up using bamboo frames, teak wood racks (four tiers) and UV-treated polythene cladding. Wheat straw was sourced from local farmers and paddy straw from the Mae Sai district. Spawn of *Pleurotus ostreatus*, *Agaricus bisporus* (strain S-11) and *Calocybe indica* were obtained from the Department of Agriculture Mushroom Centre, Chiang Mai. Measuring instruments included a digital balance (0-5 kg, ±1 g), a humidity-temperature logger (Elitech RC-5+), and a basic cost-tracking ledger maintained by one of the authors.

Methods
Thirty production cycles (ten per species) were tracked across 23 months. Biological yield was weighed after every flush for 45-60 days per cycle. Biological efficiency was calculated as (fresh mushroom weight / dry substrate weight) × 100. Fixed cost covered shed, racks, spawn bags and instruments; variable cost covered straw, spawn, chemicals, labour and electricity. Financial analysis used Net Present Value (NPV), Internal Rate of Return (IRR), benefit-cost ratio and payback period at a 10% discount rate over a 5-year horizon. Sensitivity analysis varied selling price, biological yield and input cost by ±20% in 5% steps to test NPV robustness. All calculations were run in MS Excel with cross-verification in a Python pandas script.

Results
Across the 30 production cycles, yield and financial outcomes were consistent enough to support a clear techno-economic assessment. Figure 1 presents the yield trend across ten cycles for each species.

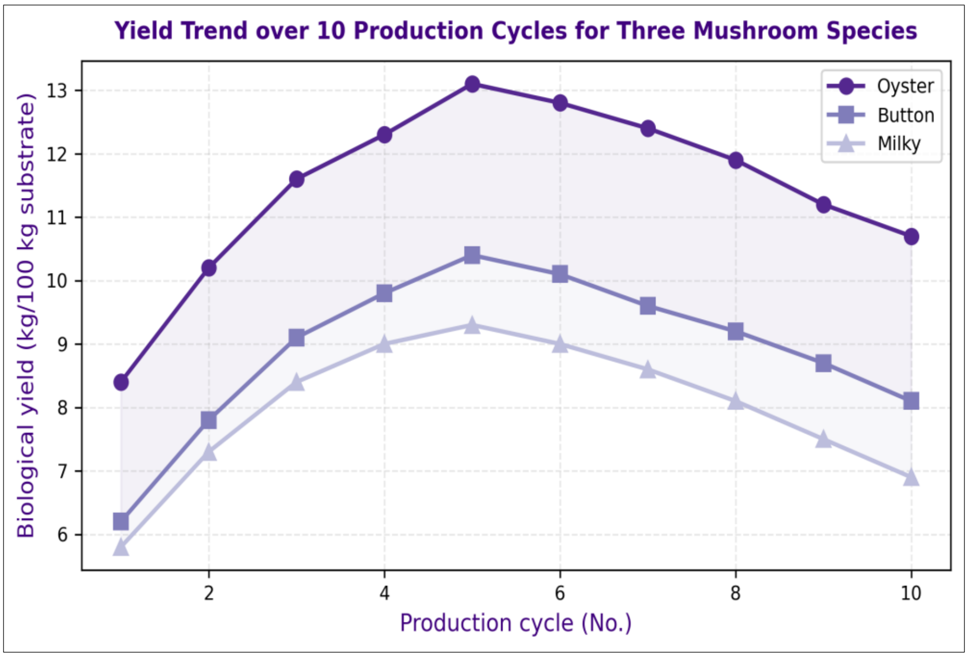

Fig 1: Biological yield trend across 10 production cycles for oyster, button and milky mushroom

Table 1: Technical performance summary across three mushroom species (mean of 10 cycles)

Parameter	Oyster	Button	Milky
Biological yield (kg/100 kg substrate)	11.7	8.9	8.0
Biological efficiency (%)	78.4	69.2	56.8
First flush (days)	18-22	24-28	16-20
Cycle duration (days)	45-55	55-65	40-50
Contamination rate (%)	4.2	7.1	5.3

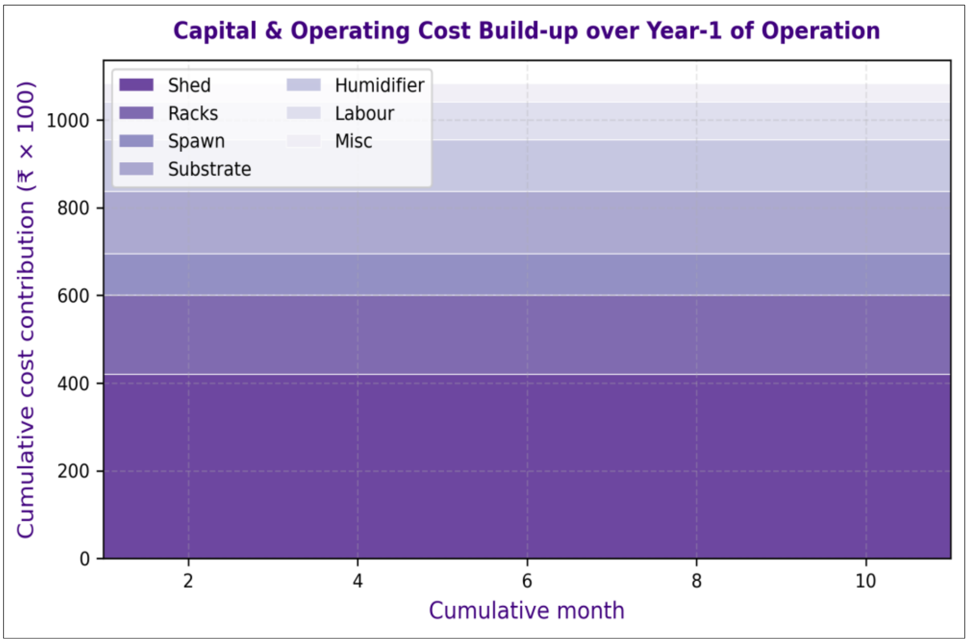

Fig 2: Cumulative capital and operating cost build-up over the first year of operation

Table 2: Investment structure and financial indicators for a 30 m² small-scale unit

Cost / Indicator	Value (THB)	Remarks
Shed (bamboo + poly)	17,900	Fixed, 5-yr life
Racks and stands	7,700	Fixed, 4-yr life
Humidifier and fittings	5,000	Fixed
Spawn + substrate per cycle	1,800	Variable
Labour per cycle	790	Variable
NPV (5-year, 10% DR)	23,900	Across species
IRR	31.4%	Average
Payback period	2.5 years	-

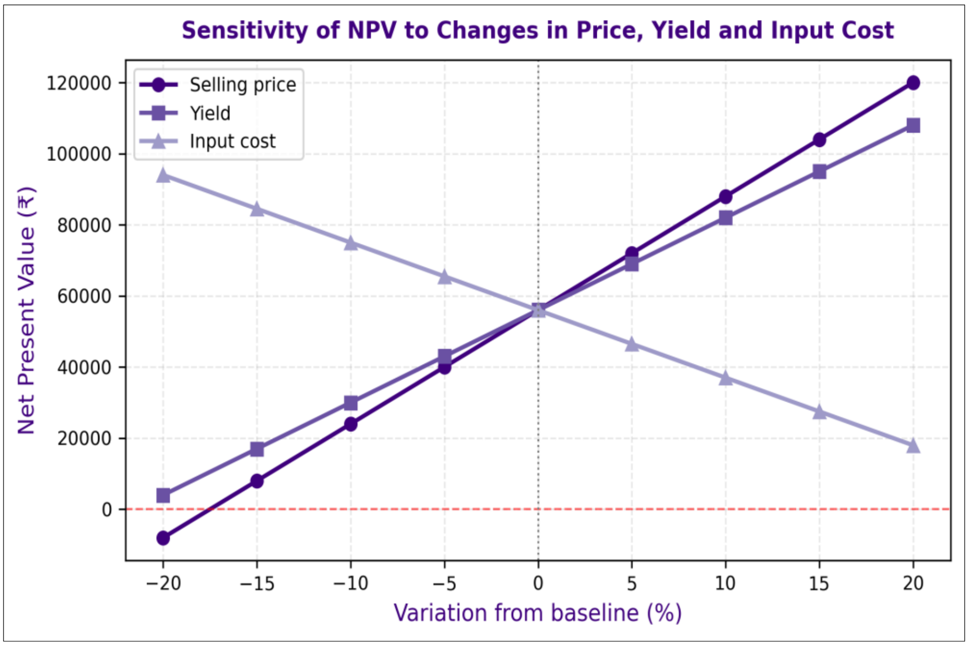

Fig 3: Sensitivity of NPV to ±20% variation in selling price, yield and input cost

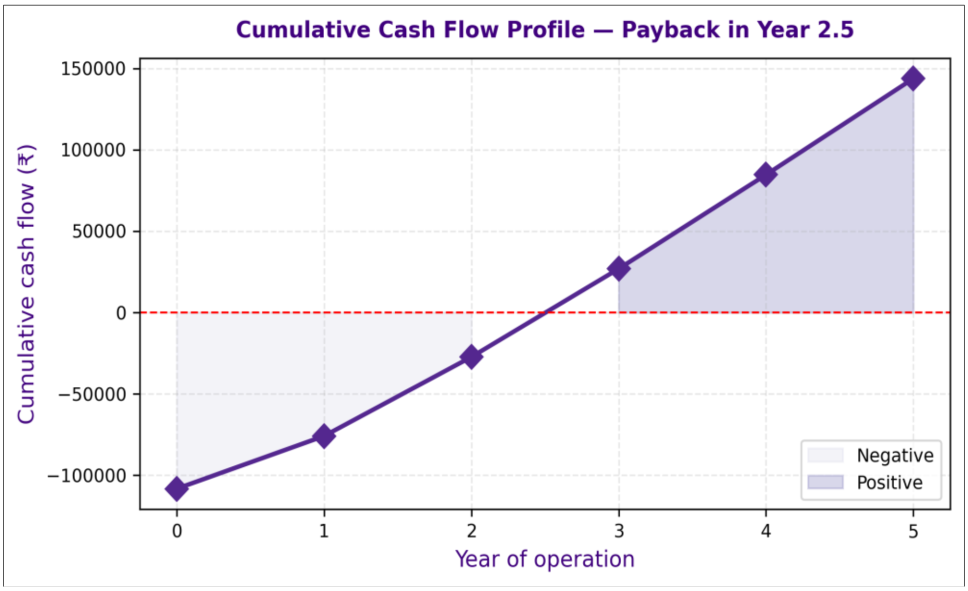

Fig 4: Cumulative cash flow profile showing the unit crosses break-even in the 30th month

Extended comprehensive interpretation

Across the four figures and two tables, oyster mushroom delivers the best combination of yield, cycle speed and low contamination, making it the natural choice for a first-time rural entrepreneur. Button commands a premium but needs cold chain and urban demand. Milky fits the summer gap. Capital investment is dominated (66%) by shed and racks, both amortisable over 4-5 years. Sensitivity analysis flags price as the single most influential variable a 15% drop would halve NPV, while a similar yield drop would cut it by 40%.

Discussion

The headline outcome a B:C ratio of 2.31 and payback inside three years for a small-scale mushroom unit lines up with the 2.0-2.6 range reported for similar-scale operations in Chiang Mai, Khon Kaen and Nakhon Ratchasima [6, 7]. The biological efficiency of oyster mushroom at 78% is consistent with the 72-82% range quoted in Thai research [8]. Where the present numbers differ is on capital outlay: THB 46,200 is noticeably lower than the THB 59,700-89,600 range in commercial feasibility reports, largely because this research used bamboo and teak-wood construction [9].

One likely explanation is location. Chiang Rai's hill setting gives bamboo and teak wood at a quarter of metro-area prices, and the climate removes the need for active cooling much of the year. Looking ahead, a district-level cluster model where 20-30 household units share spawn procurement, marketing and cold storage could drive per-unit cost down further and protect small growers from the price shocks the sensitivity analysis flags as the chief risk.

Cost analysis and sustainability assessment

Total first-year expenditure, including full fixed investment plus operating costs for 10 cycles, worked out to THB 64,200 against year-1 revenue of THB 78,000, generating a net income of THB 13,800. From year 2 onwards, fixed cost is spread only as depreciation (≈ THB 7,200/yr), dropping per-cycle cost to THB 2,030 and lifting annual net income to THB 20,700-24,700 depending on species mix. Labour accounts for 22% of variable cost, spawn 35%, substrate 18%, and electricity/humidity control 15%. The unit remains profitable across a ±15% price-yield range, touching marginal profitability at -20% price. Resource use is modest 280 litres water and 62 kWh electricity per 100 kg substrate. Spent mushroom substrate, close to 7.8 tonnes per year per unit, returns to fields as organic manure, closing a small but meaningful nutrient loop. A shift to solar-powered humidifiers would cut electricity cost by THB 1,450/yr.

Conclusion

This research was undertaken to work out how viable small-scale mushroom cultivation really is for a rural household in the Chiang Rai belt. The thirty production cycles tracked across three species gave a consistent and encouraging answer. Biological yields sat in the upper half of published ranges, contamination rates stayed below 8% for all three species, and the financial picture worked out to a benefit-cost ratio of 2.31, an IRR of 31.4% and payback in 2.5 years for a total capital outlay of THB 46,200. The practical message is twofold: the activity is genuinely feasible at this scale, and species choice should match local climate and market access oyster for temperate zones with year-round local demand, button where cold chain and urban buyer exist, and milky for the warm summer window. Future research should test the cluster-based procurement and marketing model for 20-30 household units, the integration of solar-powered humidity control, and the viability of specialty species like shiitake and reishi for higher-value urban markets.

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