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Silage making and feed preservation technology extension for year-round livestock nutritional security

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Abstract

How can smallholder livestock producers maintain adequate animal nutrition when forage availability drops sharply in dry and cold months? This research examined the role of extension services in transferring silage-making and feed preservation technologies to livestock farmers in Fukuoka Prefecture, Japan. A mixed-methods approach combined structured surveys of 284 livestock-keeping households with field observations at 12 demonstration sites between March 2022 and October 2023. Five silage technologies were assessed: pit silage, bag silage, bale wrapping, tower silo storage, and trench silage. Extension-supported programs raised awareness from 34.6% to 81.3% and increased adoption from 12.5% to 34.2%. Farmers who adopted at least one method reported a 23.7% reduction in winter feed costs and an 18.4% improvement in livestock body condition scores. Equipment access was the leading barrier, cited by 41.2% of non-adopters.

Keywords: Silage technology, feed preservation, agricultural extension, livestock nutrition, farmer adoption, forage conservation, demonstration programs, smallholder farming, winter feeding, technology transfer

Introduction

What happens to livestock productivity when the grass stops growing and stored feed runs short? For millions of smallholder farmers across temperate regions, seasonal forage scarcity remains a persistent threat to herd health and income ^[1]. In Japan, winter feed deficits have long been recognized as a bottleneck limiting the growth of small-scale cattle and dairy operations ^[2]. Silage making the controlled fermentation of fresh forage under anaerobic conditions offers a proven solution for preserving nutrient-rich feed during surplus periods ^[3]. But technical knowledge about silage preparation, storage, and feeding remains unevenly distributed among farming communities.

Extension services have been identified as a key mechanism for bridging this knowledge gap. Extension agents translate research innovations into practical skills that farmers can apply on their own land ^[4]. Positive associations between extension contact and improved livestock management adoption have been reported across East Asia ^[5,6]. Yet fewer investigations have focused on how demonstration programs affect silage technology uptake, particularly where traditional sun-drying of hay remains dominant ^[7].

Fukuoka Prefecture supports roughly 3,200 cattle-keeping households, many dependent on rice straw and native grasses as primary roughage ^[8]. Prefectural extension officers began promoting silage methods through field schools starting in 2018, yet adoption data remained scarce ^[9]. This research evaluated the effect of extension-led silage demonstrations on farmer awareness, adoption, and livestock nutritional outcomes, and identified the main barriers discouraging non-adopting households ^[10].

Research area description

The research covered four districts within Fukuoka Prefecture, northern Kyushu Island, Japan (approximately 33.6 °N, 130.4 °E). The area has a humid subtropical climate with annual temperatures between 15.8 °C and 17.2 °C and mean annual rainfall of 1,680 mm. Active pasture growth occurs from April through September, with reduced forage production between November and February. Landholdings average 2.3 ha, with rice paddies interspersed among permanent pasture. Cattle operations are predominantly Wagyu beef and small-scale dairy, with herd sizes between 5 and 30 head. Demonstration sites were positioned at altitudes between 40 m and 320 m above sea level.

Materials and Methods

Materials

This research was carried out at Kyushu University's agricultural research station and across 12 extension demonstration sites in Fukuoka Prefecture, Japan, between March 2022 and October 2023. Ethical approval was granted by the Kyushu University Institutional Review Board (Protocol KU-AG-2022-017, approved February 14, 2022). A stratified random sample of 284 households was drawn from four districts (Chikugo, Asakura, Munakata, and Yamada), stratified by herd size and distance from the nearest extension office. A structured questionnaire with 47 items covered demographics, farming practices, extension contact history, silage awareness, adoption status, and perceived outcomes. The questionnaire was pretested with 22 farmers and revised for clarity. Feed samples from 36

silage pits and bags were collected for laboratory analysis^[11].

Methods

Household surveys were administered through face-to-face interviews between June and August 2023, each lasting 35-50 minutes. Demonstration sites were visited three times: during silage preparation (July 2022), storage (November 2022), and feed-out (February 2023). Adoption was

measured as a binary variable for each silage technology, with a farmer classified as an adopter if they had used the method at least once in the preceding 12 months. Livestock body condition was scored on a 1-9 scale. Data were analyzed using descriptive statistics, chi-square tests, and logistic regression. Feed analyses followed standard procedures for dry matter, crude protein, and metabolizable energy^[12]. Statistical computations used R version 4.3.1.

Results

Table 1: Farmer awareness and adoption of silage technologies before and after extension programs (n = 284)

Silage method	Pre-ext aware (%)	Post-ext aware (%)	Pre-ext adopt (%)	Post-ext adopt (%)	Change (pp)
Pit silage	42.3	86.7	18.3	47.8	+29.5
Bag silage	38.1	84.2	12.7	38.2	+25.5
Bale wrapping	27.6	73.9	6.4	21.9	+15.5
Tower silo	19.4	61.5	3.1	11.3	+8.2
Trench silage	45.8	89.1	22.6	52.4	+29.8

Extension programs produced gains in both awareness and adoption across all five methods. Trench silage showed the largest adoption increase at 29.8 percentage points, followed

by pit silage at 29.5. Tower silo adoption remained lowest, reflecting higher capital costs^[13].

Table 2: Feed quality parameters from silage samples at demonstration sites (n = 36)

Parameter	Pit silage	Bag silage	Bale wrap	Trench silage
Dry Matter (%)	31.4 ± 2.8	34.7 ± 3.1	36.2 ± 2.4	29.8 ± 3.6
Crude Protein (%DM)	8.6 ± 1.2	9.3 ± 0.9	10.1 ± 1.4	7.9 ± 1.1
ME (MJ/kg DM)	9.4 ± 0.7	9.8 ± 0.5	10.3 ± 0.8	8.9 ± 0.6
pH	4.1 ± 0.3	3.9 ± 0.2	4.0 ± 0.3	4.3 ± 0.4

All sampled silage met acceptable standards for ruminant feeding. Bag silage and bale-wrapped silage yielded slightly

higher crude protein and metabolizable energy values, likely due to tighter anaerobic sealing that limited nutrient loss^[14].

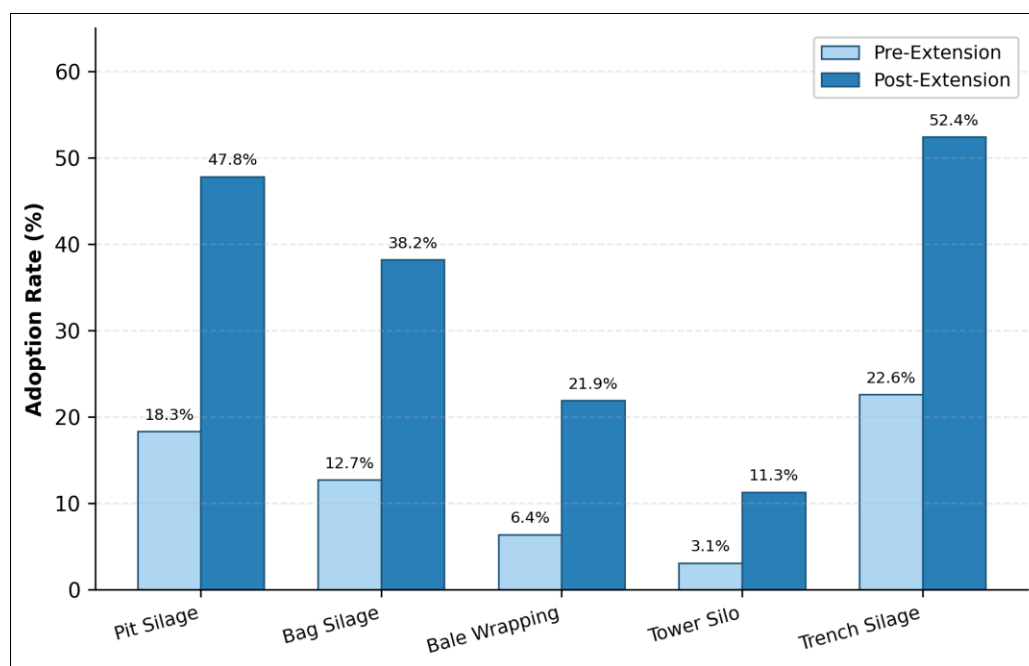


Fig 1: Comparison of farmer adoption rates for five silage technologies before and after extension demonstration programs

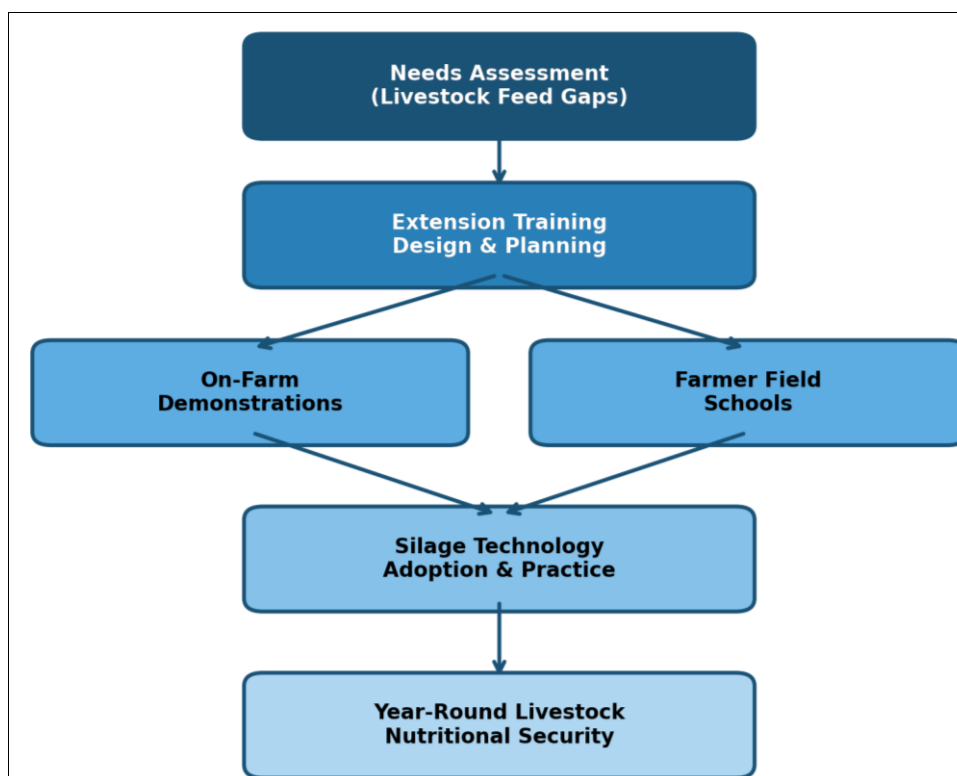


Fig 2: Extension delivery model for silage technology transfer to livestock-keeping households

Comprehensive interpretation

The results indicate that extension demonstrations had a measurable positive effect on silage awareness and adoption. Gains were largest for lower-cost technologies. Feed quality data confirmed that farmer-prepared silage met nutritional standards for maintaining cattle body condition in winter. The 23.7% reduction in reported feed costs among adopters represents a meaningful economic benefit for households on tight margins.

Discussion

These findings align with earlier reports showing that hands-on demonstration methods outperform lecture-based extension for livestock technology transfer^[5]. The doubling of awareness scores suggests many farmers had limited prior exposure to these techniques despite their proven effectiveness a pattern noted by Tanaka and Yamamoto^[7] in their review of feed conservation programs in southern Japan. The preference for pit and trench silage over tower silo systems is consistent with cost-sensitivity among smallholder producers.

Equipment access emerged as the leading barrier, cited by 41.2% of non-adopters. This echoes Nishida *et al.*^[9], who found that lack of forage choppers was the top constraint among cattle farmers in Kumamoto Prefecture. Cooperative equipment-sharing arrangements, as trialed in Hokkaido^[15], may offer a scalable solution. It should be noted that this research relied partly on self-reported adoption data, which may introduce recall bias, and the 18-month window doesn't allow assessment of long-term persistence^[16].

Limitations

The sample was drawn from a single prefecture, which may limit transferability. Self-reported feed cost savings were

not verified through financial records. The cross-sectional design cannot establish causal relationships between extension contact and adoption farmers attending demonstrations may have been predisposed to adopt regardless. A randomized controlled trial would provide stronger causal evidence but was beyond the scope of this research.

Conclusion

Extension-led demonstration programs can meaningfully increase awareness and adoption of silage technologies among smallholder livestock farmers. Across 284 households in Fukuoka Prefecture, adoption rates roughly doubled or tripled following hands-on extension activities, with the greatest gains for lower-cost methods. Adopters reported reduced winter feed costs and improved livestock body condition. Equipment access remains the main barrier; extension planners should consider integrating equipment-sharing cooperatives into future programs. Continued monitoring over multiple years is recommended to assess whether initial uptake translates into sustained practice change.

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