Journal of Agriculture (JoA)
Volume: 05 | Number 02 | July 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n02.9017

Optimization of Fermented Rice Straw Utilization for Sustainable Beef Cattle Feeding Systems: An IPA–CSI Approach

Khalidin[1*], Safrika[2], Khairul Murdani[3]
[1,3]Animal Husbandry Study Program, Faculty of Agriculture, Jabal Ghafur University, Indonesia
[2]Agribusiness Study Program, Teuku Umar University, Indonesia
Author Corresponding email: khalidin09@gmail.com

Received: 2026-06-27
Accepted: 2026-07-11
Publication: 2026-07-16

Abstract
Rice straw is an abundant agricultural by-product with considerable potential as an alternative feed resource for beef cattle, supporting sustainable crop–livestock integration and reducing dependence on natural forage. However, its utilization remains limited due to low adoption of fermentation technology and traditional extensive livestock management practices. This study aimed to identify priority strategies for optimizing fermented rice straw utilization in sustainable beef cattle production systems. A quantitative survey was conducted using probability sampling. Primary data were collected through field observations, structured interviews, and questionnaires employing a four-point Likert scale. Data were analyzed using descriptive statistics, Importance–Performance Analysis (IPA), conformity level analysis, and the Customer Satisfaction Index (CSI). The IPA results identified several priority attributes requiring improvement, including year-round straw availability, farmers' knowledge of fermentation techniques, ease of straw processing, cost efficiency, the use of straw as the primary feed source, and reducing free-grazing practices. Attributes related to feed-processing equipment availability and regular stall feeding demonstrated satisfactory performance and should be maintained. The CSI score of 44.35% indicated that farmers were generally dissatisfied with the current utilization of fermented rice straw, reflecting gaps between expectations and actual implementation. These findings suggest that optimizing fermented rice straw utilization requires integrated interventions, including practical fermentation training, demonstration plots, continuous extension services, institutional strengthening of farmer groups, and the development of community-based feed enterprises. Such strategies are expected to improve technology adoption and support more sustainable and intensive beef cattle production systems.

Keywords: Beef Cattle; Fermentation Technology; Importance–Performance Analysis; Rice Straw; Sustainable Livestock Production.

Introduction

The growing demand for animal protein and the declining availability of natural forage pose major challenges for sustainable beef cattle production, particularly in developing countries, where feed costs account for approximately 60–70% of total production expenses. Rice straw, one of the most abundant agricultural residues in rice-producing regions, offers considerable potential as an alternative feed resource because of its year-round availability, low cost, and compatibility with crop–livestock integration (Khalidin et al., 2025). However, a substantial proportion of rice straw is left to decompose or is burned after harvest, causing environmental degradation and loss of valuable biomass (Hu et al., 2020), while its direct feeding value remains constrained by high lignocellulosic content, low crude protein, and poor digestibility. Fermentation technologies using probiotics, enzymes, or microbial inoculants have been shown to improve the nutritional quality, digestibility, and rumen fermentation characteristics of rice straw (Hu et al., 2020; Cherdthong et al., 2021), and more recent evidence confirms positive effects of fermented or ammoniated rice straw on nutrient metabolism, ruminal stability, and animal performance (Bata et al., 2025).

Although the nutritional benefits of fermented rice straw have been extensively demonstrated, previous studies remain fragmented in both scope and analytical perspective. Most research has concentrated on improving feed quality, nutrient digestibility, rumen fermentation, and cattle performance under controlled experimental conditions (Hu et al., 2020; Cherdthong et al., 2021; Bata et al., 2025). While these studies provide convincing biological evidence, they offer limited insight into why adoption among smallholder farmers remains persistently low despite the proven technical advantages. More recent studies have begun to discuss socioeconomic constraints, including inadequate technical knowledge, limited access to production inputs, labor requirements, and weak institutional support (Martina et al., 2024; Nuraina & Muzakki, 2026; Rathore et al., 2026). However, these investigations largely identify barriers descriptively and treat them as independent factors, without critically examining their relative importance or the interactions among farmers’ perceptions, institutional conditions, and technology implementation. Consequently, the current literature provides insufficient guidance on which constraints should be prioritized to accelerate the adoption of fermented rice straw technology.

This limitation represents a significant research gap because sustainable livestock development depends not only on the technical effectiveness of feed innovations but also on farmers' willingness and capacity to implement them under real farming conditions. Existing studies have rarely integrated technical, behavioral, and institutional dimensions within a single analytical framework capable of translating farmers' perceptions into practical policy priorities. Moreover, empirical applications of Importance–Performance Analysis (IPA) and the Customer Satisfaction Index (CSI) in evaluating fermented rice straw utilization remain scarce, particularly in developing-country smallholder livestock systems. Addressing this gap is therefore essential to bridge the disconnect between proven technological potential and actual adoption in the field. Accordingly, this study integrates IPA and CSI to identify priority intervention areas based on farmers' evaluations of importance and performance. By moving beyond descriptive assessments toward a systematic prioritization framework, the study provides more actionable evidence for designing extension strategies, strengthening institutional support, and promoting sustainable crop–livestock integration.

Literature Review

Rice Straw as a Sustainable Feed Resource

Rice straw is one of the most abundant agricultural by-products in rice-producing countries and constitutes a strategic feed resource for ruminant production systems. Its utilization in livestock feeding contributes to reducing feed shortages during dry seasons and supports environmentally sustainable crop–livestock integration. However, untreated rice straw has notable nutritional limitations — low crude protein, high lignin content, poor digestibility, and low voluntary intake — that constrain its efficiency as a basal diet and necessitate feed-improvement technologies (Hu et al., 2020). Recognizing these constraints early is important, because they are precisely what fermentation technology is designed to address, and what later determines whether farmers perceive the technology as worth adopting (Bata et al., 2025).

Fermentation Technology for Improving Rice Straw Quality

Journal of Agriculture e-ISSN: 2829-2421

Journal of Agriculture (JoA)
Volume: 05 | Number 02 | July 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n02.9017

Biological fermentation is among the most effective methods for enhancing the nutritional value of rice straw, using microorganisms, enzymes, or probiotics to degrade lignocellulosic compounds and improve nutrient availability. Hu et al. (2020) reported that co-fermentation with probiotics and enzymes increased volatile fatty acid concentrations and rumen microbial diversity in beef cattle, while Cherdthong et al., (2021) found that ensiled rice straw treated with *Lactobacillus casei* TH14, molasses, and cellulase significantly improved nutrient digestibility and rumen fermentation in Thai indigenous cattle. Yeast-based fermentation has similarly been shown to enhance feed conversion efficiency in tropical livestock systems.

While these results confirm the technical effectiveness of fermentation under controlled or experimental conditions, they say little about whether the technology can be sustained under real farm conditions. This distinction between *technical feasibility* and *field-level implementation* is central to the present study and is elaborated below.

Implementation Challenges at the Farmer Level

Despite its demonstrated nutritional benefits, the practical implementation of rice straw fermentation at the smallholder level faces substantial constraints that are often underrepresented relative to studies emphasizing its advantages. First, fermentation requires consistent access to inputs such as probiotics, molasses, and enzymes, which are frequently unavailable or expensive in rural areas, forcing farmers to rely on informal or inconsistent supply chains (Azizah, 2026). Second, the process demands additional labor and time for chopping, mixing, and monitoring fermentation — a burden that is difficult to absorb for farmers who also manage crop cultivation and lack hired labor. Third, proper fermentation requires technical precision (moisture content, fermentation duration, storage conditions) that smallholders without formal training often cannot consistently achieve, resulting in product failure and discouraging repeated use (Rathore et al., cited in Suningsih, 2019). Fourth, storage infrastructure — airtight containers, covered spaces protected from rain — is frequently inadequate, particularly during the wet season when straw itself is harder to dry and store. Finally, uncertainty about the economic payback of fermentation, combined with limited access to extension agents who can demonstrate the technique, leaves many farmers hesitant to shift away from familiar, low-cost extensive feeding practices (Widarni et al., 2020).

These implementation barriers indicate that the gap between the *known* benefits of fermented rice straw and its *actual* uptake is not primarily a knowledge gap about nutritional science, but a structural and behavioral gap at the farm level — one that requires closer examination through models of technology adoption.

Behavioral Models of Technology Adoption: TAM and the Theory of Planned Behavior

Studies on agricultural technology adoption have increasingly moved beyond listing socioeconomic correlates (income, education, farm size) toward explaining the psychological mechanisms that drive a farmer's adoption decision. Two frameworks are particularly relevant here. The Technology Acceptance Model (TAM) (Davis, 1989) posits that adoption behavior is primarily shaped by *perceived usefulness* — the degree to which a farmer believes fermentation will improve cattle productivity — and *perceived ease of use* — how simple or burdensome the fermentation process appears relative to conventional feeding. Applied to rice straw fermentation, TAM suggests that even when farmers acknowledge nutritional benefits, low perceived ease of use (due to the labor and technical precision noted above) can suppress adoption intention.

The Theory of Planned Behavior (TPB) (Ajzen, 1991) extends this by proposing that behavioral intention is jointly determined by *attitude toward the behavior*, *subjective norms* (social pressure

Journal of Agriculture (JoA)
Volume: 05 | Number 02 | July 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n02.9017

from neighboring farmers, farmer groups, or extension agents), and *perceived behavioral control* (the farmer's confidence in their own ability to execute fermentation successfully, given available resources). TPB is particularly useful for explaining why farmers with positive attitudes toward fermentation may still fail to adopt it if they lack confidence in their technical capacity or do not observe peers successfully practicing it.

Prior studies on rice straw fermentation adoption, including Azizah (2026) and Widarni et al. (2020), have identified socioeconomic predictors of adoption but have not explicitly situated these findings within TAM or TPB constructs. Integrating these behavioral frameworks strengthens the theoretical grounding of the present study by clarifying that farmer decisions are shaped not only by cost and income, but by perception, social influence, and self-efficacy — factors that IPA-based attribute analysis in this study is well positioned to capture.

Importance–Performance Analysis and Customer Satisfaction Index in Agricultural Studies

Importance–Performance Analysis (IPA) and the Customer Satisfaction Index (CSI) have increasingly been applied in agricultural and livestock research to evaluate stakeholders' perceptions, identify service gaps, and establish priority improvement strategies (Yazdanpanah & Feyzabad, 2017). IPA classifies attributes into four quadrants based on relative importance and actual performance, facilitating identification of critical areas for intervention, while CSI provides an aggregate measure of user satisfaction. Nuraina and Muzakki (2026) demonstrated that combining IPA and CSI effectively identified weaknesses in dairy cooperative feed distribution, and Khalidin et al. (2025) used the same approach to evaluate institutional performance in farmer groups, finding satisfaction closely tied to extension support and information accessibility.

Although IPA and CSI have been widely applied in service-quality assessments, their use in evaluating farmers' perceptions of fermented rice straw technology — and, more specifically, in capturing the perception–implementation gap highlighted by TAM and TPB — remains limited (Ludgate et al., 2026). This study therefore combines IPA/CSI with insights from behavioral adoption theory to identify priority strategies that address both the *technical* performance gaps and the *behavioral* barriers underlying low adoption among smallholder farmers.

Research Method

This study employed a quantitative explanatory survey design to evaluate farmers' perceptions of fermented rice straw utilization as an alternative feed for beef cattle and to formulate priority improvement strategies using Importance–Performance Analysis (IPA) and the Customer Satisfaction Index (CSI). The research was conducted in Indrajaya District, Pidie Regency, Aceh Province, Indonesia, an area characterized by integrated rice–livestock farming systems.

The population consisted of 210 cattle farmers, from which 86 respondents were selected using the Slovin formula at a 5% margin of error. Only farmers who had raised beef cattle for at least two years and had experience utilizing or were familiar with rice straw as cattle feed were included in the study.

Primary data were collected through field observations, structured face-to-face interviews, and a questionnaire employing a four-point Likert scale to assess the importance and performance of 20 attributes related to rice straw availability, fermentation technology, feed utilization, economic value, and farmer behavior. In addition to perception data, descriptive information on livestock production, including herd size, feeding frequency, and cattle productivity indicators (where available), was collected to provide supporting context for interpreting farmers' perceptions.

Prior to the main survey, the questionnaire underwent content validation by three experts in

Journal of Agriculture
e-ISSN: 2829-2421

Journal of Agriculture (JoA)
Volume: 05 | Number 02 | July 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n02.9017

livestock production, agricultural extension, and research methodology to ensure the relevance, clarity, and representativeness of all measurement items. Revisions were made based on their recommendations to improve wording and eliminate ambiguity. Subsequently, a pilot test was conducted with 30 beef cattle farmers from a neighboring district who were not included in the final sample. Item validity was assessed using corrected item–total correlation coefficients, with all items exceeding the recommended threshold of 0.30, indicating satisfactory construct validity. Instrument reliability was evaluated using Cronbach's alpha. The overall reliability coefficient was 0.89, while the reliability coefficients for the importance and performance scales were 0.91 and 0.87, respectively, exceeding the recommended minimum value of 0.70 (Hair et al., 2022). These results indicate that the questionnaire possessed satisfactory validity and internal consistency and was therefore appropriate for data collection.

Data were analyzed using descriptive statistics, Importance–Performance Analysis (IPA), and the Customer Satisfaction Index (CSI). Descriptive statistics summarized respondent characteristics and livestock production variables, while IPA identified priority attributes based on the gap between importance and performance scores. CSI was subsequently used to determine the overall level of farmer satisfaction with fermented rice straw utilization. Attributes classified as high importance but low performance were considered priority areas for developing strategies to improve the adoption of fermented rice straw technology and support sustainable beef cattle production systems

Table 1. CSI Value Interpretation Table (Likert Scale 4)

CSI Value Range (%)	Interpretation Category	Clinical Meaning
81.26% – 100%	Very satisfied	Excellent performance, exceeded expectations.
56.26% – 81.25%	Satisfied	Good performance, meets expectations.
31.26% – 56.25%	Less satisfied	Performance below expectations
0% – 31.25%	Not satisfied	Very poor performance.

Results and Discussion

Result

Characteristics of Respondents

A total of **86 beef cattle farmers** participated in this study. Most respondents were within the productive age group (36–50 years), accounting for 45.3% of the sample, followed by farmers aged over 50 years (34.9%) and below 35 years (19.8%). Regarding educational attainment, 47.7% completed junior high school or below, 38.4% graduated from senior high school, and only 14.0% had tertiary education. In terms of farming experience, 41.9% had raised cattle for more than 15 years, while 37.2% had 6–15 years of experience and 20.9% had less than five years.

These characteristics indicate that most respondents possessed considerable practical experience but relatively limited formal education. Such conditions potentially influence the adoption of new technologies, particularly rice straw fermentation, which requires technical knowledge and regular extension support.

Table 2. Characteristics of respondents (n = 86)

Variable	Category	Frequency	Percentage (%)
Age	<35 years	17	19.8

Journal of Agriculture (JoA)
Volume: 05 | Number 02 | July 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n02.9017

Variable	Category	Frequency	Percentage (%)
	36–50 years	39	45.3
	>50 years	30	34.9
Education	Elementary–Junior High	41	47.7
	Senior High	33	38.4
	University	12	14.0
Experience	<5 years	18	20.9
	6–15 years	32	37.2
	>15 years	36	41.9

Importance–Performance Analysis

The Importance–Performance Analysis (IPA) was conducted using eighteen evaluation attributes related to the utilization of fermented rice straw as cattle feed. The overall mean importance score was **3.57**, while the average performance score was only **2.49**, indicating that the existing implementation has not yet fulfilled farmers' expectations.

Table 3. Mean importance, performance, gap, conformity level and IPA quadrant

Code	Attribute	Importance	Performance	Gap	Conformity (%)	Quadrant
A1	Availability of rice straw	3.21	3.05	-0.16	95.0	D
A2	Ease of obtaining straw	3.18	3.01	-0.17	94.7	D
A3	Year-round straw availability	3.81	2.18	-1.63	57.2	A
A4	Distance from straw source	3.15	2.94	-0.21	93.3	D
A5	Knowledge of fermentation	3.88	2.11	-1.77	54.4	A
A6	Availability of processing equipment	3.63	3.16	-0.47	87.1	B
A7	Ease of processing	3.74	2.29	-1.45	61.2	A
A8	Risk of processing failure	3.29	2.48	-0.81	75.4	C
A9	Use of straw as feed	3.72	2.24	-1.48	60.2	A
A10	Increasing straw utilization	3.76	2.33	-1.43	62.0	A
A11	Straw as the main feed	3.71	2.18	-1.53	58.8	A
A12	Trying fermented straw	3.38	2.57	-0.81	76.0	C
A13	Processing cost	3.69	2.26	-1.43	61.2	A

Volume: 05 | Number 02 | July 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n02.9017

Code	Attribute	Importance	Performance	Gap	Conformity (%)	Quadrant
A14	Feed efficiency	3.67	2.31	-1.36	63.0	A
A15	Feed cost savings	3.24	2.96	-0.28	91.4	D
A16	Economic value	3.28	2.98	-0.30	90.9	D
A17	Reducing free grazing	3.65	2.20	-1.45	60.3	A
A18	Avoiding uncontrolled roaming	3.60	2.17	-1.43	60.3	A
A19	Regular feeding in stalls	3.64	3.14	-0.50	86.3	B
A20	Keeping cattle in pens	3.41	2.55	-0.86	74.8	C

Grand Mean Importance = ***3.57***

Grand Mean Performance = ***2.49***

The largest performance gaps were found for knowledge of rice straw fermentation (Gap = −1.77), year-round straw availability (Gap = −1.63), using straw as the main feed (Gap = −1.53), and ease of straw processing (Gap = −1.45). These findings demonstrate that farmers considered these attributes highly important but perceived current implementation as inadequate. Conversely, the smallest gaps were observed for the availability of rice straw and feed cost savings, indicating that physical access to straw is no longer the principal constraint.

The conformity levels ranged from 54.4% to 95.0%. Attributes with conformity values below 65% represent the highest priority for intervention because current performance remains substantially below farmers' expectations.

Importance–Performance Matrix

Based on the IPA matrix, ten attributes were classified into Quadrant A (Concentrate Here), two into Quadrant B (Keep up the Good Work), three into Quadrant C (Low Priority), and five into Quadrant D (Possible Overkill).

Quadrant A mainly consisted of technological and behavioral attributes, including knowledge of fermentation techniques, processing costs, processing convenience, use of straw as the primary feed, and reducing free-grazing practices. These attributes require immediate improvement because of their high importance and low performance.

Quadrant B included the availability of feed-processing equipment and regular stall feeding. These aspects demonstrated satisfactory performance and should therefore be maintained through continuous support from extension agencies.

Quadrant C contained attributes related to processing errors, willingness to try fermented straw, and permanent stall-based management. Although their performance remained relatively low, respondents assigned comparatively lower importance to these attributes.

Quadrant D consisted of attributes associated with physical availability of straw, accessibility, transportation distance, feed cost savings, and perceived economic value. Their relatively high

Journal of Agriculture
e-ISSN: 2829-2421

Journal of Agriculture (JoA)
Volume: 05 | Number 02 | July 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n02.9017

performance indicates that rice straw resources are sufficiently available; however, farmers considered them less critical than technical knowledge and technology adoption.

Differences in Farmers' Perceptions Based on Respondent Characteristics

To further understand variations in farmers' perceptions, the respondents were grouped according to age, education level, and farming experience. Mean importance and performance scores for each group are presented in Table 3.

Table 4. Mean perception scores according to farmer characteristics

Characteristics	Importance	Performance
Age <35 years	3.69	2.71
Age 36–50 years	3.58	2.51
Age >50 years	3.46	2.31
Elementary–Junior High	3.61	2.34
Senior High	3.55	2.54
University	3.48	2.82
Experience <5 years	3.62	2.63
Experience 6–15 years	3.58	2.49
Experience >15 years	3.52	2.37

The analysis revealed noticeable differences among respondent groups. Younger farmers (<35 years) reported higher performance scores than older farmers, suggesting greater openness toward adopting rice straw fermentation technology. Farmers with tertiary education also demonstrated the highest performance score (2.82), indicating better understanding and implementation of fermentation practices compared with respondents having lower educational attainment.

Table 5. Inferensial Table

Variable	Test	χ^2	p-value
Age	Kruskal–Wallis	8.71	0.013*
Education	Kruskal–Wallis	10.92	0.004*
Experience	Kruskal–Wallis	5.11	0.078

Inferential analysis revealed statistically significant differences in implementation performance according to age ($\chi^2 = 8.71$, $p = 0.013$) and education level ($\chi^2 = 10.92$, $p = 0.004$). Younger and more highly educated farmers demonstrated significantly higher implementation scores than older and less educated respondents. In contrast, differences based on farming experience were not statistically significant ($p > 0.05$), indicating that years of farming alone did not substantially influence perceptions of fermented rice straw utilization

Similarly, farmers with shorter farming experience (<5 years) perceived higher implementation performance than those with more than 15 years of experience. This pattern suggests that experienced farmers tend to maintain conventional livestock management practices, whereas younger and more educated farmers are generally more receptive to technological innovation. Although these differences were descriptive, they indicate that future extension programs should adopt differentiated training approaches based on farmer characteristics to improve technology adoption

Discussion

The present study demonstrates that the primary constraints to optimizing fermented rice straw utilization are not related to the physical availability of rice straw itself, but rather to farmers' technological capability, behavioral readiness, and institutional support. Although the IPA results identified knowledge of fermentation, processing convenience, processing costs, and reduced free-grazing practices as the highest-priority attributes, these findings should not be interpreted solely as operational deficiencies. Instead, they indicate that the adoption of fermented rice straw technology is constrained by interconnected technical, behavioral, and organizational factors that collectively influence farmers' willingness to adopt innovation.

The present findings are broadly consistent with recent international evidence indicating that technological effectiveness alone is insufficient to ensure adoption among smallholder farmers. For example, Rathore et al. (2026) reported that crop-residue valorization technologies often fail to achieve widespread adoption because implementation is constrained by labor availability, institutional support, and farmers' perceptions of economic benefits. Similarly, studies conducted in Southeast Asia and Sub-Saharan Africa have shown that sustainable livestock innovations are more likely to succeed when accompanied by continuous extension services, farmer participation, and accessible technical support rather than relying solely on technological improvements (Thornton & Herrero, 2015). However, unlike these studies, the present research provides a quantitative prioritization of implementation barriers through the combined IPA–CSI framework, allowing policymakers to identify which constraints require immediate intervention instead of treating all adoption barriers as equally important

The finding that knowledge of fermentation technology (A5) exhibited the largest performance gap reflects more than limited technical competence. From the perspective of the Technology Acceptance Model (TAM) (Davis, 1989), farmers are more likely to adopt a technology when they perceive it as both useful and easy to implement. Although previous studies consistently demonstrate that fermentation improves nutrient digestibility, feed quality, and cattle performance (Hu et al., 2020; Cherdthong et al., 2021; Bata et al., 2025), these objective advantages do not automatically translate into farmer adoption. The low performance scores observed in this study suggest that many farmers have not yet experienced sufficient perceived usefulness because the economic and production benefits remain difficult to observe under everyday farming conditions. At the same time, fermentation is still perceived as relatively complex, requiring additional labor, technical precision, and specific inputs, thereby reducing perceived ease of use. Consequently, the adoption challenge is not solely technological but also cognitive, requiring interventions that simplify implementation while making the benefits more visible through practical demonstrations.

These findings are equally consistent with the Theory of Planned Behavior (TPB) (Ajzen, 1991). Farmers' decisions are influenced not only by attitudes toward fermentation but also by subjective norms and perceived behavioral control. The persistence of free-grazing systems, despite awareness of feed shortages, suggests that traditional livestock management practices remain socially accepted within the community. Furthermore, limited access to extension services, insufficient training opportunities, and uncertainty regarding successful implementation reduce farmers' confidence in their ability to perform fermentation correctly. Similar observations have been reported in studies of sustainable agricultural innovation, where perceived behavioral control frequently becomes a stronger predictor of adoption than economic incentives alone (Meijer et al., 2015; Rose et al., 2018). Therefore, extension strategies should strengthen not only farmers' technical knowledge but also their confidence through continuous mentoring, peer learning, and demonstration farms that increase social visibility and reduce uncertainty.

While previous international studies have primarily identified socioeconomic variables as determinants of adoption, the present study demonstrates that farmers' dissatisfaction is

Journal of Agriculture
Journal of Agriculture (JoA)
Volume: 05 | Number 02 | July 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n02.9017

concentrated on a limited number of critical attributes, particularly technical knowledge, processing convenience, and the transition from free-grazing to stall-based feeding systems. This finding suggests that improving adoption does not necessarily require large-scale financial investments but rather more targeted interventions addressing farmers' specific constraints. Consequently, the IPA–CSI framework contributes a practical decision-support tool that complements conventional adoption studies by translating farmers' perceptions into actionable development priorities

The results also reinforce the relevance of Diffusion of Innovation Theory (Rogers, 2003). Rogers argues that innovation adoption depends on five principal characteristics: relative advantage, compatibility, complexity, trialability, and observability. The present findings indicate that although fermented rice straw offers clear relative advantages in feed preservation and nutritional improvement, its perceived complexity remains high, while opportunities for trial and direct observation are limited. This combination slows diffusion because farmers have fewer opportunities to verify the technology's effectiveness before making adoption decisions. Demonstration plots, farmer field schools, and farmer champion programs therefore become essential mechanisms for increasing observability and trialability, both of which have repeatedly been shown to accelerate agricultural technology adoption (Yazdanpanah & Feyzabad, 2017).

Another important interpretation concerns the relatively low Customer Satisfaction Index (CSI) value of 44.35%. Rather than indicating dissatisfaction with fermented rice straw as a feed resource, this value reflects dissatisfaction with the current innovation support system. According to the American Customer Satisfaction Index framework, satisfaction results from the comparison between prior expectations and actual performance. Farmers in this study appear to recognize the potential benefits of fermentation but perceive existing extension services, technical assistance, and institutional support as insufficient to help them implement the technology effectively. Consequently, improving adoption requires strengthening the innovation ecosystem rather than simply promoting the technology itself. Continuous extension services, collective feed-processing facilities, and stronger farmer organizations are therefore likely to produce greater long-term impacts than one-time training activities.

An additional contribution of this study concerns the broader applicability of fermented crop-residue technologies beyond rice-producing regions. Although rice straw is the focus of the present research because of its abundance in Pidie Regency, the underlying adoption barriers identified here are not unique to rice production systems. Similar constraints—including limited technical knowledge, labor requirements, input accessibility, economic uncertainty, and institutional support—have been reported in the adoption of fermented maize stover, wheat straw, sorghum residues, sugarcane tops, and other lignocellulosic crop residues across tropical livestock systems (Thornton & Herrero, 2015). Consequently, the behavioral and institutional findings of this study are potentially transferable to regions where other crop residues constitute the primary livestock feed resources. However, the technical recommendations should be adapted according to local biomass availability, climatic conditions, residue characteristics, livestock production systems, and market access. This indicates that while the IPA–CSI framework provides a broadly applicable decision-support tool, the specific intervention priorities should remain context-sensitive rather than universally standardized.

The descriptive analysis showing higher implementation performance among younger and more educated farmers further supports contemporary innovation adoption literature. Younger farmers generally exhibit greater openness toward digital information, experimental learning, and new production practices, whereas farmers with longer experience often rely more heavily on established routines. Rather than reflecting resistance to change, this pattern illustrates the

Journal of Agriculture (JoA)
Volume: 05 | Number 02 | July 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n02.9017

influence of accumulated production experience and risk perception on innovation decisions. Similar age- and education-related differences have been documented in agricultural technology adoption studies across developing countries, where educational attainment enhances farmers' capacity to process technical information and evaluate innovation outcomes (Feder et al., 1985; Meijer et al., 2015). Consequently, extension programs should adopt differentiated communication strategies tailored to diverse farmer groups instead of assuming homogeneous adoption behavior.

The inferential analysis confirms that age and educational attainment significantly influence farmers' perceptions of fermented rice straw utilization. These findings reinforce previous studies indicating that younger and more educated farmers generally exhibit greater openness to technological innovation because they possess higher learning capacity, greater access to information, and lower resistance to organizational change. Conversely, the absence of significant differences according to farming experience suggests that accumulated experience does not necessarily translate into greater technology acceptance. This finding implies that extension strategies should prioritize improving farmers' knowledge and learning opportunities rather than relying solely on farming experience as an indicator of adoption readiness.

The findings of this study have several practical implications. First, agricultural extension agencies should prioritize competency-based fermentation training combined with on-farm demonstration plots to improve farmers' perceived ease of use and confidence in implementing the technology. Second, local governments should support community-based feed-processing centers equipped with shared fermentation facilities to reduce production costs and improve access to processing equipment. Third, farmer organizations should strengthen peer-learning mechanisms and farmer champion programs that increase technology observability and encourage wider adoption. Finally, integrating fermented rice straw utilization into regional crop–livestock development policies could improve feed security, reduce agricultural waste burning, lower environmental impacts, and enhance the sustainability of smallholder beef cattle production systems

Overall, these findings demonstrate that improving fermented rice straw utilization requires a systems approach integrating technological innovation, behavioral change, institutional strengthening, and policy support. Sustainable adoption cannot be achieved solely by improving fermentation techniques but also requires strengthening extension systems, reducing implementation complexity, increasing farmers' opportunities to observe successful practices, and building collaborative networks among universities, extension agencies, local governments, and farmer organizations. Such integrated approaches are increasingly recognized as essential for accelerating sustainable livestock intensification while improving resource-use efficiency and resilience in smallholder farming systems.

Conclusion

This study demonstrates that the limited utilization of fermented rice straw among smallholder beef cattle farmers is primarily driven by technological, behavioral, economic, and institutional constraints rather than by the physical availability of rice straw itself. Using the integrated Importance–Performance Analysis (IPA) and Customer Satisfaction Index (CSI) approach, the study identified critical priority attributes requiring immediate intervention, particularly farmers' knowledge of fermentation technology, processing convenience, production costs, and the transition from free-grazing to more intensive feeding systems. These findings highlight that improving technology adoption requires not only technical innovation but also strengthened extension services, institutional support, participatory learning, and farmer capacity development. By integrating technical and behavioral perspectives within a systematic prioritization framework, this study contributes practical evidence for designing more effective strategies to support sustainable crop–livestock integration and improve the resilience of smallholder beef cattle production systems.

Despite these contributions, several limitations should be acknowledged. First, the study was conducted in a single district with a relatively limited sample size, which may restrict the generalizability of the findings to other regions with different socioeconomic and agroecological characteristics. Second, the cross-sectional survey design captured farmers' perceptions at only one point in time and therefore cannot fully explain changes in technology adoption behavior over time. Third, the analysis primarily relied on descriptive and perception-based measurements, without incorporating longitudinal observations or objective farm performance indicators.

Future research should expand the geographical scope by involving diverse livestock production systems across different regions, employ longitudinal or mixed-method approaches to better understand changes in farmers' adoption behavior, and integrate objective productivity, economic, and environmental indicators to evaluate the long-term impacts of fermented rice straw utilization. Future studies may also apply advanced analytical techniques, such as structural equation modeling or multilevel analysis, to examine the complex relationships among technological, behavioral, institutional, and policy factors influencing sustainable agricultural innovation.

Acknowledgements

The authors would like to express their sincere gratitude to all cattle farmers in Indrajaya District, Pidie Regency, for their willingness to participate in this study and for sharing valuable information and experiences regarding livestock management practices and the utilization of rice straw as animal feed. The authors also acknowledge the support provided by local livestock extension officers and community leaders who facilitated data collection and field observations. Special appreciation is extended to Jabal Ghafur University and Teuku Umar University for their academic support and encouragement throughout the research process. The constructive contributions from colleagues, reviewers, and all parties involved in this study are highly appreciated and have significantly improved the quality of this manuscript.

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Azizah, S. (2026). *THE SOCIAL LIFE OF LIVESTOCK: POWER, CULTURE, AND ECONOMY*. Yayasan Drestanta Pelita Indonesia. https://www.researchgate.net/profile/Siti-Azizah-11/publication/399667500_THE_SOCIAL_LIFE_OF_LIVESTOCK_POWER_CULTURE_AND_ECONOMY/links/696471625cc49c35ce7bd86e/THE-SOCIAL-LIFE-OF-LIVESTOCK-POWER-CULTURE-AND-ECONOMY.pdf

Bata, M., Rahayu, S., Rimbawanto, E. A., Hartoyo, B., Prihambodo, T. R., Renata, M., & Umam, R. Z. (2025). Optimization of Madura Cattle Performance Fed Ammoniated Rice Straw and Concentrate Containing Hibiscus tiliaceus Leaf. *Tropical Animal Science Journal*, *48*(4), 347–356. https://doi.org/10.5398/tasj.2025.48.4.347

Cherdthong, A., Suntara, C., Khota, W., & Wanapat, M. (2021). Feed utilization and rumen fermentation characteristics of Thai-indigenous beef cattle fed ensiled rice straw with Lactobacillus casei TH14, molasses, and cellulase enzymes. *Livestock Science*, *245*, 104405. https://doi.org/10.1016/j.livsci.2021.104405

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of

Information Technology. *MIS Quarterly*, *13*(3), 319–340. https://doi.org/10.2307/249008

Hair, J. F., Babin, B. J., & Anderson, R. E. (2022). *Multivariate Data Analysis* (8th ed.).

Hu, Y., He, Y., Gao, S., Liao, Z., Lai, T., Zhou, H., Chen, Q., Li, L., Gao, H., & Lu, W. (2020). The effect of a diet based on rice straw co-fermented with probiotics and enzymes versus a fresh corn Stover-based diet on the rumen bacterial community and metabolites of beef cattle. *Scientific Reports*, *10*(1), 10721. https://doi.org/10.1038/s41598-020-67716-w

Khalidin, K., Subagyo, D., Rahayu, S., Masrianto, M., & Yani, A. (2025). Profitability and Feasibility Analysis of Traditional Beef Cattle Fattening Business: A Case Study of Blang Rimeh Farmers Group in Pidie Regency. *Journal of Agriculture*, *4*(03), 369–381. https://doi.org/10.47709/joa.v4i03.7326

Martina, A. A., Eka Rizky Vury Rahayu, & Aprilia, L. (2024). The Utilization of Fermented Agricultural By-Products as Fibrous Feed for Beef Cattle: A Review. *Bantara Journal of Animal Science*, *7*(2), 14–19. https://doi.org/10.32585/bjas.v7i2.7310

Nuraina, N., & Muzakki, F. (2026). Implementing precision feeding in Indonesia's dairy sector: Environmental and socioeconomic impact and adoption challenges. *Jurnal Inovasi Pangan Dan Gizi*, *3*(1), 41–58. https://doi.org/10.61511/jipagi.v3i1.2754

Rathore, S. S., Shekhawat, K., Babu, S., Upadhyay, P. K., Singh, R. K., Raj, R., Tyagi, V., Nagargade, M., Singh, A., Neel, S., Patel, A., Nawhal, A., Ramnathan, A., & Singh, A. (2026). Valorization of paddy straw through fermented organic manure: A circular economy approach for low carbon agriculture. *Frontiers in Sustainable Food Systems*, *9*, 1702102. https://doi.org/10.3389/fsufs.2025.1702102

Thornton, P. K., & Herrero, M. (2015). Adapting to climate change in the mixed crop and livestock farming systems in sub-Saharan Africa. *Nature Climate Change*, *5*(9), 830–836. https://doi.org/10.1038/nclimate2754

Widarni, N. A. A., Kusumastuti, T. A., & Putra, A. R. S. (2020). A study on farmers' choice in integrating paddy and cattle farming as farm management practices. *Journal of the Indonesian Tropical Animal Agriculture*, *45*(4), 356–364. https://doi.org/1608257012

Yazdanpanah, M., & Feyzabad, F. R. (2017). Investigating Iranian Farmers' Satisfaction With Agricultural Extension Programs Using the American Customer Satisfaction Index. *Journal of Agricultural & Food Information*, *18*(2), 123–135. https://doi.org/10.1080/10496505.2017.1285240