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The Dynamics and Challenges of Human Resources in the Innovation of Silage as an Alternative Feed: A Systematic Literature Review

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Abstract

Human resources (HR) play a crucial role in feed innovation to achieve food self-sufficiency. Active community participation, ongoing education for livestock farmers, and capacity building for local human resources are key to the sustainability of innovation. This study aims to systematically synthesize the latest literature on the role and actual barriers faced by human resources in feed innovation. This Systematic Literature Review was conducted using the PRISMA protocol. A comprehensive search was performed through the Dimensions bibliographic database for publications released between 2020 and 2026. From a total of 194 documents identified through the search, a rigorous screening and eligibility evaluation process yielded 20 key articles that were extracted and analyzed thematically. The literature synthesis identified significant transformations in the role of human resources in silage feed innovation as an alternative feed for all seasons. However, there are a number of obstacles faced by human resources in silage feed innovation, including 1) a lack of skills resulting in low silage quality, limited production scale, and distribution inefficiency; 2) a lack of coordination among farmers; 3) weak farmer groups, and resistance to adopting new technologies due to traditional cultural values; and 4) limited capital for procuring raw materials, equipment, and silage additives. Policy implications call for government support in providing comprehensive training."

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INTRODUCTION

In Indonesia, the agricultural innovation system reveals that small-scale livestock farmers struggle to access innovations due to weak institutions and insufficient technological support at the local level. Livestock innovations will not reach their full potential if farmers continue to face difficulties in accessing development resources (Valerio et al. 2022). Human resource dynamics become more complex as they are influenced by community characteristics, culture, education, and farmer motivation. Harta et al. (2021) found that although silage technology is available, its adoption in villages remains low due to a lack of silage-making skills, insufficient understanding of the benefits of alternative feed, and social barriers such as resistance to changing traditional practices. This issue is not only a concern for researchers but also a real social problem because it directly impacts livestock productivity, farmers' income, and food security in the region. Small-scale farms often face challenges in obtaining high-quality forage. This problem worsens during the dry season when fresh forage is hard to come by and feed prices rise. Irma et al. (2025) note that reliance on conventional feeds, such as elephant grass or concentrates, makes farmers vulnerable to fluctuations in prices and the availability of raw materials. Conversely, silage production can serve as a solution to ensure feed availability, reduce costs, and enhance livestock productivity. The primary challenges identified include farmers' lack of technical knowledge regarding forage fermentation, limited training opportunities, and insufficient support from extension workers in disseminating the technology.

Competent human resources are capable of maximizing the fermentation process, minimizing nutrient loss, and maintaining good feed quality (Heriyanto 2025). Therefore, this study employs a literature review to identify human resource barriers to feed innovation, so that the research findings can serve as a basis for formulating livestock feed development strategies. The objective of this study is to identify, evaluate, and synthesize the latest literature on the role of human resources and the barriers they face, as well as to examine farmers' participation in knowledge regarding feed nutrition, types of feed ingredients, and feed innovation. A novel aspect of this study is its ability to integrate disparate findings into a unified understanding. The results of this study are expected to provide two benefits: theoretically, to enrich the literature on efforts to provide alternative feed sources that rely on human resources; and practically, to provide a basis for policy makers to allocate targeted resources to address the gap between current capacity and expectations for the advancement of the livestock sector.

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METHODOLOGY

This study employed a systematic literature review method following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol to ensure that the literature selection process was conducted in a transparent, structured, and reproducible manner. The initial phase of the study, namely Identification, focused on a literature search using the Dimensions digital bibliographic database, with publications limited to those between 2020 and 2026. This search utilized a combination of specific keywords. Using the specific keyword combination: "Human Resources" AND "role" AND "silage feed innovation" AND "HR barriers," the initial data extraction process yielded 194 documents. After initial validation, 165 articles were deemed relevant for further review, while the remaining 29 documents were excluded (Excluded Articles) because they were identified as duplicates or did not meet the standards for scientific publication format.

Next, during the Screening phase, the 165 articles were further evaluated through a selection process. The research publications were assessed based on the relevance of their titles and abstracts. At this stage, strict criteria were applied to distinguish general studies from literature specifically examining the dynamics of human resources in relation to feed innovation. This screening process resulted in the exclusion of 145 documents (Excluded Documents) because they were deemed to fall outside the scope of human resources in relation to feed innovation and lacked relevant technical substance.

In the final stage, namely Eligibility, 20 documents were designated as Eligible Documents and underwent a full-text review. After being evaluated based on methodological quality and the significance of their findings, these 20 studies were definitively selected as Selected Articles for Analysis. Data from this collection of selected articles was then thoroughly extracted to synthesize empirical insights regarding the capacity, proactive role, and systemic challenges faced by human resources in supporting national food security.

RESULT AND DISCUSSION

The Human Resource Transformation in Feed Innovation: Feed Supports the Livestock Industry

Human resources (HR) play a crucial role in managing livestock operations, particularly in feed management, which is a key determinant of livestock productivity. Several studies indicate that HR capabilities in feed management, nutritional formulation, raw material selection, and feed processing technology significantly influence livestock farm performance (Firmansyah et al., 2022) In the dairy cattle sector, highly skilled HR can optimize feed provision according to

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Livestock nutritional needs, thereby increasing milk production (Alfiansyah & Erniawati, 2024). Other studies indicate that utilizing agricultural waste and local forage as alternative feed requires the knowledge and skills of human resources to ensure the feed is safe and nutritious (Ali et al., 2023).

Beyond technical aspects, human resources also play a role in feed management innovation and technology adoption, including feed formulation and effective storage systems (Shobirin, 2023). The quality of human resources also determines the Success of livestock business partnerships, distribution networks, and access to supporting resources such as feed companies and farmer organizations (Firmansyah et al., 2022). Limited human resources are a major obstacle, especially for small-scale farmers. A lack of knowledge regarding feed management results in low feed efficiency and livestock productivity (Setiawan & Adlan, 2022). Therefore, strategies to improve human resources through training, extension services, and institutional capacity building are crucial in supporting the sustainability of livestock businesses (Ramadhan et al., 2022).

Additionally, the social and economic aspects of human resources also influence their ability to access feed materials, technology, and the latest information on livestock nutrition (Amam & Soetriono, 2020). Improving the quality of human resources has been shown to increase feed utilization efficiency, reduce production costs, and improve the quality and quantity of livestock output (Nisa et.al, 2025). Overall, research indicates that human resources are not merely technical implementers but also drivers of innovation, managers of feed resources, and institutional liaisons who play a role in enhancing the productivity and sustainability of livestock enterprises.

The Role of Human Resources in Silage Feed Innovation

Silage is a preserved livestock feed that is essential for ensuring a year-round supply of high-quality feed, particularly for ruminants (Budiyoko & Zulkifli, 2025). Human resources (HR) play a vital role in silage innovation, ranging from raw material selection, the fermentation process, the use of additives, to post-fermentation management (Huda et al., 2024). Skilled and knowledgeable HR can utilize local feed materials, such as corn stover, cocoa pod husks, or agricultural waste, to produce high-quality silage, thereby reducing dependence on commercial feed (Amalyadi, 2026). Research indicates that training, mentoring, and technology transfer from academics or research institutions can enhance farmers' ability to produce silage (Sungkono et al., 2026).

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In addition to technical skills, human resources also play a role in feed processing innovations based on the circular economy, such as pineapple peel silage, which not only improves feed quality but also provides economic value to the community (Budiyoko & Zulkifli, 2025). The implementation of precision technology and efficient feed processing systems requires effective human resource coordination to ensure the success of innovations (Amalyadi, 2026).

The success of silage innovation also depends on social and institutional factors related to human resources. Organized groups of livestock farmers with good human resource management are better able to implement feed innovations sustainably (Rahmawati et al., 2025). Training in silage production, the use of choppers, and bokashi fermentation has been shown to increase farmers' self-reliance and livestock productivity (Fitroh et al., 2025).

Research also highlights the importance of social innovations accompanying technical innovations. Community participation, farmer education, and capacity building of local human resources contribute to the sustainability of silage innovation (Rahmawati et al., 2025). Thus, human resources are not merely technical implementers but also agents of change driving silage feed innovation to support feed security and the local economy.

Systemic and Structural Barriers to Feed Innovation

Feed innovation in the livestock industry faces various challenges, both systemic and structural. Systemic challenges are generally related to planning, resource management, and technical procedures, while structural challenges relate to infrastructure, institutional frameworks, and regulations governing the livestock sector (Harmayani, 2025). Technical challenges include farmers' limited ability to make silage, process raw materials anaerobically, and use appropriate fermentation additives (Rahmawati et al., 2025). This lack of skill is often the primary cause of the low quality of the resulting silage.

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Research indicates that farmers' or field practitioners' lack of knowledge poses a significant initial barrier to the adoption of feed innovations. This is evident in the utilization of local feed materials, such as sapu-sapu fish, which, despite their potential, are often not fully utilized due to human resource limitations (Abdullah et al., 2025). Other structural constraints include limited access to feed processing technology, inefficient feed distribution, and a lack of institutional support (Agustina et al., 2025).

Structural constraints stem from infrastructure limitations, such as the lack of choppers, storage silos, and feed transportation facilities (Mustaniroh et al., 2020). This limits the scale of silage production and the efficiency of feed distribution.

Additionally, financial and policy constraints also slow down innovation. Many farmers lack the capital to purchase modern equipment such as choppers or silos, thereby limiting the adoption of silage feed innovations (Mulyati et al., 2025).

Social and institutional barriers also play a significant role. A lack of coordination among farmers, weak farmer groups, and cultural values that favor traditional methods hinder the adoption of new technologies (Sahroni, 2025).

Social and cultural barriers also influence the acceptance of innovations; for example, traditional values or farming practices passed down through generations can hinder the adoption of new technologies (Dahrun et al., 2025).

Additionally, economic and financial constraints arise due to limited capital for purchasing raw materials, equipment, and silage additives (Zulfanita et al., 2025). Many farmers still rely on fresh forage, which is sometimes difficult to obtain during the dry season, so silage as an alternative feed has not been optimally utilized (Robbani et al. 2025).

Other literature reviews emphasize the importance of systemic coordination among innovators, institutions, and technology providers to address structural constraints. Innovation system-based approaches and human resource capacity building have proven effective in promoting the implementation of feed innovations (Mulyati et al., 2025). Limited information, bureaucratic procedures, and a lack of policy support remain the primary factors slowing down feed innovation transformation at the local and national levels (Suvianti et al., 2025).

Challenges in feed innovation are multidimensional, encompassing technical, social, institutional, economic, and policy aspects. Addressing these challenges requires a comprehensive strategy that combines human resource capacity building, technological modernization, institutional strengthening, and adaptive regulatory support (Novarista et al. 2025).

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Several studies emphasize the importance of mentoring and training as solutions to mitigate these challenges. Training in silage production, the use of choppers, and the processing of forage into fermented feed has been shown to improve feed availability and livestock productivity (Silsilah et al. 2025). Additionally, institutional support, agricultural system integration, and technology transfer from academia and the government play a crucial role in reducing barriers to innovation adoption (Nurtanti et al., 2025).

Strategies and Policy Implications for Alternative Silage Feed

Strategic innovations in the management of silage as an alternative feed are a key factor in improving livestock productivity and food security. Silage, as a preserved feed based on local forage, can address fluctuations in feed availability throughout the year and support the sustainability of livestock operations (Wafik et al. 2025). Research indicates that the success of silage innovations depends on the capabilities of livestock farmers, the use of appropriate technology, and adaptive management strategies and feed formulations (Aprillia et al. 2026). The implementation of these innovations includes the use of agricultural waste, composite forage formulations, and fermentation techniques with probiotic additives to improve silage quality (Ismiraj et al. 2024).

Policy implications take the form of government support for training provision, technology access, feed quality regulations, and economic incentives for small-scale farmers (Sulistyowati et al. 2025). Strategic policies are needed to expand the adoption of silage innovations, improve feed production efficiency, and maximize the availability of locally sourced feed based on existing resources. Several studies emphasize the importance of Combining technical innovations and public policy.For example, the adoption of precision-based feeding systems and the processing of agricultural waste as a source of forage enhances the competitiveness of local livestock farmers while supporting regional food security (Amalyadi, 2026). Community empowerment strategies through silage training have also proven to strengthen farmers' ability to cope with dry seasons and feed price fluctuations (Nawawi & Muchlis 2025).

Additionally, research indicates positive impacts on socio-economic aspects. The adoption of silage enhances farmers' self-reliance, reduces dependence on commercial feed, and promotes livestock business diversification (Azis et al., 2026). Thus strategic innovations in silage as an alternative feed not only impact productivity but also drive policy changes to support food security and the sustainability of local agribusiness.

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CONCLUSION

Human resources (HR) play a crucial role in feed innovation to support food self-sufficiency. HR not only serve as technical implementers but also as drivers of innovation, managers of feed resources, and institutional liaisons who contribute to increased productivity and the sustainability of livestock businesses. Community involvement, education for farmers, and capacity building for local HR are vital to achieving sustainability. However, silage feed innovation faces various HR-related challenges, including a lack of skills leading to poor silage quality, limited production scale and distribution efficiency, insufficient coordination among farmers, weak farmer groups, cultural values that favor traditional methods hindering the adoption of new technologies, and limited capital to purchase raw materials, equipment, and silage additives. Therefore, the resulting policy implication is the need for government support in the form of training programs.

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