



A Study on Factors Influencing the Adoption of Crop Residues as Cattle Feed among Farmers in Kelantan, Malaysia

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ABSTRACT

Utilising crop residues as cattle feed is a promising strategy for improving sustainability and reducing feed shortages in Malaysia's cattle farming industry. This study investigates the factors influencing the adoption of crop residues among cattle farmers in Kelantan since the industry faces challenges including limited grazing land, high feed costs, and dependency on traditional feed sources. A quantitative research approach was employed involving structured interviews with 109 cattle farmers across six districts. Descriptive statistical analysis revealed a moderate proportion of farmers who recognise the benefits of crop residues, yet adoption remains constrained due to economic limitations, lack of awareness, and inadequate technical support. Many farmers perceive crop residues as cost-effective and beneficial for productivity; however, knowledge gaps and logistical constraints hinder widespread implementation. Findings suggest that targeted training programs, financial support and improved extension services are critical for increasing adoption rates. Encouraging the use of crop residues can enhance local cattle farming sustainability, reduce reliance on imported feed, and contribute to Malaysia's food security objectives.

1. INTRODUCTION

Malaysia's agriculture sector is undergoing a significant transformation as the government promotes modern technology and sustainable practices, including crop rotation and integration, to boost

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productivity and food security (Firdaus et al., 2020). Contributing 10.9% to GDP in early 2024, agriculture remains a key pillar of the national economy. Within this sector, the ruminant industry is advancing under the National Beef Industry Development Strategic Plan (2021–2025), which targets 111,000 tonnes of beef production and a 50% self-sufficiency rate by 2025 (Kamarudin et al., 2025). Despite these goals, Malaysia remains heavily reliant on imported beef and mutton, with domestic beef production covering only 20%-25% of total consumption (Abdullah et al., 2020).

A key challenge faced by the local cattle industry is the persistent shortage of affordable and sustainable feed resources. Napier grass (*Cenchrus purpureus*), the primary feed, is increasingly affected by climate variability, including droughts and erratic rainfall (Balehgn et al., 2022). On top of that, limited grazing land, high production costs, and underdeveloped breeding programs further constrain productivity (Mat Lazim et al., 2020). From 2018 to 2023, Malaysia's beef import dependency rose from 77.47% to 88.76%, as illustrated in Figure 1, reflecting a widening gap in domestic production, largely driven by feed scarcity.

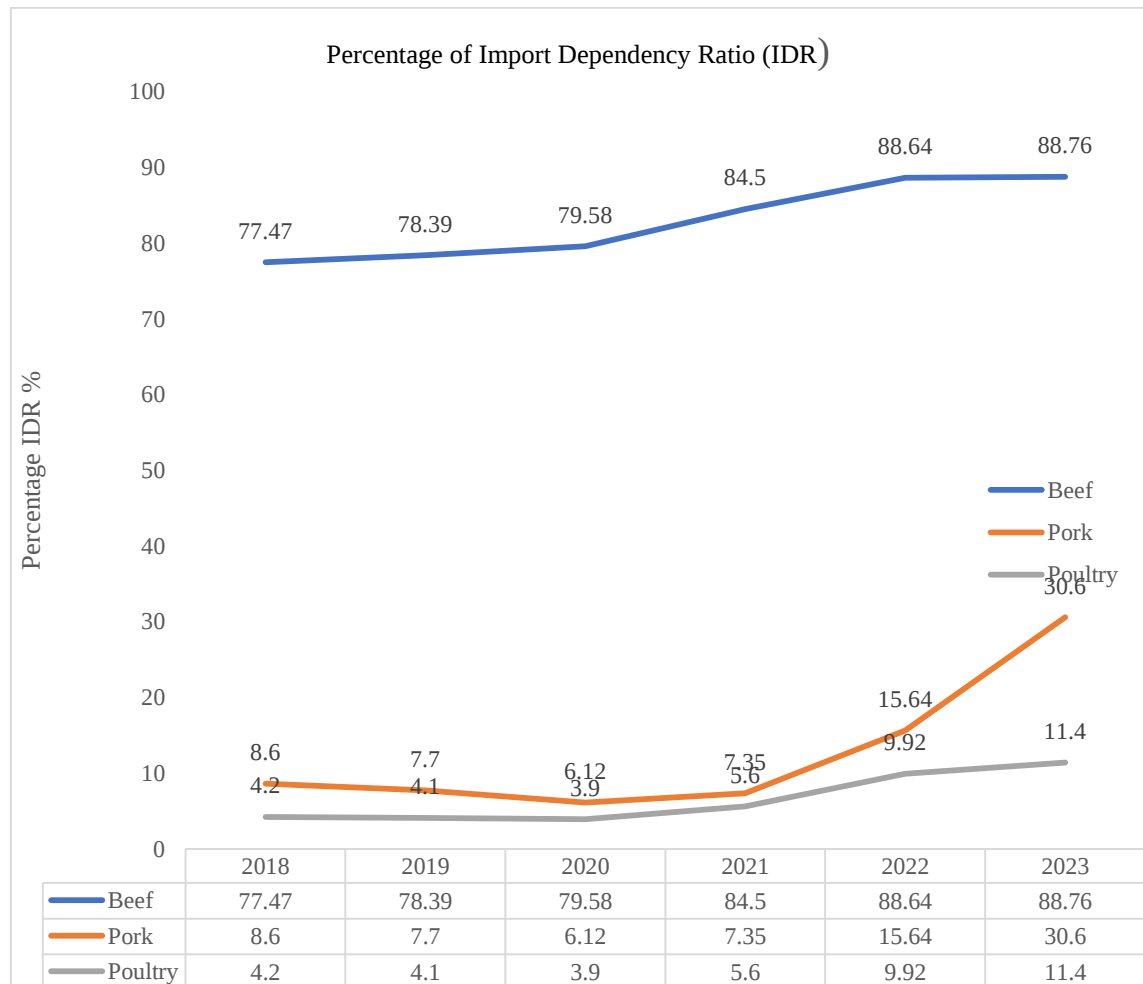


Figure 1. Import Dependency Ratio of Cattle in Malaysia 2018-2023

Since 2017, the number of cattle farmers and breeders in Malaysia's east coast states (Pahang, Terengganu and Kelantan) has been declining, significantly affecting the local beef supply (Department of Veterinary Malaysia, 2024). Kelantan has the highest number of cattle farmers, totalling 19,840, followed by Terengganu with 6,920 and Pahang with 3,287. The overall number of cattle farmers and breeders in the region dropped from 20,342 in 2009 to 16,937 in 2018 (Department of Veterinary Malaysia, 2024). This downward trend poses a risk to domestic beef production, increasing Malaysia's reliance on imports from countries such as Thailand, India and New Zealand.

To address this issue, the government is promoting the integration of livestock with plantation crops and exploring alternative feed sources, such as crop residues from oil palm, paddy and pineapple. These byproducts can be processed into silage, bran and fodder, offering an environmentally friendly solution that reduces waste and supports sustainability goals (Malenica et al., 2023). This strategy aligns with the United Nations' Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 13 (Climate Action), by enhancing food security and reducing agriculture's carbon footprint (Wijerathna-Yapa & Pathirana, 2022).

Despite these opportunities, the adoption of crop residues as cattle feed remains limited in key cattle-rearing regions like Kelantan. Although Kelantan has the highest number of cattle farmers in Peninsular Malaysia with 19,840 farmers, compared to 6,920 in Terengganu and 3,287 in Pahang, the overall number has declined from 20,342 in 2009 to 16,937 in 2018 (Department of Veterinary Malaysia, 2024). This downward trend threatens local beef production and increases reliance on imports from countries like Thailand, India and New Zealand.

Nonetheless, farmers in Kelantan remain reluctant to transition from traditional feed sources, such as Napier grass and commercial silage, to crop residues. This hesitation stems from limited awareness, lack of technical support and minimal research on crop residue-based feed technologies (Abdullah et al., 2020). Consequently, productivity remains low, while the cattle industry struggles to meet rising consumer demand.

Given these challenges, this study focuses on exploring the adoption of crop residues as cattle feed among farmers in Kelantan. It seeks to understand the barriers hindering this transition and identify opportunities for promoting sustainable feed practices. By uncovering the practical, economic and social factors affecting adoption, this study aims to inform future policies and strategies that can enhance food security, reduce import dependency, and build a more resilient cattle farming sector in Malaysia.

2. METHODOLOGY

A quantitative research design was employed in this study involving 109 cattle farmers from the higher districts of beef cattle farmers in Kelantan, including Kota Bharu, Pasir Mas, Pasir Puteh, Bachok, Kuala Krai and Jeli. Face-to-face interviews were conducted to collect detailed data from the participants. A simple random sampling method was used to ensure each respondent in Kelantan had an equal chance of being selected (Sekaran & Wiley, 2006). The questionnaire included socio-demographic information and assessed the adoption of crop residues, introducing a Likert scale from 1 (strongly disagree) to 4 (strongly agree) (O'Neill, 2017). A pilot test involving 34 farmers from Pasir Mas district was carried out, with 30 valid responses collected. The reliability analysis produced a Cronbach's Alpha of 0.873, indicating a high level of internal consistency. Meanwhile, descriptive statistical analysis, including frequency, percentage and mean score analysis was performed using SPSS.

3. FINDINGS AND DISCUSSION

3.1 Demographic Factor

Table 1. Demographic Factor of the Respondents

Demographic profile	Frequency, n=109	Percentage (%)	Mean
District			
Kota Bharu	13	11.5	
Pasir Mas	14	12.4	
Pasir Puteh	21	18.6	
Bachok	12	10.6	
Kuala Krai	28	24.8	
Jeli	21	18.6	
Age, years			45.4
≤30	31	27.4	
31 - 40	13	11.9	
41 - 50	27	24.8	
51-60	10	9.2	
61-70	15	13.8	
≥70	13	11.9	
Gender			
Male	103	91.2	
Female	6	5.3	
Education			
Unschooler	4	3.5	
Primary School	0	0	
LCE/SRP/PMR	18	15.9	
MCE/SPM	39	34.5	
STPM/Diploma	20	17.7	
Bachelor degree	28	24.8	
Profit, Ringgit Malaysia (RM)/year			30,000
≤50000	94	83.2	
50001-100000	7	6.2	
100001-150000	2	1.8	
150001-200000	6	5.3	
Experience as a cattle farmer, years			6
≤10	83	73.5	
11-20	20	17.7	
≥21	6	5.3	
Main Job			
Farmer	68	60.2	
Private	34	30.1	
Government	7	6.2	
Side Job			
Yes	91	80.5	
No	18	15.9	

The demographic profile of the respondents offered valuable insights into the characteristics of cattle farmers in the study area. Data revealed that a considerable proportion of respondents were based in Kuala Krai (24.8%), with notable representation also from Pasir Puteh (18.6%) and Jeli (18.6%). This distribution suggests that cattle farming activities are relatively more prevalent in these districts. The average age of respondents was 45.4 years, with a large segment falling into the younger age categories, particularly those aged ≤30 years (27.4%) and between 41 and 50 years (24.8%). This indicates a

substantial presence of younger individuals in the cattle farming sector, which may influence openness to adopting new technologies and practices, such as incorporating crop residues into cattle feed. These findings are consistent with those by Kamarudin et al. (2025), observing that beef cattle farmers adopting crop residues as feed in Kedah typically fall within the 40 to 49 age range and often engage in the practice as part of a family legacy. In terms of gender, cattle farming appeared to be heavily male-dominated (91.2%), with minimal involvement from women (5.3%). This trend may reflect traditional gender roles or the physically demanding nature of livestock management, as noted by Widarni et al. (2020a). When looking at educational attainment, a significant share of respondents possessed secondary-level qualifications (34.5% with MCE/SPM), while others held higher academic credentials (17.7% with STPM/Diploma and 24.8% with a bachelor's degree). The presence of well-educated individuals in the sector could facilitate the uptake of modern agricultural innovations, as educational background often correlates with greater awareness and informed decision-making (Abdullah et al., 2021).

The economic profile of the respondents illustrated that cattle farmers typically earn an average annual profit of RM 30,000, with 83.2% reporting earnings of RM 50,000 or less. Only a limited segment (13.3%) reported annual profits exceeding RM 50,000, indicating that for many, cattle farming may not be a highly lucrative enterprise. This relatively modest income level could influence their capacity or motivation to invest in alternative feeding strategies, including the use of crop residues (Oosting et al., 2022). Farming experience among respondents varied considerably, with 73.5% having been involved in the field for 10 years or less. This suggests that a large number of cattle farmers are relatively new to the industry, which may affect their readiness to adopt innovative feeding methods (Sudrajat et al., 2020). In contrast, only a small fraction (5.3%) has over 21 years of experience, potentially indicating a stronger reliance on traditional practices within this group. Regarding occupation, 60.2% of the respondents engaged in cattle farming on a full-time basis, while others were employed in the private sector (30.1%) or the government sector (6.2%). It is apparent that while cattle farming serves as the main livelihood for many, it also functions as a secondary source of income for others. Supporting this, 80.5% of respondents were also involved in side jobs, reflecting the possibility that income from cattle farming alone may be insufficient to meet their financial needs.

3.2 Adoption of Crop Residue

Table 2. Findings on Adoption of Crop Residue

Item(s)	Frequency, n=50				Mean
	Strongly disagree 1	Disagree 2	Agree 3	Strongly agree 4	
1 I utilise and incorporate crop residues in cattle farming	12 (10.6%)	28 (24.8%)	23 (20.4%)	46 (40.7%)	3.28
2 I make use of crop residues to boost my farm's productivity	11 (9.7%)	24 (21.2%)	45 (39.8%)	39 (25.7%)	3.36
3 I consider the use of crop residues essential in cattle farming	30 (26.5%)	24 (21.2%)	41 (36.3%)	14 (12.4%)	3.02
4 I have experienced numerous advantages from incorporating crop residues in cattle farming	16 (14.2%)	53 (46.9%)	31 (27.4%)	9 (8%)	3.34
5 I keep up to date with the latest advancements in crop residue technologies for cattle farming	14 (12.4%)	57 (50.4%)	23 (20.4%)	15 (13.3%)	2.86
6 I consider the use of crop residues to be cost-effective	21 (18.6%)	30 (26.5%)	45 (39.8%)	13 (11.9%)	2.98

7	I consistently recognise the significance of using crop residues in cattle farming	13 (11.5%)	56 (49.6%)	28 (24.8%)	12 (10.6%)	3.02
8	I consider implementing an integrated farming system as a way of utilising agricultural waste for cattle feed	14 (12.4%)	58 (51.3%)	24 (21.2%)	13 (11.5%)	3.2

3.3 Acceptance and Utilisation of Crop Residues

A substantial proportion of respondents to the question “I utilise and incorporate crop residues in cattle farming” (40.7%) strongly agreed that they accept and use crop residues for cattle farming (Mean = 3.28). This finding underscores a generally positive attitude toward crop residue utilisation, and reflects an understanding of its potential benefits. Farmers who incorporate crop residues into their cattle farming practices are likely to benefit from cost savings and improved livestock nutrition (Sudrajat et al., 2020). However, some farmers may still be hesitant due to a lack of proper guidance on best practices (Kamarudin et al., 2025).

3.4 Enhancement of Productivity Using Crop Residues

A notable portion of farmers (39.8%) strongly agreed with the statement, “I consider the use of crop residues to be cost-effective,” suggesting that many perceive crop residues as beneficial to farm productivity (Mean = 3.36). In contrast, a smaller segment (9.7%) strongly disagreed with the statement, reflecting scepticism among some farmers regarding the effectiveness of crop residues. This divergence in perception may stem from variations in farm management practices, limited access to high-quality residues, or difficulties in proper application (Li et al., 2022). Furthermore, the lack of adequate knowledge or technical support in using crop residues efficiently could be a contributing factor to the doubts expressed by some respondents about their cost-effectiveness.

3.5 Perceived Importance of Crop Residues in Cattle Farming

Given a significant portion of respondents (36.3%) who strongly agreed on “I consider the use of crop residues essential in cattle farming” owing to the importance of crop residues in cattle farming, a notable 21.2% still expressed disagreement. This variation in perspectives highlights the differing levels of awareness and acceptance among farmers regarding the role of crop residues in sustainable agricultural practices. The mean score of 3.02 indicates a generally positive perception; however, the presence of disagreement reveals that some farmers may still harbour doubts or lack sufficient knowledge about the benefits of utilising crop residues effectively. The farmers who expressed disagreement may have various reasons for their stance. Some may not have experienced significant improvements in productivity or cost savings from using crop residues, leading them to question its effectiveness (Widarni et al., 2020b). Others might face challenges of limited access to high-quality crop residues, difficulties in proper storage and processing, or a lack of technical know-how on the ways to incorporate residues efficiently into cattle feed (Duguma & Janssens, 2021). Additionally, misconceptions or traditional feeding practices could contribute to their reluctance to adopt crop residue utilisation. As emphasised by Prajapati et al. (2025), enhancing farmers’ knowledge and technical skills plays a fundamental role in encouraging the widespread adoption of sustainable agricultural practices. When farmers are well informed about the benefits, proper techniques and long-term advantages of utilising crop residues, they are more likely to incorporate these methods into their farming operations.

3.6 Benefits Derived from Crop Residue Utilisation

Interestingly, a significant 46.9% of respondents disagreed with the statement, “I have experienced numerous advantages from incorporating crop residues in cattle farming.” Nevertheless, the mean score

of 3.34 indicates that, overall, many farmers have still gained substantial benefits from using crop residues. This apparent discrepancy suggests that while some farmers recognise the positive impact of crop residues on their farming operations, others may be facing challenges that prevent them from fully realising these benefits (Bhuvaneshwari et al., 2019). One possible explanation for this divide is the presence of inefficiencies in the way crop residues are utilised on different farms. Some farmers may have successfully integrated crop residues into their feeding systems, optimising their use to enhance cattle nutrition and reduce feeding costs (Sarkar et al., 2020). These farmers likely have access to the necessary knowledge, technology and infrastructure required to process and store residues effectively, ensuring that their cattle receive high-quality feed.

On the other hand, those who disagreed with the statement may be experiencing difficulties in various aspects of crop residue management. Challenges like improper storage, which can lead to spoilage and loss of nutritional value, may hinder the effectiveness of crop residues as a feed source. Additionally, inefficient processing methods might result in poor feed conversion efficiency, making it difficult for farmers to see tangible improvements in cattle growth and farm productivity (Olayemi Sennuga et al., 2022). A lack of technical knowledge on how to incorporate residues into balanced feed formulations could also contribute to farmers perceiving minimal advantages from their use. Moreover, as highlighted by Mouratiadou et al. (2020), the need for improved dissemination of best practices serves a crucial role in addressing these issues. If farmers do not receive adequate training or guidance on how to optimise the utilisation of crop residues, their ability to fully benefit from this resource will remain limited.

3.7 Awareness of Crop Residue Technologies

A considerable proportion of farmers, specifically 50.4%, disagreed with the statement, “I keep up to date with the latest advancements in crop residue technologies for cattle farming”. With a mean score of 2.86, this finding underscores a significant gap in knowledge dissemination, which could hinder progress in the sustainable utilisation of crop residues. When farmers lack access to the latest techniques, innovations and best practices, they may struggle to optimise residue utilisation, potentially limiting productivity gains and sustainability benefits (Kamarudin et al., 2025). Several factors could contribute to this lack of awareness. One key issue is limited access to agricultural extension services, which plays a crucial role in educating farmers about new technologies and providing hands-on training (Widarni et al., 2020a). If farmers are not regularly engaged with extension officers or do not participate in agricultural outreach programs, they may miss out on valuable information that could enhance their farming practices. Additionally, in some rural areas, the availability of extension services may be inconsistent or inadequate to meet the needs of all farmers, further exacerbating the knowledge gap (Abdullah et al., 2020). Another contributing factor is the lack of structured training programs tailored to educating farmers about crop residue utilisation. While research and technological advancements continue to evolve, farmers may not have the necessary opportunities to learn and implement these innovations (Karunathilake et al., 2023). Many farmers rely on traditional methods of cattle feeding; without targeted training sessions, workshops, or demonstration projects, they may be unaware of more efficient and cost-effective ways to incorporate crop residues into their feeding systems.

Technological constraints also have a significant influence in limiting farmers’ access to information. In many cases, small-scale farmers may not have reliable internet access, preventing them from utilising online resources, agricultural databases, or digital training materials (Sudrajat et al., 2020). Moreover, the lack of user-friendly platforms that cater to farmers with varying levels of digital literacy further restricts their ability to stay informed about new advancements. As highlighted by Abdullah et al. (2021), addressing this knowledge gap is essential for improving the adoption of sustainable agricultural practices. Strengthening agricultural extension services and increasing the availability of farmer-friendly training programs could significantly enhance farmers’ awareness of crop residue technologies, besides leveraging accessible communication channels such as radio broadcasts, farmer cooperatives and mobile advisory services.

3.8 Perception of Cost Associated with Crop Residue Utilisation

The statement, “I consider the use of crop residues to be cost-effective”, received mixed responses from farmers, with 39.8% strongly agreeing that it does not involve high costs, while 26.5% expressed disagreement. The mean score of 2.98 indicates a moderate level of agreement suggesting that while many farmers perceive crop residue utilisation as an economical practice, a significant proportion still harbours concerns about its financial implications. This variation in responses highlights the complexity of cost considerations associated with incorporating crop residues into cattle farming systems (Olayemi Sennuga et al., 2022). For those who strongly agreed, the cost-effectiveness of using crop residues likely stems from the fact that these materials are readily available by-products of agricultural production. Instead of purchasing expensive commercial feed, farmers can repurpose crop residues, thereby reducing feed costs and improving the overall efficiency of resource utilisation (Duguma & Janssens, 2021). This practice aligns with sustainable farming principles, as it minimises waste while providing an affordable feed alternative for cattle (Widarni et al., 2020a). However, the 26.5% of farmers who disagreed with the cost-effectiveness of crop residue utilisation may be facing specific challenges that heighten the financial burden of implementing this practice. One key factor could be the additional costs related to processing, storage and transportation (Firdaus et al., 2020). Unlike conventional feeds that are readily available in the market, crop residues often require further preparation, such as chopping, grinding, or mixing with other feed components to enhance their nutritional value (Mat Lazim et al., 2020). Without proper processing, some residues may be less digestible for livestock, thus reducing their effectiveness as a feed source.

Transportation costs can also be a significant concern, particularly for farmers who do not have easy access to sufficient quantities of crop residues within their immediate surroundings (Bhuvaneshwari et al., 2019). In cases where crop residues need to be sourced from other farms or regions, logistical challenges and fuel expenses may make their use less economical. Additionally, small-scale farmers with limited financial resources may struggle to invest in the necessary equipment, such as choppers, mixers, or silage-making tools that can improve the efficiency of residue utilisation but require upfront capital investment (Karunathilake et al., 2023). Furthermore, differences in farm size and operational scale may contribute to the varying perceptions of cost-effectiveness. Larger commercial farms with well-established residue management systems and mechanised operations may find it easier to incorporate crop residues into their feeding strategies at minimal additional cost. In contrast, smaller farms with fewer resources may find the process labour-intensive and financially burdensome, making them less inclined to view residue utilisation as a cost-saving practice.

3.9 Awareness of the Importance of Crop Residues

Nearly half of the respondents (49.6%) disagreed with the statement, “I consistently recognise the significance of using crop residues in cattle farming”, highlighting a significant gap in awareness regarding the potential benefits of this practice. With a mean score of 3.02, the responses indicate a mixed level of recognition among farmers, suggesting that while some acknowledge the importance of crop residues, a substantial proportion remains uncertain or unconvinced about their value. This underscores the critical need for improved extension services, targeted training programs, and awareness campaigns to promote the sustainable use of crop residues in livestock farming. A lack of awareness about the advantages of crop residue utilisation may stem from multiple factors. Some farmers may not have enough exposure to sufficient information on the environmental and economic benefits of incorporating residues into cattle feeding systems (Sarkar et al., 2020). Without adequate education, they may perceive crop residues as agricultural waste rather than a valuable resource that can enhance farm productivity and sustainability (Duguma & Janssens, 2021). Furthermore, traditional feeding practices, which rely heavily on conventional feed sources, may contribute to farmers’ reluctance to adopt new approaches, especially if they are unfamiliar with the nutritional potential of crop residues.

Another possible explanation for the scepticism among farmers is the absence of practical demonstrations or success stories within their communities (Li et al., 2022). Farmers are more inclined to

adopt innovative practices when they witness tangible benefits from their peers' experiences. However, in the absence of firsthand exposure to the positive outcomes of crop residue utilisation, they may be hesitant to incorporate it into their farming systems (Abdullah et al., 2021). This highlights the importance of farmer-to-farmer knowledge sharing, field trials, and extension-led demonstrations to illustrate the real-world advantages of crop residues in cattle farming. Furthermore, logistical and technical challenges may contribute to the lower recognition of crop residue significance. Some farmers may be aware of the potential benefits but struggle with practical barriers such as proper storage, processing, or feed formulation. Without access to the necessary tools, infrastructure, or expert guidance, they may find it a challenge to maximise the effectiveness of crop residues in their feeding systems. This could lead to a perception that residue utilisation is not as beneficial or significant as other feed options.

3.10 Integration of Agricultural Waste in Farming Systems

More than half (51.3%) of the respondents disagreed with the notion that practising an integrated farming system is equivalent to utilising agricultural waste for cattle feed (Mean = 3.2). This finding suggests a potential gap in understanding the broader principles of integrated farming, which may necessitate targeted training programs to enhance farmers' knowledge and awareness. Integrated farming is a holistic approach incorporating multiple agricultural activities such as crop cultivation, livestock rearing, aquaculture and agroforestry to optimise resource utilisation, improve productivity and promote sustainability (Sudrajat et al., 2020). One of the key aspects of an integrated farming system is the efficient recycling of agricultural byproducts, such as crop residues, manure and other organic materials, which can be repurposed as animal feed, compost, or bioenergy sources (Wijerathna-Yapa & Pathirana, 2022).

The reluctance or misunderstanding among farmers regarding the role of agricultural waste in integrated farming may be attributed to traditional farming practices, limited access to information, or concerns about the practicality and economic viability of such methods (Kamarudin et al., 2025). To tackle these challenges, comprehensive training programs and extension services should be implemented to educate farmers on the benefits of integrating crop and livestock production, as well as the various ways of efficiently utilising agricultural waste. These programs should emphasise real-world applications, provide demonstrations and offer technical guidance to encourage farmers to adopt sustainable waste management practices.

4. CONCLUSION

This study provides valuable insights into the factors influencing the adoption of crop residues as cattle feed in Peninsular Malaysia, with a specific focus on Kelantan. While a moderate level of acceptance exists among farmers, the overall adoption rate remains limited. The research highlighted key barriers, including economic constraints, inadequate infrastructure and insufficient knowledge, which hinder widespread utilisation. One of the study's key contributions is its comprehensive analysis of the interplay between socioeconomic variables and adoption behaviour, which offers a clearer understanding of the conditions under which farmers are more likely to incorporate crop residues into their livestock feeding practices. This study confirmed existing findings regarding the importance of economic and informational support but extended the discourse by emphasising the regional nuances and practical challenges specific to Kelantan.

To translate these findings into action, policymakers and agricultural stakeholders must consider multifaceted strategies. Financial assistance in the form of subsidies or low-interest loans can mitigate cost barriers. Simultaneously, structured training programs tailored to local contexts should be developed to enhance farmers' technical know-how. Moreover, awareness campaigns through traditional and digital media can further bridge knowledge gaps and promote the benefits of crop residue utilisation. Integrating crop residues into sustainable livestock feeding systems not only promises enhanced productivity but also supports broader goals of agricultural sustainability and environmental conservation.

4.1 Suggestions for Future Research

Future research should focus on advancing the utilisation of crop residues as cattle feed through the identification and development of cost-effective and accessible technologies. Innovations such as affordable silage-making equipment and mobile feed-processing units tailored to smallholder needs could significantly enhance adoption rates. Investigations into government subsidy schemes, cooperative funding models and microfinance solutions are critical to addressing the financial constraints that limit uptake. Moreover, studies should evaluate the design and effectiveness of training modules and extension services, particularly in terms of their ability to build technical skills and promote behavioural change among farmers. Environmental assessments should also be prioritised to explore how crop residue-based feeding systems contribute to lowering greenhouse gas emissions, improving soil health and optimising resource use. Comparative studies across various agroecological zones can uncover regional differences in adoption patterns and effectiveness, while also identifying other underutilised agricultural byproducts, such as oil palm fronds and pineapple waste as viable feed alternatives.

In addition, future research should incorporate a socio-anthropological lens to examine how factors like education level, gender dynamics, household decision-making structures and access to farming resources influence adoption behaviour. Lastly, longitudinal studies assessing the impact of integrated crop-livestock systems on productivity, profitability and ecological sustainability would provide a more holistic understanding and inform the design of long-term solutions for promoting the adoption of crop residues in the Malaysian cattle industry.

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CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest regarding the publication of this journal. All efforts have been made to ensure that the research was conducted in an objective manner, free from any influence that could affect the integrity or outcomes of the study. No financial, professional, or personal relationships have influenced the research findings, interpretations, or conclusions presented in this work.

AUTHORS' CONTRIBUTION

Muhammad Aidil Ikhwan contributed to the conceptualisation, data curation, formal analysis, investigation, methodology and writing of the original draft. Fazleen Abdul Fatah Farah was involved in conceptualisation, data curation, formal analysis, investigation, methodology and project administration, as well as writing the original draft and reviewing and editing the manuscript. Farah Adila Abdullah contributed to conceptualisation, funding acquisition, investigation, methodology and project administration. Nur Aziera Ruslan participated in conceptualisation, methodology and project administration. Mohd Nur Badriyah Kamarul Zaman contributed to conceptualisation, methodology, and project administration. Finally, Tengku Halimatun Sa'adiah T Abu Bakar was involved in conceptualisation, methodology and project administration.

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