

Reducing Greenhouse Gas Emissions in Beef Cattle Farming through the Implementation of Animal Welfare Principles, as Part of Sustainable Rural Area Development

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Received: January 3, 2024

Revised: March 15, 2024

Accepted: April 25, 2024

Published: April 30, 2024

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DOI: [10.29303/jppipa.v10i4.6824](https://doi.org/10.29303/jppipa.v10i4.6824)

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Abstract: The beef cattle farming industry is facing a dual challenge - the need to reduce greenhouse gas emissions to combat climate change and the imperative to enhance the daily weight gain of cattle to meet growing global demand for meat. The integration of animal welfare principles stands out as a crucial and multifaceted solution that not only mitigates greenhouse gas emissions but also improves the daily weight gain of beef cattle. The results of this study indicate that the implementation of animal welfare guidelines plays a pivotal role in reducing greenhouse gas emissions. By providing cattle with appropriate nutrition, minimizing stress, and ensuring a healthy and stress-free environment, the emission of methane, a potent greenhouse gas, can be significantly lowered. This approach is not just ecologically responsible; it is essential for meeting international climate commitments and preserving the health of the planet's ecosystems. In addition to its environmental benefits, the integration of animal welfare practices has a profound economic impact. Healthy and content cattle are more likely to exhibit efficient digestion and increased feed utilization, leading to higher daily weight gains. This directly improves the productivity and profitability of beef cattle farming operations. Furthermore, the production of higher-quality meat from well-cared-for animals can drive market demand and revenue, strengthening the industry's economic viability.

Keywords: Animal Welfare; Beef Cattle Farming; Greenhouse Gas Emissions; Mitigation

Introduction

The demand for animal protein derived from beef cattle in Indonesia has shown a significant annual increase. In 2022, beef consumption reached 2.23 kg per capita per year and is projected to rise to 2.41 kg per capita per year by 2029. However, this consumption level still falls far below the global average beef consumption of 6.33 kg per capita per year (OECD-FAO, 2022). The low meat consumption rates also have an impact on the insufficient intake of animal protein in the Indonesian population, particularly among those in the lower to middle-income brackets. Yet, animal protein is recognized as a valuable food source, especially for the

growth and development of children, owing to its complete amino acid profile (Day et al., 2022).

Despite a consistent annual population growth rate of beef cattle over the past five years, which stands at 2.53%, the overall demand for beef, estimated at approximately 30% to 40%, continues to be met through beef and live cattle imports. It is projected that the beef deficit will continue to increase, reaching 268 thousand tons by the year 2024 (Kementan, 2020).

The high demand for beef, coupled with the low production of local beef cattle, prompted the government to launch the 'SIWAB' program in 2017, which was later renamed 'SIKOMANDAN' in 2020. This program aimed to implement mass artificial insemination to boost the local cattle population. The

How to Cite:

Saefullah, E., Kenedi, K., & Khaerudin, D. (2024). Reducing Greenhouse Gas Emissions in Beef Cattle Farming through the Implementation of Animal Welfare Principles, as Part of Sustainable Rural Area Development. *Jurnal Penelitian Pendidikan IPA*, 10(4), 1468-1476. <https://doi.org/10.29303/jppipa.v10i4.6824>

program proved successful, resulting in a significant increase in the beef cattle population by 9% compared to 2017, reaching 18.05 million head in 2021 (Badan Pusat Statistik, 2022).

However, the increase in beef cattle population has been accompanied by the issue of a rising contribution to greenhouse gas (GHG) production, which is one of the major sources of global warming and climate change (Munawaroh & Widiawati, 2017). Beef cattle farming is a significant source of methane emissions (Vechi et al., 2022). Methane, a potent greenhouse gas, is released during enteric fermentation in cattle's stomachs and during manure decomposition (Smith et al., 2021). The global livestock sector, particularly beef production, contributes substantially to methane emissions. This methane, although relatively short-lived in the atmosphere compared to carbon dioxide (CO₂), has a significantly higher warming potential, making it a major driver of climate change (Mar et al., 2022).

According to a report by the FAO, the emission intensity (emission per unit of product) from beef production has nearly reached 300 kg CO₂-eq per kilogram of protein produced, the highest among livestock products. Globally, agricultural activities from crop and livestock production released significant non-CO₂ emissions (methane (CH₄) and nitrous oxide (N₂O)), totaling 5.3 Gt CO₂eq in 2018, marking a 14% increase from 2000, with cattle farming contributing two-thirds of that total. The report also highlights that the largest contributions, accounting for 39% and 20% of the total GHG emissions from the livestock sub-sector, come from enteric fermentation in the digestive systems of ruminant animals and livestock manure. Indonesia itself ranks as the fifth-largest emitter globally from agricultural activities (crop and livestock production) with nearly 200 million tons of CO₂eq (FAO, 2021).

Sustainability aspects in beef cattle farming have become a paramount concern in the livestock industry today, particularly concerning animal welfare. The Farm Animal Welfare Council (FAWC), in its report titled 'Sustainable Agriculture and Farm Animal Welfare,' emphasizes that animal welfare is an integral part of sustainable agriculture. The discussion of this concept is driven by the perception of the need to produce more food to feed the ever-growing global population while simultaneously striving to protect the environment and reduce or prevent contributions to climate change (FAWC, 2016).

From this report, the urgency of establishing a beef cattle farming model that integrates economic, environmental, and social aspects as part of sustainable development becomes essential for research. Sustainability, which takes into account carbon footprint, business income, and animal welfare, as

depicted in the following scheme, is vital for investigation (Galioto et al., 2017).

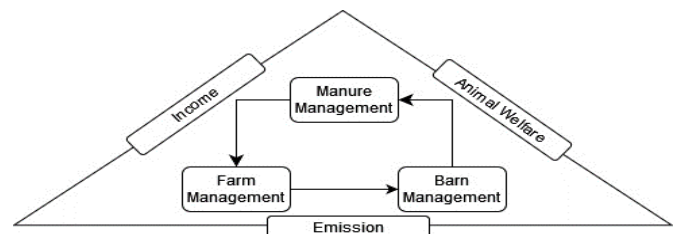


Figure 1. The Relationship Between Emissions, Income, and Animal Welfare

From Figure 1, it can be observed that animal welfare principles are an inseparable part of creating a sustainable livestock industry. Various strategies for mitigating greenhouse gas emissions (GHG) involving changes in beef cattle farming practices have become crucial and should continue to be promoted. It is essential to consider sustainability aspects, ensuring economic viability, social and cultural responsibility, and environmental friendliness. This situation creates a paradox that requires open-minded thinking, with the hope of building a path towards sustainable livestock development. In this context, the role of livestock as a producer of animal protein can be realized while also contributing to global agreements on greenhouse gas emissions. This dual role can lead to responsible global citizenship.

Several previous studies have attempted to develop models for reducing greenhouse gas (GHG) emissions in beef cattle farming. For example, the Whole-Farm Approach has concluded that changes in soil carbon content can have a significant impact on assessing the GHG emission intensity of beef production in grassland farming systems (Samsonstuen et al., 2019). Additionally, an integrated model combining dairy and beef cattle, resulting in crossbred calves, was able to reduce annual GHG emissions from beef production by nearly 2000 kt CO₂e or 22% in New Zealand (Blignaut et al., 2022). Genetic selection methods conducted in Spain are estimated to reduce total methane emissions by 2% to 5% over the next 10 years (van Selm et al., 2021).

Other research has emphasized the importance of good feed management as a key element in managing GHG and nitrogen emissions in beef cattle farming systems (González-Recio et al., 2020). Extensive production systems, where cattle graze in open pastures and are fed natural forage, can enhance carbon sequestration capacity (Ouatahar et al., 2021). Combining biochar with livestock manure through either direct mixing or co-composting has proven effective in stabilizing nutrients and reducing greenhouse gas emissions (GHG) during manure

processing (El-Naggar et al., 2019; Escribano et al., 2022; Oldfield et al., 2018).

However, research bridging the gap between reducing GHG emissions while considering animal welfare principles in efforts towards sustainable rural development has been limited. To address this gap, this study aims to develop a GHG emission reduction model while considering animal welfare principles, thereby promoting sustainable rural development.

Addressing greenhouse gas emissions from beef cattle farming is an urgent global imperative. It is essential for mitigating climate change, safeguarding the sustainability of the industry itself, fulfilling international climate commitments, preserving biodiversity, and meeting consumer preferences for environmentally conscious food production. Immediate and concerted efforts to reduce emissions in this sector are necessary for a more sustainable and resilient future.

Method

The method employed in this research is a mixed-method approach, combining both quantitative and qualitative methods. The choice of using a mixed-method approach is based on the complexity and variability of variables involved in the research, such as environmental aspects, animal production, animal welfare, and greenhouse gas emissions. The use of a mixed-method approach can assist in broadening the scope of the research and gaining a deeper understanding of the research issues (Timans et al., 2019).

The population in this study consists of beef cattle farming/feedlot enterprises that engage in the fattening of imported feeder cattle from Australia while

implementing the concept of animal welfare. The research samples are categorized into three groups based on the population of cattle kept during each fattening period, namely feedlots with populations of up to 5000 head of beef cattle, 5001-10000 head, and above 10000 head, with feedlot locations spread across the provinces of Banten, West Java, and Lampung. Data collection for primary data was obtained through surveys, interviews, observations, and measurements. Meanwhile, secondary data was obtained from literature reviews, documents, and media studies. The number of cattle selected as observation samples was determined using a cross-sectional research formula (Hsieh & Liu, 1990). The formula as represented by Formula 1.

$$n = \frac{Z\alpha^2 \cdot p \cdot (1-p)}{e^2} \tag{1}$$

Where:

n = number of samples

Zα² = The z-value at a certain level of confidence (α = 5% Z= 1.96)

p = The proportion of the population with specific characteristics (Imported cattle population = 9.81%)

e = Margin of error or allowable standard error (5%)

$$n = \frac{1,96^2 \cdot 0,0981 \cdot (1-0,0981)}{0,05^2}$$

$$n = 136$$

Since there are three categories of farms based on the cattle population during the fattening period, the total number of beef cattle taken as observation samples is 408 head.

The observation and data collection period spanned for three months (June - August 2023). An overview of the research object can be seen in the Table 1.

Table 1. Research Object Description

Category	Location	Cattle Population	Cattle Type	Feed Proportion	Sample
> 10.000	Lampung	11,256	Brahman Cross (BX)	> 85 % concentrate	136
	West Java	10,280	Brahman Cross (BX)	> 85 % concentrate	
	West Java	6,455	Brahman Cross (BX)	> 85 % concentrate	
5001 - 10.000	West Java	6,923	Brahman Cross (BX)	> 85 % concentrate	136
	Lampung	7,531	Brahman Cross (BX)	> 85 % concentrate	
	Banten	3,412	Brahman Cross (BX)	> 85 % concentrate	
< 5000	Banten	4,211	Brahman Cross (BX)	> 85 % concentrate	136
	West Java	3,980	Brahman Cross (BX)	> 85 % concentrate	
	West Java	2,535	Brahman Cross (BX)	> 85 % concentrate	
	West Java	3,725	Brahman Cross (BX)	> 85 % concentrate	

Animal Welfare

To assess the implementation of animal welfare, this research utilizes guidelines and instruments developed by the Farm Animal Welfare Council (FAWC), an institution focused on the welfare of farm animals in the United Kingdom, which has developed

the concept of the 'Five Freedoms' to measure the welfare of farm animals. These Five Freedoms serve as general guidelines used to ensure that farm animals such as beef cattle are provided with appropriate care and conditions for their welfare. The guidelines for

measuring these Five Freedoms are as follows (FAWC, 2016).

Freedom from Hunger and Thirst: To measure this freedom in beef cattle, it is essential to ensure that the animals have continuous access to an adequate supply of food and clean water. This involves providing appropriate food in terms of quantity and quality and allowing unrestricted access to a clean and safe water source; **Freedom from Discomfort:** It is crucial to ensure that beef cattle are placed in a comfortable environment. This includes protection from extreme weather conditions such as rain, heat, and cold. Properly designed pens and shelter arrangements can help fulfill this freedom; **Freedom from Pain, Injury, and Disease:** Measuring this freedom involves monitoring and regularly providing healthcare to the animals, ensuring that beef cattle do not suffer from untreated pain or injuries. This includes appropriate vaccination and medical care when needed; **Freedom to Express Normal Behavior:** Beef cattle have natural behaviors such as grazing, roaming, and lying down, so it is necessary to ensure that their farming environment allows for the expression of these natural behaviors. This may involve providing sufficient space and access to pasture or exercise areas; and **Freedom from Fear and Distress:** Measuring this freedom means ensuring that beef cattle do not experience excessive stress or fear. This may involve gentle handling, avoiding disturbing situations, and providing a peaceful environment.

These five freedoms are then observed in each randomly selected sample of cattle and assessed on a scale from 0 to 100 for each indicator, based on the assessment categories according to Welfare Quality (Veissier, 2020). The criteria for assessing the implementation of animal welfare principles can be seen in the following Table 2.

Tabel 2. Animal Welfare Score

Score	Criteria
0 - 20	Not Classified
21 - 59	Acceptable Welfare
60 - 80	Enhanced Welfare
81 - 100	Excellent Welfare

Greenhouse Gas Emissions

To calculate the CH₄ emissions produced by beef cattle, this study focuses solely on cattle manure generated from the enteric fermentation process, which is the microbial fermentation process that occurs in the digestive system of four-legged animals, including cattle, goats, sheep, and other ruminant animals (Olijhoek et al., 2018).

This process occurs in the front part of their digestive tract, primarily in the rumen, which is a specialized compartment in their digestive system.

Methane gas (CH₄) is a byproduct of this enteric fermentation and is typically released by animals when they eructate (belch) or flatulate (fart), as well as during defecation (van Gastelen et al., 2015). Methane emissions from enteric fermentation are a significant contributor to greenhouse gas emissions in the livestock sector and have been a focus of environmental mitigation efforts in animal farming (Moate et al., 2020).

The instrument used to measure CH₄ generated from cattle manure is a portable natural gas analyzer with an accuracy level of ≤ 5% F.S. To obtain accurate results, measurements are taken twice for each instance of manure expulsion from each beef cattle selected as observation samples. In addition to measuring using the gas analyzer, a comparison is also made by calculating the level of methane produced by the enteric fermentation of beef cattle based on guidelines from the Intergovernmental Panel on Climate Change (IPCC) using Tier 1 (IPCC, 2006) and Tier 2 (Widiawati et al., 2016) calculation methods. The formula used is: CH₄ emission = EF_(T) × (N_(T)/10⁶) × 21/1000

The equation calculates CH₄ emissions in gigagrams of CO₂-equivalents per year (Gg CO₂-e/year) from enteric fermentation. It involves the emission factor (EF_T), which is unique to each sub-category of beef cattle and denotes the amount of CH₄ emissions per head per year in kilograms (kg CH₄/head/year). N_T represents the population of beef cattle within each sub-category T in Indonesia, measured in head. T signifies the specific sub-category of beef cattle in Indonesia. The conversion factor from CH₄ to CO₂-equivalents is 21/1000.

Average Daily Gain

The research method employed is the data recording observation method. The data obtained are in the form of secondary data. The data obtained were analyzed using a Balanced Completely Randomized Design (BCRD) with a factorial pattern consisting of one treatment factor, frame, and body weight treatment (Collins, 2018). Average daily weight gain is calculated by dividing the weight gain during the fattening period by the duration of fattening (Day of feed) in kilograms.

Result and Discussion

Animal Welfare Principles

The process of assessing farms that implement animal welfare concepts based on the FAWC (Farm Animal Welfare Council) involves a systematic evaluation of various aspects of animal welfare. The following are the general steps in this observation process: **Parameter Identification:** Identify the parameters or indicators used to measure animal welfare. FAWC has developed the "five freedoms" as general guidelines for assessing animal welfare,

including aspects such as freedom from hunger and thirst, freedom from discomfort, and others; Visual Observation: Researchers will conduct visual observations of the animals on the farm. Observe the physical condition of the animals, their behavior, and the environment they inhabit; Physical Examination: Physical examination may involve checking the animals' physical condition, including assessing body weight, body condition, and signs of health, including eyes, nose, and skin.

Environmental Evaluation: The environment where the animals reside is also evaluated, including the cleanliness of the pens, temperature, humidity, ventilation, and the presence of protection from extreme weather; Interaction with Humans: Observations also include how animals interact with humans. This includes how animals respond to handling by farmers or caretakers; Data Recording: Data from these observations are systematically recorded. This data is then used to calculate animal welfare scores based on predefined parameters; Scoring Assessment: Animal welfare scores are calculated based on the observed parameters. These scores can range from 0 to 100, where higher scores indicate better animal welfare; and Result Interpretation: The assessment results are used to evaluate the level of animal welfare on the farm. If there are issues or deficiencies, improvement measures can be recommended.

This observation process aims to ensure that animals raised on the farm receive proper care and adequate environmental conditions for their welfare. It can also help farmers or farm owners improve their practices to be more animal-friendly and in line with the concept of good animal welfare. The observation results can be seen in the Table 3.

Based on the calculation results presented in Table 3, it was found that farms with a population of > 10,000 head and between 5001 - 10,000 head scored 82 and 73, respectively, falling into the category of "Excellent and

Enhanced Welfare." This indicates that the animals have a higher level of welfare than those that only meet the minimum standards. This includes factors that provide extra welfare to the animals, such as a more natural environment or better care. Meanwhile, farms in the category with a population below 5000 head scored 58, placing them in the "Acceptable Welfare" category. This indicates that the level of animal welfare meets the minimum accepted standards. In this category, animals have access to food, water, comfort, and freedom from unnecessary pain or suffering, but they do not reach a higher level of welfare.

Table 3. The results of the Animal Welfare Principles

Beef Population	Average Score	Criteria
> 10.000	82	Excellent Welfare
5001 - 10.000	73	Enhanced Welfare
< 5000	58	Enhanced Welfare

However, these results cannot be taken as a definitive indicator that the feedlot-raised beef cattle are genuinely well-off, as noted by (McCulloch, 2013) in his research that the primary drawback of the Five Freedoms is their inherent idealistic nature. Being framed as ideals, the freedoms alone cannot definitively assess whether an animal's welfare is deemed unacceptable, satisfactory, or excellent

Estimation of Methane Emission

The measurement of methane (CH₄) emissions from enteric fermentation in livestock, including beef cattle, is a process to estimate the amount of methane gas produced during the microbial fermentation process in the digestive system of animals. This process primarily occurs in specialized compartments such as the rumen in four-legged animals that have a rumen-based digestive system, such as cattle. The results of calculations and measurements using Tier 1, Tier 2, and gas analyzer methods are presented in detail in the Table 4.

Table 4. Methane (CH₄) Emissions from Enteric Fermentation

Category	Beef Population	Tier 1 (CO ₂ -e Gg/Year)	Tier 2 (CO ₂ -e Gg/Year)	Gas Analyzer (CO ₂ -e Gg/Year)
> 10.000	21,536	0.0213	0.0115	0.0110
5001 - 10.000	20,909	0.0206	0.0112	0.0107
< 5000	17,863	0.0176	0.0096	0.0091
Total	60,308	0.0595	0.0323	0.0309

Based on table 4, the calculations using Tier 1, the methane (CH₄) emission rate produced by each imported beef cattle for fattening are 0.0595 CO₂-e Gg/year. When calculated using Tier 2, the result is 0.0323 CO₂-e Gg/year. Methane emissions measured using a gas analyzer on the imported beef cattle

fattening farm that adheres to animal welfare standards yield a methane emission rate of 0.0309 CO₂-e Gg/year. Compared to Tier 1, this result is lower by approximately 48.17%, and when compared to Tier 2, there is a reduction of 11.18% in methane emission rates from enteric fermentation of animal manure. The

implementation of animal welfare principles in beef cattle farming can help reduce methane (CH₄) emissions in several ways. Ensuring better nutrition, with balanced and adequate nutrient intake, is crucial in diminishing methane emissions (Geyik et al., 2022).

Properly nourished cattle tend to have more efficient digestive systems, resulting in lower methane production during food digestion (Kenny et al., 2018). Effective feed management practices, such as using high-quality feed and accurate feeding schedules, can further reduce methane generated during the digestion process (Chojnacka et al., 2021). Additionally, reducing stress in animals through proper care and suitable living conditions contributes to lower methane emissions, as stress-induced adrenaline can affect the animals' digestive systems (Romero et al., 2015; Wrzecińska et al., 2021). Improved waste management, involving efficient waste processing systems, also plays a role in reducing methane emissions from livestock waste (Ahirwar & Tripathi, 2021). Integrating animal welfare practices not only benefits animal well-being but also mitigates environmentally harmful methane emissions. By incorporating these principles in beef cattle farming, farms can foster environmental sustainability and contribute to global efforts to reduce greenhouse gas emissions, thereby combating climate change.

These findings support the research conducted by (Llonch et al., 2017), which explains that mitigation

strategies to reduce methane emissions by implementing animal welfare standards have the potential to reduce emissions by 3% to 6% solely from improvements in animal health and welfare. The findings of this study also support (Niloofar et al., 2021) which states that effective approaches for mitigating greenhouse gas emissions from livestock involve enhancing the quality and digestibility of animal feed, enhancing the well-being and health of animals, and implementing comprehensive manure management, which encompasses the gathering, storage, and productive utilization of manure.

Estimation of Average Daily Gain

In the beef fattening industry, achieving daily weight gain is of utmost importance, with a 120-day fattening period per cycle. Therefore, the target weight gain of cattle in kilograms per day must be met, and high-quality feed plays a critical role in achieving this goal. Imported Brahman Cross (BX) cattle from Australia, based on observations during the data collection period in this study, are typically provided with high-quality concentrate feed. The concentrate-to-roughage ratio exceeds 85 percent, and the feeding process adheres to the principles of animal welfare, ensuring that the animals are free from hunger and thirst. The average daily weight gain, as calculated, is presented in the Table 5.

Table 5. Average Daily Weight Gain

Category	Beef Population	Sample	Initial Body Weight (Kg)	Average Daily Gain (Kg/Day)
> 10.000	21,536	136	> 350	1.15 ± 0.30
5001 - 10.000	20,909	136	> 350	1.14 ± 0.32
< 5000	17,863	136	> 350	1.19 ± 0.33
Total	60,308	408		1.16 ± 0.32

Based on the data in Table 5, the daily weight gain in each population category of cattle is not significantly different. The average daily weight gain for Brahman Cross (BX) cattle with a body weight of > 350 Kg reaches 1.16 Kg/Day, and this weight gain is achieved in the third month of the fattening period. This result is slightly higher than a previous study conducted by (Firdausi et al., 2012) which reported a daily weight gain of 1.13 Kg/Day for cattle with a body weight of > 350 Kg.

The implementation of animal welfare principles not only has the potential to reduce greenhouse gas emissions produced by beef cattle farming but also offers economic benefits due to its association with efforts to enhance livestock daily weight gain. This is a critical component of beef cattle farming productivity, and it occurs for several reasons. It enhances the overall health and physical condition of the cattle, promoting increased activity, better eating habits, and more efficient digestive systems, consequently elevating the

daily weight gain rate (Sinclair et al., 2019). Furthermore, it leads to improved feed utilization efficiency, ensuring that the cattle make optimal use of nutrition with adequate access to water, facilitating growth and weight gain. Additionally, creating an environment aligned with animal welfare principles reduces stress and tension in beef cattle (Place, 2018). Stress reduction improves their feed utilization and metabolic processes, positively impacting their daily weight gain (Gonzalez-Rivas et al., 2020).

Better care results in the production of higher-quality meat, characterized by superior texture, flavor, and nutritional value (Clinquart et al., 2022). Disease and infection risks are mitigated through the implementation of animal welfare guidelines, supported by clean and hygienic housing conditions and effective livestock management practices, preventing disease transmission. The health and proper care of beef cattle correlate with increased productivity and profitability of

farms, and this, in turn, has favorable implications for the environment (McAllister et al., 2020). Animal welfare principles also influence waste management and overall environmental impact (Singh & Rashid, 2017). By ensuring the comfort and safety of the animals, livestock waste can be managed efficiently and sustainably. The application of animal welfare principles extends beyond daily weight gain improvements; it enhances the overall well-being and quality of life for cattle. These benefits are advantageous not only for farmers but also for consumers and the environment.

Conclusion

The implementation of animal welfare principles in beef cattle farming presents a multifaceted opportunity that encompasses both environmental and economic advantages. This holistic approach addresses two vital aspects: the mitigation of greenhouse gas emissions and the enhancement of daily weight gain in beef cattle. First and foremost, the application of animal welfare guidelines has the potential to substantially reduce greenhouse gas emissions within the beef cattle industry. By ensuring that cattle receive adequate nutrition and care, and by providing a stress-free and healthy environment, methane emissions can be curtailed significantly. Improved feeding practices, stress reduction, and efficient waste management contribute to this reduction, aligning with global initiatives to combat climate change and reduce the industry's carbon footprint. This environmentally-conscious approach is vital for meeting international climate commitments and preserving the planet's ecosystems. Simultaneously, the integration of animal welfare practices also yields economic benefits for beef cattle farming operations. By focusing on the well-being of cattle, farmers can achieve higher daily weight gains. Healthier and less stressed cattle tend to have more efficient digestive systems, leading to increased feed utilization and better overall growth. The economic ramifications are substantial, as this can enhance the productivity and profitability of the farming enterprise. High-quality meat production resulting from well-cared-for animals can further boost market demand and overall revenue.

Acknowledgments

On this occasion, the research team would like to express their gratitude to the Directorate General of Higher Education, Ministry of Education, Culture, Research, and Technology, for funding this research.

Author Contribution

This article was prepared by three authors, namely A.S., M.F, and H. All members of the writing team carried out each stage together.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

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