China Petroleum Processing and Petrochemical Technology

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 4476-4491

IMPLEMENTATION OF ANIMAL WELFARE PRINCIPLES AS A MITIGATION STRATEGY FOR REDUCING GREENHOUSE GAS EMISSIONS IN BEEF CATTLE FARMING OPERATIONS

Encep Saefullah[1], Kenedi[2*], and Dedy Khaerudin[3]

[1]Department of Management, Faculty of Economic and Business, Universitas Bina Bangsa, Serang, Indonesia

[2]Department of Economic, Faculty of Economic and Business, Universitas Bina Bangsa, Serang, Indonesia

[3]Department of Industry, Faculty of Science and Technology, Serang, Indonesia

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, greenhouse gas emissions, beef cattle farming, mitigation, sustainability

Abstrak

Industri peternakan sapi potong menghadapi dua tantangan sekaligus - perlunya mengurangi emisi gas rumah kaca untuk mengatasi perubahan iklim dan keharusan untuk meningkatkan pertambahan bobot harian ternak guna memenuhi permintaan daging yang terus meningkat secara global. Integrasi prinsip kesejahteraan hewan muncul sebagai solusi yang krusial dan kompleks yang tidak hanya mengurangi emisi gas rumah kaca tetapi juga meningkatkan pertambahan bobot harian sapi potong. Hasil dari penelitian ini menunjukkan bahwa penerapan kaidah kesejahteraan hewan memiliki peran sentral dalam mengurangi emisi gas rumah kaca. Dengan memberikan nutrisi yang sesuai, mengurangi stres, dan memastikan lingkungan yang sehat dan bebas stres bagi sapi potong, emisi metana faktor penting dalam pembentukan gas rumah kaca, dapat berkurang secara signifikan. Pendekatan ini tidak hanya bertanggung jawab secara ekologis; namun juga untuk memenuhi komitmen iklim internasional dan menjaga kesehatan ekosistem planet ini. Selain manfaat lingkungan, integrasi praktik kesejahteraan hewan memiliki dampak ekonomi yang mendalam. Sapi yang sehat dan bahagia cenderung memiliki sistem pencernaan yang lebih efisien dan memanfaatkan pakan dengan lebih baik, menghasilkan pertambahan bobot harian yang lebih tinggi. Ini secara langsung meningkatkan produktivitas dan profitabilitas operasi peternakan sapi potong. Selain itu, produksi daging berkualitas tinggi dari hewan yang mendapat perawatan baik dapat meningkatkan permintaan pasar dan pendapatan, memperkuat kelangsungan ekonomi industri ini.

Kata Kunci: kesejahteraan hewan, emisi gas rumah kaca, peternakan sapi potong, mitigasi, keberlanjutan

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 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 (CO_2), 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 CO_2-eq per kilogram of protein produced, the highest among livestock products. Globally, agricultural activities from crop and livestock production released significant non-CO_2 emissions (methane (CH_4) and nitrous oxide (N2O)), totaling 5.3 Gt CO_2eq 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 CO_2eq (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).

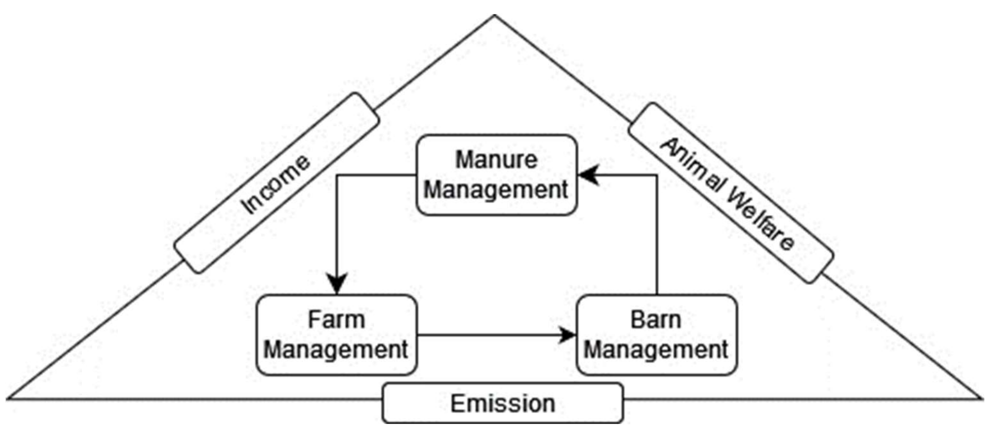

Figure 1. The Relationship Between Emissions, Income, and Animal Welfare

From Figure 1 above, 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

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 4476-4491

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 CO_2e 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.

Materials and Methods

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 which was developed by Stanley Lemeshow et. (Hsieh & Liu, 1990).

The formula is as follows:

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

Where:

n = number of samples

$Z\alpha^2$ = 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%)

$$n = \frac{1{,}96^2 . 0{,}0981. (1 - 0{,}0981)}{0.05^2}$$

$$n = 136$$

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 following 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	
5001 - 10.000	West Java	6,455	Brahman Cross (BX)	> 85 % concentrate	136
	West Java	6,923	Brahman Cross (BX)	> 85 % concentrate	
	Lampung	7,531	Brahman Cross (BX)	> 85 % concentrate	

	Banten	3,412	Brahman Cross (BX)	> 85 % concentrate	
	Banten	4,211	Brahman Cross (BX)	> 85 % concentrate	
< 5000	West Java	3,980	Brahman Cross (BX)	> 85 % concentrate	136
	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):

1. 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.
2. 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.
3. 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.
4. 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.
5. 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

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 4476-4491

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 CH_4 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 (CH_4) 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 CH_4 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:

$$CH_4 \text{ emission} = EF_{(T)} \times (N_{(T)}/10^6) \times 21/1000$$

The equation calculates CH_4 emissions in gigagrams of CO_2-equivalents per year (Gg CO_2-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 CH_4 emissions per head per year in kilograms (kg CH_4/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 CH_4 to CO_2-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.

Results 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:

1. 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.
2. 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.
3. 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.
4. 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.
5. Interaction with Humans: Observations also include how animals interact with humans. This includes how animals respond to handling by farmers or caretakers.
6. Data Recording: Data from these observations are systematically recorded. This data is then used to calculate animal welfare scores based on predefined parameters.
7. 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.
8. 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 following table:

Tabel 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*

Source: Data Calculation

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.

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 (CH_4) 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 following table.

Tabel 4. Methane (CH_4) 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

Source: Data Calculation

Based on table 4, the calculations using Tier 1, the methane (CH_4) emission rate produced by each imported beef cattle for fattening are 0.0595 CO_2-e Gg/year. When calculated using Tier 2, the result is 0.0323 CO_2-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 CO_2-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 (CH_4) 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 below.

Tabel 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

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 4476-4491

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

Source: Data Calculation

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.

Conclusions

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.

These combined advantages demonstrate that the implementation of animal welfare principles is a win-win strategy for beef cattle farming. It offers a sustainable solution to reduce greenhouse gas emissions, aligning with global environmental goals, while concurrently boosting economic outcomes for the industry. This dual impact positions it as a comprehensive and practical approach for the future of beef cattle farming. As we navigate the challenges of a changing climate and a growing demand for responsibly sourced food products, the adoption of animal welfare principles emerges as a crucial element in achieving both environmental and economic sustainability.

Acknowledgement

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

References

Ahirwar, R., & Tripathi, A. K. (2021). E-waste management: A review of recycling process, environmental and occupational health hazards, and potential solutions. *Environmental Nanotechnology, Monitoring & Management*, *15*, 100409. https://doi.org/10.1016/j.enmm.2020.100409

Badan Pusat Statistik. (2022). *Peternakan Dalam Angka 2022*. Badan Pusat Statistik.

Blignaut, J., Meissner, H., Smith, H., & du Toit, L. (2022). An integrative bio-physical approach to determine the greenhouse gas emissions and carbon sinks of a cow and her offspring in a beef cattle operation: A system dynamics approach. *Agricultural Systems*, *195*(October 2021), 103286. https://doi.org/10.1016/j.agsy.2021.103286

Chojnacka, K., Mikula, K., Izydorczyk, G., Skrzypczak, D., Witek-Krowiak, A., Gersz, A., Moustakas, K., Iwaniuk, J., Grzędzicki, M., & Korczyński, M. (2021). Innovative high digestibility protein feed materials reducing environmental impact through improved nitrogen-use efficiency in sustainable agriculture. *Journal of Environmental Management*, *291*, 112693. https://doi.org/10.1016/j.jenvman.2021.112693

Clinquart, A., Ellies-Oury, M. P., Hocquette, J. F., Guillier, L., Santé-Lhoutellier, V., & Prache, S. (2022). Review: On-farm and processing factors affecting bovine carcass and meat quality. *Animal*, *16*, 100426. https://doi.org/10.1016/j.animal.2021.100426

Collins, L. M. (2018). *Balanced and Unbalanced Reduced Factorial Designs* (pp. 145–191). https://doi.org/10.1007/978-3-319-72206-1_5

Day, L., Cakebread, J. A., & Loveday, S. M. (2022). Food proteins from animals and plants: Differences in the nutritional and functional properties. *Trends in Food Science and Technology*, *119*(June 2021), 428–442. https://doi.org/10.1016/j.tifs.2021.12.020

El-Naggar, A., Lee, S. S., Rinklebe, J., Farooq, M., Song, H., Sarmah, A. K., Zimmerman, A. R., Ahmad, M., Shaheen, S. M., & Ok, Y. S. (2019). Biochar application to low fertility soils: A review of current status, and future prospects. *Geoderma*, *337*, 536–554. https://doi.org/10.1016/j.geoderma.2018.09.034

Escribano, M., Horrillo, A., & Mesías, F. J. (2022). Greenhouse gas emissions and carbon sequestration in organic dehesa livestock farms. Does technical-economic management matters? *Journal of Cleaner Production*, *372*(August). https://doi.org/10.1016/j.jclepro.2022.133779

FAO. (2021). Emissions due to agriculture. Global, Regional and Country Trends 2000–2018. FAOSTAT Analytical Brief Series No 18. Rome Cover. *No.18*, *7*(1), 87–98.

FAWC. (2016). *Sustainable agriculture and farm animal welfare*. *February*, 19.

Firdausi, A., Susilawati., T., Nasich., M., & Kuswati. (2012). Pertambahan bobot badan harian sapi brahman. *Jurnal Ternal Tropika*, *13*(1), 46–62.

Galioto, F., Paffarini, C., Chiorri, M., Torquati, B., & Cecchini, L. (2017). Economic, environmental, and animal welfare performance on livestock farms: Conceptual model and application to some case studies in Italy. *Sustainability (Switzerland)*, *9*(9). https://doi.org/10.3390/su9091615

Geyik, Ö., Hadjikakou, M., & Bryan, B. A. (2022). Climate-friendly and nutrition-sensitive interventions can close the global dietary nutrient gap while reducing GHG emissions. *Nature Food*, *4*(1), 61–73. https://doi.org/10.1038/s43016-022-00648-y

González-Recio, O., López-Paredes, J., Ouatahar, L., Charfeddine, N., Ugarte, E., Alenda, R., & Jiménez-Montero, J. A. (2020). Mitigation of greenhouse gases in dairy cattle via genetic selection: 2. Incorporating methane emissions into the breeding goal. *Journal of Dairy Science*, *103*(8), 7210–7221. https://doi.org/10.3168/jds.2019-17598

Gonzalez-Rivas, P. A., Chauhan, S. S., Ha, M., Fegan, N., Dunshea, F. R., & Warner, R. D. (2020). Effects of heat stress on animal physiology, metabolism, and meat quality: A review. *Meat Science*, *162*, 108025. https://doi.org/10.1016/j.meatsci.2019.108025

Hsieh, F. Y., & Liu, A. A. (1990). Adequacy of sample size in health studies. Stanley Lemeshow, David W. Hosmer Jr., Janelle Klar and Stephen K. Lwanga published on behalf of WHO by

Wiley, Chichester, 1990. No. of pages: xii + 233. Price:£D17.50. *Statistics in Medicine*, *9*(11), 1382–1382. https://doi.org/10.1002/sim.4780091115

IPCC. (2006). IPCC Guidelines for National Greenhouse Inventories. In *National Greenhouse Gas Inventories Programme*.

Kammann, C., Ippolito, J., Hagemann, N., Borchard, N., Luz, C. M., Estavillo, J. M., Fuertes-Mendizabal, T., Jeffery, S., Kern, J., Novak, J., Rasse, D., Saarnio, S., Schmidt, H.-P., Spokas, K., & Wrage-Monning, N. (2017). BIOCHAR AS A TOOL TO REDUCE THE AGRICULTURAL GREENHOUSE-GAS BURDEN – KNOWNS, UNKNOWNS AND FUTURE RESEARCH NEEDS. *Journal of Environmental Engineering and Landscape Management*, *25*(2), 114–139. https://doi.org/10.3846/16486897.2017.1319375

Kementan. (2020). Buku Outlook Komoditas Peternakan Daging Sapi Tahun 2020. *Pusat Data Dan Sistem Informasi Pertanian Sekretariat Jenderal Kementerian Pertanian*, *1907–1507*, 1–100. http://epublikasi.pertanian.go.id/download/file/579-outlook-daging-sapi-2020

Kenny, D. A., Fitzsimons, C., Waters, S. M., & McGee, M. (2018). Invited review: Improving feed efficiency of beef cattle – the current state of the art and future challenges. *Animal*, *12*(9), 1815–1826. https://doi.org/10.1017/S1751731118000976

Llonch, P., Haskell, M. J., Dewhurst, R. J., & Turner, S. P. (2017). Current available strategies to mitigate greenhouse gas emissions in livestock systems: an animal welfare perspective. *Animal*, *11*(2), 274–284. https://doi.org/10.1017/S1751731116001440

Mar, K. A., Unger, C., Walderdorff, L., & Butler, T. (2022). Beyond CO2 equivalence: The impacts of methane on climate, ecosystems, and health. *Environmental Science & Policy*, *134*, 127–136. https://doi.org/10.1016/j.envsci.2022.03.027

McAllister, T. A., Stanford, K., Chaves, A. V., Evans, P. R., Eustaquio de Souza Figueiredo, E., & Ribeiro, G. (2020). Nutrition, feeding and management of beef cattle in intensive and extensive production systems. In *Animal Agriculture* (pp. 75–98). Elsevier. https://doi.org/10.1016/B978-0-12-817052-6.00005-7

McCulloch, S. P. (2013). A Critique of FAWC's Five Freedoms as a Framework for the Analysis of Animal Welfare. *Journal of Agricultural and Environmental Ethics*, *26*(5), 959–975. https://doi.org/10.1007/s10806-012-9434-7

Moate, P. J., Deighton, M. H., Jacobs, J., Ribaux, B. E., Morris, G. L., Hannah, M. C., Mapleson, D., Islam, M. S., Wales, W. J., & Williams, S. R. O. (2020). Influence of proportion of wheat in a pasture-based diet on milk yield, methane emissions, methane yield, and ruminal protozoa of dairy cows. *Journal of Dairy Science*, *103*(3), 2373–2386. https://doi.org/10.3168/jds.2019-17514

Munawaroh, I. S., & Widiawati, Y. (2017). *Profil Emisi Gas Rumah Kaca dari Sapi Potong di 34 Provinsi Menggunakan Metode Tier-2*. *2*, 280–291. https://doi.org/10.14334/pros.semnas.tpv-2017-p.281-292

Niloofar, P., Francis, D. P., Lazarova-Molnar, S., Vulpe, A., Vochin, M. C., Suciu, G., Balanescu, M., Anestis, V., & Bartzanas, T. (2021). Data-driven decision support in livestock farming for improved animal health, welfare and greenhouse gas emissions: Overview and challenges.

Computers and Electronics in Agriculture, *190*(August), 106406. https://doi.org/10.1016/j.compag.2021.106406

OECD-FAO. (2022). *OECD-FAO Agricultural Outlook 2022-2031*.

Oldfield, T. L., Sikirica, N., Mondini, C., López, G., Kuikman, P. J., & Holden, N. M. (2018). Biochar, compost and biochar-compost blend as options to recover nutrients and sequester carbon. *Journal of Environmental Management*, *218*, 465–476. https://doi.org/10.1016/j.jenvman.2018.04.061

Olijhoek, D. W., Løvendahl, P., Lassen, J., Hellwing, A. L. F., Höglund, J. K., Weisbjerg, M. R., Noel, S. J., McLean, F., Højberg, O., & Lund, P. (2018). Methane production, rumen fermentation, and diet digestibility of Holstein and Jersey dairy cows being divergent in residual feed intake and fed at 2 forage-to-concentrate ratios. *Journal of Dairy Science*, *101*(11), 9926–9940. https://doi.org/10.3168/jds.2017-14278

Ouatahar, L., Bannink, A., Lanigan, G., & Amon, B. (2021). Modelling the effect of feeding management on greenhouse gas and nitrogen emissions in cattle farming systems. *Science of the Total Environment*, *776*, 145932. https://doi.org/10.1016/j.scitotenv.2021.145932

Place, S. E. (2018). Animal welfare and environmental issues. In *Advances in Agricultural Animal Welfare* (pp. 69–89). Elsevier. https://doi.org/10.1016/B978-0-08-101215-4.00004-3

Romero, L. M., Platts, S. H., Schoech, S. J., Wada, H., Crespi, E., Martin, L. B., & Buck, C. L. (2015). Understanding stress in the healthy animal – potential paths for progress. *Stress*, *18*(5), 491–497. https://doi.org/10.3109/10253890.2015.1073255

Samsonstuen, S., Åby, B. A., Crosson, P., Beauchemin, K. A., Bonesmo, H., & Aass, L. (2019). Farm scale modelling of greenhouse gas emissions from semi-intensive suckler cow beef production. *Agricultural Systems*, *176*(September 2018), 102670. https://doi.org/10.1016/j.agsy.2019.102670

Sinclair, M., Fryer, C., & Phillips, C. (2019). The Benefits of Improving Animal Welfare from the Perspective of Livestock Stakeholders across Asia. *Animals*, *9*(4), 123. https://doi.org/10.3390/ani9040123

Singh, A., & Rashid, M. (2017). Impact of animal waste on environment, its managemental strategies and treatment protocols to reduce environmental contamination. *VETERINARY SCIENCE RESEARCH JOURNAL*, *8*(1 and 2), 1–12. https://doi.org/10.15740/HAS/VSRJ/8.1and2/1-12

Smith, P., Reay, D., & Smith, J. (2021). Agricultural methane emissions and the potential formitigation. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *379*(2210), 20200451. https://doi.org/10.1098/rsta.2020.0451

Timans, R., Wouters, P., & Heilbron, J. (2019). Mixed methods research: what it is and what it could be. *Theory and Society*, *48*(2), 193–216. https://doi.org/10.1007/s11186-019-09345-5

van Gastelen, S., Antunes-Fernandes, E. C., Hettinga, K. A., Klop, G., Alferink, S. J. J., Hendriks, W. H., & Dijkstra, J. (2015). Enteric methane production, rumen volatile fatty acid concentrations, and milk fatty acid composition in lactating Holstein-Friesian cows fed grass silage- or corn silage-based diets. *Journal of Dairy Science*, *98*(3), 1915–1927.

https://doi.org/10.3168/jds.2014-8552

van Selm, B., de Boer, I. J. M., Ledgard, S. F., & van Middelaar, C. E. (2021). Reducing greenhouse gas emissions of New Zealand beef through better integration of dairy and beef production. *Agricultural Systems*, *186*(November 2020), 102936. https://doi.org/10.1016/j.agsy.2020.102936

Vechi, N. T., Mellqvist, J., & Scheutz, C. (2022). Quantification of methane emissions from cattle farms, using the tracer gas dispersion method. *Agriculture, Ecosystems & Environment*, *330*, 107885. https://doi.org/10.1016/j.agee.2022.107885

Veissier, I. (2020). The Overall On-farm Animal Welfare Score. *Welfare Quality*, 1–2. www.welfarequality.net

Widiawati, Y., Rofiq, M. N., & Tiesnamurti, B. (2016). Methane emission factors for enteric fermentation in beef cattle using IPCC Tier-2 method in Indonesia. *Jurnal Ilmu Ternak Dan Veteriner*, *21*(2), 101. https://doi.org/10.14334/jitv.v21i2.1358

Wrzecińska, M., Czerniawska-Piątkowska, E., & Kowalczyk, A. (2021). The impact of stress and selected environmental factors on cows' reproduction. *Journal of Applied Animal Research*, *49*(1), 318–323. https://doi.org/10.1080/09712119.2021.1960842