OSJ | OPEN SCIENCE JOURNAL

RESEARCH ARTICLE

Evaluating Enteric Fermentation Emissions in Ugandan Beef Production: Effects of Feeding Practices and Chloris Gayana Supplementation in Nakasangola and Mbarara Districts

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Citation: Maholo D.M., Ogola C., Kinyanjui W., Massimo C..(2024) Evaluating Enteric Fermentation Emissions in Ugandan Beef Production: Effects of Feeding Practices and Cloris Gayana Supplementation in Nakasangola and Mbarara Districts . Open Science Journal 9(2)

Received: 12th February 2024

Accepted: 27th June 2024

Published: 22nd August 2024

Funding: The author(s) received no specific funding for this work

Competing Interests: The authors have declared that no competing interests exists.

Abstract:

The rising concentrations of greenhouse gases (GHGs) in the atmosphere pose a significant threat to global climate stability, primarily due to human activities. Agriculture, particularly animal production, contributes substantially to GHG emissions, with cattle production systems being a major contributor. In Uganda, where livestock plays a central role in the economy, there is a need to balance economic growth with environmental sustainability. Our study aims to evaluate and mitigate GHG emissions in Ugandan beef production, focusing on enteric fermentation emissions. By examining the impact of feeding practices, including Chloris gayana supplementation, we seek to identify strategies for emission reduction. Through meticulous data collection and analysis in Mbarara and Nakasongola districts, we observed significant effects of body weight, daily weight gain, breed, and feeding systems on various parameters related to energy, methane yield, and emission intensity. While Ankole cattle showed higher weight gain in Mbarara, Chloris gayana supplementation increased methane emissions. Both breeds and feeding systems influenced weight gain and emission intensity in Nakasongola. These findings emphasize the need for tailored mitigation strategies in the Ugandan beef industry to balance productivity and environmental sustainability. We recommend stakeholders reconsider current feeding and breeding practices to optimize both aspects, emphasizing the importance of sustainable practices for the industry's future.

Keywords: Greenhouse gases (GHGs), Agriculture livestock emission reduction Feeding practices sustainability

Introduction

The surge in greenhouse gas (GHG) concentrations in Earth's atmosphere, primarily attributed to human activities, presents a critical challenge to global climate stability (IPCC, 2013). Notably, methane (CH4) concentrations have doubled, and nitrous oxide (N2O) levels have risen by 20% since pre-industrial times, underlining the urgency of addressing this trend. Agriculture emerges as a significant contributor to GHG emissions, with animal production alone responsible for 14.5% of human-induced emissions, with a substantial share of global CH4 and N2O emissions (Gerber et al., 2013; Steinfeld and Wassenaar, 2007). Cattle production systems in Uganda, like elsewhere, exhibit diverse practices ranging from confined to grassland-based systems (Erikson et al., 2020; Seré et al., 1996). Management strategies within these systems profoundly influence GHG emissions, with grazing systems contributing significantly to emissions through direct manure deposition onto pastures (Aguirre-Villegas and Larson, 2017). This underscores the need to assess and mitigate emissions within the context of specific production systems to devise effective strategies for reducing environmental impact. Despite variations in estimates, Uganda's livestock sector plays a pivotal role in the national economy, contributing substantially to the Gross Domestic Product (GDP) (UBOS, 2022; Behnke and Nakirya, 2012). Cattle, in particular, are integral to Uganda's livestock value, with both milk and meat production serving as key economic drivers. However, the sector's contribution to GHG emissions necessitates concerted efforts to balance economic growth with environmental sustainability. Within the regulatory framework of the United Nations Framework Convention on Climate Change (UNFCCC), developing countries like Uganda are mandated to report GHG emissions through National Communications (IPCC, 2008). These reports adhere to IPCC Guidelines, which provide methodologies for estimating emissions, including the Tier 2 method for assessing enteric fermentation emissions (Ndao, 2021). Given the significance of enteric fermentation in GHG emissions from ruminant livestock (Kiggundu et al., 2019; Gerber et al., 2012), understanding and mitigating these emissions are crucial for climate resilience. To tackle this issue, our study aimed to evaluate and reduce enteric greenhouse gas (GHG) emissions in Ugandan beef production. We investigated how common cattle breeds in Uganda respond to supplementation with Chloris gayana in natural pasture grazing systems. By collecting and analyzing comprehensive data and conducting on-site surveys, we quantified emissions through weight gain measurements and identified strategies for reducing these emissions. This research aims to offer valuable insights into sustainable beef production practices specific to the Ugandan context.

Materials and methods

To ensure ethical treatment of animals and minimize the influence of various non-quantifiable variables stemming from different management systems, field trial farms were carefully selected based on similar management and husbandry practices. This approach not only standardized the conditions for our research but also adhered to animal ethics guidelines, ensuring the welfare of the cattle throughout the study.

Experimental design

In Mbarara, a 2 × 2 factorial experimental design was utilized, involving 24 animals divided into two groups: growing animals aged 1-3 years (Dairy Crosses and Non-Dairy Ankole) with initial live weights ranging from 178-283 kg, and mature animals over 3 years old (Mature Dairy Crosses and Mature Ankole cattle) with initial live weights ranging from 387-466 kg. The feeding systems included basal feeding on open grazing (F1) and experimental feeding (F2), where natural pasture basal feeding was supplemented with Chloris gayana ad libitum after establishing a pasture garden. The trial spanned 90 days, preceded by a 10-day adaptation period for animals in the F2 feeding system. Livestock weights were recorded at the beginning and end of the experimental period to evaluate changes in live body weight and daily weight gain. In Nakasongola, a similar 2 × 3 factorial experimental design was applied, involving 36 animals categorized similarly to those in Mbarara, with initial weights ranging from 137-261 kg for young cattle and 335-407 kg for adult cattle. The feeding systems and trial duration mirrored those in the Mbarara trial. Livestock body weight was measured using Heart Girth Tape (HGT) every two weeks for 90 days by trained field monitors to ensure accuracy, with conversion to live weight performed using a weight conversion table.

Methods

Dry Matter Intake (DMI) was determined using the Livestock Activity Data Guidance tool (L-ADG-Tool-A.2), developed by the Food and Agriculture Organization of the United Nations (FAO), which considered live body weight and feed digestibility in its calculation. The resulting DMI was then converted into a percentage of live weight. Estimation of CH4 enteric emission utilized the same tool, employing the IPCC-recommended Tier 2 model and allowing customization to region-specific parameters for increased accuracy. Input parameters included live body weight, daily weight gain, and methane conversion rates. Primary and computed input parameters, covering cattle sub-categories, population, energy requirements, and more, were utilized to calculate methane emission factors. The analysis used analysis of variance (ANOVA) with a p-value of 0.05 to assess the impact of different feeding systems and cattle genotypes on body weight gain and emission factors. Additionally, correlation and regression analyses were conducted to explore the relationships between these variables.

Results and discussion

Body weight and weight gain (Kgs)

Table 1:Summary table for Minimum, Mean and Maximum body weight and daily weight gain (Kgs) for Mbarara and Nakasongola

Variable description	**Minimum**		**Mean**		**Maximum**	
	Mbarara	***Nakasongola***	***Mbarara***	***Nakasongola***	***Mbarara***	***Nakasongola***
Body weight, 1-3 Years	209.0	165.8	268.3	245.5	342.1	306.6
Body weight, > 3 Years	398.7	395.6	447.4	419.3	508.8	443.3
Daily weight gain, 1-3 Years	0.40	0.43	0.68	0.62	1.22	0.83
Daily weight gain, >3 Years	0.007	0.007	0.009	0.009	0.010	0.010

The study revealed that Mbarara exhibited a slightly higher average daily weight gain (0.68 kg/day) compared to Nakasongola (0.62 kg/day). These findings align with earlier studies where Ankole-Friesian Crosses demonstrated an average daily gain (ADG) of 0.62 kg/day, with a maximum of 0.85 kg/day (Asizua et al., 2009). Our results indicate minimal improvements in feeding systems for weight gain. Further research is needed to optimize cattle growth and energy utilization. The strong correlation between gross energy and actual body weight ($r = 0.86$) underscores the importance of nutrition in achieving desirable weight gain. Therefore, understanding weight gain dynamics is crucial for sustainable cattle farming. By addressing feeding practices and emphasizing nutritional quality, we can enhance weight gain outcomes and contribute to Uganda's livestock sector.

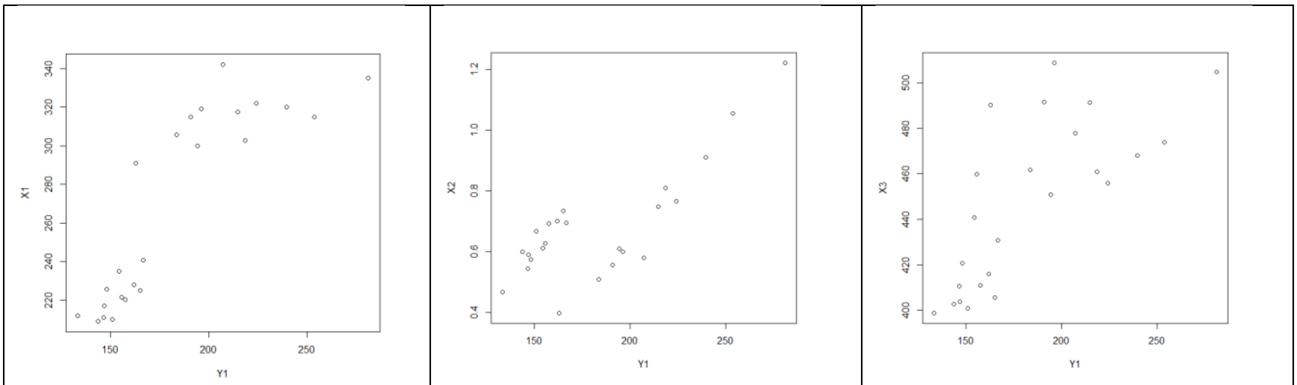
Relationship between Body weight and Gross energy, Total enteric fermentation and Emission intensity

Table 2: Correlation Coefficients (Mbarara)

Variable Description	Gross Energy	Methane Yield	Methane Yield per Kg weight gain
Actual body weight	0.86***	0.62**	0.27
Daily weight gain	0.80***	0.46*	-0.51*
Mature weight	0.73***	0.39	0.17

method="Pearson"

The results from Mbarara indicate that as body weight and weight gain increase, gross energy, enteric fermentation, and emission intensity also rise. Notably, the correlation coefficient ® for gross energy with actual body weight was particularly strong (0.86). The observed negative correlation coefficient -0.51 suggests that an increase in daily weight gain is associated with a decrease in energy expenditure on methane production. This reduction in methane production allows for more energy to be available and redirected towards growth.



Relationship between Gross energy (Y1) and Body weight of growing cattle (X1) (r = 0.86)

Relationship between Gross energy (Y1) and Body weight gain of growing cattle (X2) (r = 0.80)

Relationship between Gross energy (Y1) and Mature body weight of cattle (X3) (r = 0.73)

Figure 1:Relationship between Gross energy and Body weight (actual of growing cattle, mature body weight and average daily weight gain) for Mbarara

Table 3:Correlation Coefficients (Nakasongola)

Variable Description	Gross Energy	Methane Yield	Methane Yield per Kg weight gain
Actual body weight	0.90***	0.73***	0.63
Daily weight gain	0.74	0.30	-0.27
Mature weight	0.63	0.63	0.30***

method="Pearson"

In Nakasongola, similar trends were observed, with strong correlations between gross energy and actual body weight (r = 0.90), weight gain (r = 0.73), and mature weight (r = 0.63). However, the relationships between body weight and enteric fermentation, as well as emission intensity, were weaker and less reliable for making assertions.

Similar to observations by Asizua et al. (2009) the findings in this study highlight the importance of nutrition and energy utilization in cattle growth. Feeding practices should be optimized to enhance weight gain while minimizing environmental impact.

Table 4: Regression analysis of body weight, average daily weight gain, gross energy, methane from enteric fermentation and enteric fermentation for growing cattle in Mbarara district

	GE	TEF	EEE
Body Weight			
Estimate	0.680 ± 0.086	0.209 ± 0.056	0.161± 0.123
t value	7.932	3.711	1.308
Adjusted r^2	0.729	0.357	0.02995
p-Value	$6.803X10^{-8}$***	0.001217**	$0.2045^{N.S}$
Average daily weight gain			
Estimate	171.72 ± 27.63	42.09 ± 17.34	-82.78 ± 30.01
t value	6.215	2.427	-2.759
Adjusted r^2	0.621	0.176	0.2233
p-Value	$2.963X10^{-6}$***	0.02386*	0.01146*

Significancy. codes: '***' 0.001 '**' 0.01 '*' 0.05 '$^{N.S}$' Not significant. Title codes: 'ADG' Average daily weight gain, 'GE' Gross energy, 'TEF' Total enteric fermentation (Methane), 'EEF' Enteric emission efficiency (Unit of Methane per Unit weight gain).

Table 5: Regression analysis of body weight, average daily weight gain, gross energy, methane from enteric fermentation and enteric fermentation for mature cattle in Mbarara district

	GE	TEF	EEE
Body Weight			
Estimate	1.138 ± 0.120	0.294 ± 0.102	0.010 ± 0.014
t value	9.454	2.867	0.749
Adjusted r^2	0.794	0.239	0.020
p-Value	$3.32X10^{-9}$***	0.00896*	$0.462^{N.S}$
Average daily weight gain			
Estimate	32,163.39 ± 6,241.67	3486.95 ± 4041.68	-638.267 ± 489.471
t value	5.153	0.863	-1.304
Adjusted r^2	0.526	-0.011	0.030
p-Value	$3.64X10^{-5}$***	0.398^{NS}	0.206^{NS}

Significancy. codes: '***' 0.001 '**' 0.01 '*' 0.05 'N.S' Not significant. Title codes: 'ADG' Average daily weight gain, 'GE' Gross energy, 'TEF' Total enteric fermentation (Methane), 'EEF' Enteric emission efficiency (Unit of Methane per Unit weight gain).

In Mbarara District, robust linear relationships were evident between gross energy and various parameters, including the body weight of growing (Table 4) and mature (Table 5) cattle, as well as daily weight gain. Conversely, while weak but significant positive associations were observed between enteric fermentation and both the body weight of growing cattle and daily weight gain, a slight negative correlation was noted between emission intensity and daily weight gain (t value = -2.759; Adjusted r^2 = 0.2233; p-Value 0.01146). Notably, for cattle above three years old, significant increases in gross energy and enteric fermentation were observed with higher average daily weight gain (t value = 5.153; Adjusted r^2 = 0.526; p-Value 3.64X10-5) and the body weight of mature cattle (t value = 9.454; Adjusted r^2 = 0.794; p-Value 3.32X10-9).

Meanwhile, in Nakasongola District, regression analysis revealed noteworthy weak but significant positive changes in enteric fermentation as live body weight increased (t value = 3.752; Adjusted r^2 = 0.272; p-Value 0.000655). Unlike Mbarara, no direct correlation was found between daily weight gain and enteric fermentation for both growing and mature cattle (Table 6). However, a substantial positive relationship was established between gross energy and daily weight gain for growing (t value = 5.132; Adjusted r^2 = 0.4199; p-Value 0.0000116) and cattle older than three years (t value = 4.599; Adjusted r^2 = 0.526; p-Value 5.65X10-5), suggesting the potential for enhancing weight gain through increased energy intake. These findings underscore the importance of considering both district-specific and age-related factors when devising strategies to optimize weight gain and mitigate methane emissions in Ugandan beef production systems.

Table 6:Regression analysis of body weight, average daily weight gain, gross energy, methane from enteric fermentation and enteric fermentation for mature Cattle in Nakasongola district

	ADG	GE	TEF	EEE
Body Weight				
Estimate	$3.678X10^{-5} \pm 6.583X10^{-5}$	0.891 ± 0.117	0.149 ± 0.102	-31.01± 20.05
t value	5.587	4.266	1.275	-1.547
Adjusted r^2	0.4633	0.33	0.018	0.038
p-Value	$2.96X10^{-6}$***	0.00015 ***	0.211^{NS}	$0.1311^{N.S}$
Average daily weight gain				
Estimate		17,570.24 ± 3820.39	119.60± 2,250.09	-1,344,169±314,761
t value		4.599	0.053	-4.27
Adjusted r^2		0.526	-0.029	0.33
p-Value		$5.65X10^{-5}$***	0.958^{NS}	0.000148 ***

Significancy. codes: '***' 0.001 '**' 0.01 '*' 0.05 '$^{N.S}$' Not significant. Title codes: 'ADG' Average daily weight gain, 'GE' Gross energy, 'TEF' Total enteric fermentation (Methane), 'EEF' Enteric emission efficiency (Unit of Methane per Unit weight gain).

The regression analyses conducted in the Mbarara District shed light on the intricate interplay between growth parameters and metabolic processes in cattle. The robust linear relationships identified between gross energy (GE) and various parameters, including body weight and daily weight gain, underscore the pivotal role of energy availability in supporting growth in both growing and mature cattle. Interestingly, while weak but significant positive associations were observed between enteric fermentation and body weight, as well as daily weight gain, a nuanced understanding emerged with a slight negative correlation noted between emission intensity and daily weight gain. These findings concur with earlier studies and suggest that while enteric fermentation contributes to energy metabolism, its efficiency in converting feed into body mass may vary, impacting weight gain efficiency and emission intensity. Notably, for older cattle, the significant increases in both gross energy and enteric fermentation with higher average daily weight gain and body weight underscore the dynamic nature of metabolic processes with age and growth stage, highlighting the importance of considering age-related factors in beef production systems (Kongphitee et al., 2018).

In contrast, findings from the Nakasongola District reveal district-specific nuances in the relationships between growth parameters and metabolic processes. Although weak but significant positive changes were observed in enteric fermentation with increasing live body weight, distinct from Mbarara, no direct correlation was found between daily weight gain and enteric fermentation. However, the substantial positive relationship between gross energy and daily weight gain suggests the potential for enhancing weight gain through increased energy intake, emphasizing the role of energy availability in supporting growth irrespective of district differences. These district-specific variations support earlier observations and underscore the need for tailored management strategies that account for local environmental and physiological factors to optimize growth performance while mitigating methane emissions in diverse beef production systems (Cantalapiedra-Hijar et al., 2018; Kongphitee et al., 2018; Kenny et al., 2018).

The findings presented here support earlier observations in numerous research studies and contribute to a deeper understanding of the complex interactions between growth parameters and metabolic processes in cattle populations, providing valuable insights for the development of sustainable beef production practices in Uganda (Cantalapiedra-Hijar et al., 2018; Hurley et al., 2018; Kenny et al., 2018; Asizua et al., 2009). However, further research is warranted to explore additional variables and longitudinal studies to elucidate the mechanisms driving these relationships and inform targeted interventions for optimizing growth performance and mitigating methane emissions in diverse production systems.

Effect of Body weight and daily weight gain on Gross energy, Methane yield from enteric fermentation and Emission intensity (Unit of Methane per Unit weight gain)

The investigation delved into the influence of body weight and daily weight gain on various parameters including Gross Energy (GE), Methane Yield from Enteric Fermentation (TEF), and Emission Intensity (Efficiency) in Ugandan beef production systems. ANOVA tests were utilized to scrutinize the effects of livestock categories and feeding systems on emission factors in mature animals.

Results from the Analysis of Variance for growing cattle from Mbarara (Table 7) revealed no significant differences in daily weight gain means among breeds, although notable differences were observed in Gross Energy, enteric fermentation, and emission intensity based on breed ($p < 0.05$). Specifically, Ankole breed exhibited higher means in these parameters compared to Dairy Crosses (Table 8, 9). Additionally, supplementation with Chloris gayana significantly altered enteric fermentation and emission intensity, resulting in higher methane emissions compared to natural pasture grazing.

Table 7: Analysis of Variance for the Effect of Body weight and daily weight gain on Gross energy, Methane yield from enteric fermentation and Emission intensity (Unit of Methane per Unit weight gain).

Independent Variable	Nakasongola				Mbarara			
	ADG	GE	TEF	EEE	ADG	GE	TEF	EEE
	***P* value**							
	Growing Cattle (1-3 Years)							
BRD	0.029 *	2.07X10^{-11}***	1.67X10^{-11}***	1.70X10^{-7}***	0.162 ^{NS}	3.24X10^{-8}***	4.83X10^{-6}***	0.00153 **
FS	0.147 ^{NS}	0.0101*	1.81X10^{-8}***	1.28X10^{-13}***	0.203^{NS}	0.126^{NS}	3.80X10^{-5}***	1.14X10^{-6}***
BRD X FS	0.860 ^{NS}	0.6867^{NS}	0.0881^{NS}	0.506	0.536^{NS}	0.562^{NS}	0.581^{NS}	0.155^{NS}
	Mature Cattle (> 3 Years)							
BRD	2.66X10^{-9}***	3.09X10^{-6}***	2.95X10^{-6}***	0.095 ^{NS}	2.35X10^{-9}***	2.23X10^{-10}***	1.29X10^{-10}***	6.30 X10^{-5}***
FS	5.75X10^{-8}***	0.0785^{NS}	1.81X10^{-8}***	6.23X10^{-11}***	5.39X10^{-8}***	0.152^{NS}	1.04X10^{-8}***	5.72X10^{-9}***
BRD X FS	0.85^{NS}	0.876^{NS}	0.938 ^{NS}	0.471^{NS}	0.302^{NS}	0.876^{NS}	0.056^{NS}	0.165^{NS}

Significancy. codes: '***' 0.001 '**' 0.01 '*' 0.05 'N.S' Not significant. Title codes: 'ADG' Average daily weight gain, 'GE' Gross energy, 'TEF' Total enteric fermentation (Methane), 'EEF' Enteric emission efficiency (Unit of Methane per Unit weight gain), 'BRD' Breed, 'FS' Feeding system/treatment.

Similarly, Analysis of Variance for mature cattle from Mbarara indicated significant breed differences in daily weight gain, Gross Energy, enteric fermentation, and emission intensity. Specifically, Ankole cattle demonstrated superior performance in these aspects compared to Dairy Crosses (Table 8, 9). Feeding treatment also played a significant role, particularly in affecting enteric fermentation and emission intensity.

Table 8: Means for the Analysis of Variance for growing cattle in Mbarara district

	ADG	IGE	TEF	EFE
Breed				
Dairy Cross (DC)	0.551	138.127***	79.547***	140.730**
Non-dairy (ND)	0.487	226.748***	134.922***	244.508**
Feeding treatment				
Natural Pasture (TRT1)	0.660	203.496	86.756***	139.189***
Chloris Supplement (TRT2)	0.378	161.378	127.713***	246.049***
Breed * Feeding treatment interaction				

DC * TRT1	0.600	147.810	63.015	106.237
DC * TRT2	0.501	128.444	96.078	175.223
ND * TRT1	0.719	259.183	110.496	172.141
ND *TRT2	0.255	194.312	159.347	316.874
Residual se	0.1776	23.6014	8.6194	15.6870

Significancy. codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘N.S’ Not significant.

Table 9: Means for the Analysis of Variance for mature cattle in Mbarara district

	ADG	**IGE**	**TEF**	**EFE**
Breed				
Dairy Cross (DC)	0.00833***	170.048***	50.190***	6.023***
Ankole (ND)	0.01167***	339.826***	100.299***	9.026***
Feeding treatment				
Natural Pasture (NGR)	0.00859	243.102	103.641***	12.154***
Chloris Supplement (ACS)	0.01141	266.772	46.848***	2.894***
Breed * Feeding treatment interaction				
DC * NGR	0.00724	160.482	68.418	9.450
DC * ACS	0.00942	179.615	31.962	2.595
ND * NGR	0.00724	325.722	138.864	14.858
ND * ACS	0.00995	353.930	61.735	3.193
Residual se	0.00036	17.585	6.133	1.022

Significancy. codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘N.S’ Not significant.

The findings align with existing knowledge indicating that feeding high-quality forages enhances digestion efficiency and animal performance but also leads to higher methane emissions due to increased microbial activity (Eugène et al., 2021; Mwangi et al., 2019). Conversely, cattle grazing on natural pastures experience less efficient digestion and subsequently lower methane emissions. Despite expectations of better performance with supplementation, no significant effect on weight gain was observed, suggesting inefficiency and high emission levels associated with the current feeding system.

ANOVA results for cattle from Nakasongola highlighted significant breed differences in average daily weight gain, with mature cattle also showing sensitivity to feeding systems. Moreover, mean differences in Gross Energy, methane emission, and emission efficiency were attributed to breed and feeding system effects similar to earlier findings by Eugène et al. (2021) and Mwangi et al. (2019).

In both Mbarara and Nakasongola, no statistically significant interaction between livestock categories and feeding systems was observed, indicating independent effects. This underscores the need for further research to elucidate additional factors contributing to methane emissions and develop mitigation strategies in the beef industry similar to proposals by 6. Food and Agriculture Organization of the United Nations (FAO) and New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) (2019) for low carbon systems in the dairy industry for Uganda.

These findings underscore the significant influence of livestock breed categories and feeding systems on enteric fermentation and methane emissions in Ugandan beef production systems, calling for continued research efforts to mitigate greenhouse gas emissions in the industry in support of the National Climate Mitigation targets in the Updated Nationally Determined Contribution (MWE, 2022).

Conclusion

In conclusion, our study highlights the intricate relationship between body weight, daily weight gain, and various metabolic factors in growing and mature cattle populations in Mbarara and Nakasongola districts of Uganda. Notably, our findings underscore the influence of breed categories and feeding systems on enteric fermentation and methane emissions, crucial aspects in beef production systems. Despite anticipated benefits from high-quality forage supplementation, our results suggest that the current feeding practices may not efficiently optimize weight gain while simultaneously contributing to elevated emission intensities. These insights emphasize the need for further research and the development of targeted mitigation strategies to enhance both productivity and environmental sustainability within the Ugandan beef industry.

Recommendations

Based on the findings and conclusions presented in the current study, it is recommended that stakeholders in the Ugandan beef industry consider revising current feeding and breeding practices to optimize both weight gain and environmental sustainability. While there are anticipated benefits from breed improvement and supplementing with high-quality forages, the study suggests that current feeding systems may not efficiently maximize weight gain and simultaneously contribute to elevated emission intensities, particularly methane emissions. Therefore, there is a need for further research to explore additional factors influencing methane emissions and to develop targeted mitigation strategies. This could include evaluating alternative feeding practices or implementing measures to enhance the efficiency of current feeding systems while minimizing environmental impacts. By addressing these concerns, the beef industry in Uganda can work towards achieving improved productivity and environmental sustainability.

References

1.Aguirre-Villegas HA, Larson RA. Evaluating greenhouse gas emissions from dairy manure management practices using survey data and lifecycle tools. J Clean Prod. 2017;143:169–179. http://dx.doi.org/10.1016/j.jclepro.2016.12.133.

2.Behnke R, Nakirya M. The contribution of livestock to the Ugandan economy. IGAD LPI Working Paper. 2012;02-12. Addis Ababa, Ethiopia: IGAD Livestock Policy Initiative. https://cgspace.cgiar.org/bitstreams/b21c83ac-5c64-4abc-8788-f52a09c0365c/download.

3.Cantalapiedra-Hijar G, Abo-Ismail M, Carstens GE, et al. Biological determinants of between-animal variation in feed efficiency of growing beef cattle. Animal. 2018;12(S2):s321–s335. doi:10.1017/S1751731118001489.

4.Erikson P, Thornton P, Nelson C. Ruminant Livestock and Climate Change in the Tropics. Environ Sci Agric Food Sci. 2020. DOI:10.1079/9781789241853.0601.

5.Eugène M, Klumpp K, Sauvant D. Methane mitigating options with forages fed to ruminants. Grass Forage Sci. 2021;76:196–204. DOI: 10.1111/gfs.12540.

6.Food and Agriculture Organization of the United Nations, New Zealand Agricultural Greenhouse Gas Research Centre. Options for low emission development in the Uganda dairy sector - reducing enteric methane for food security and livelihoods. Rome: FAO; 2019. 39 pp. ISBN 978-92-5-131309-1 (FAO).

7.Gerber P, Vellinga T, Opio C, Steinfeld H. Productivity gains and Green House Gas emissions intensity in dairy systems. Livestock Sciences. 2012. https://doi.org/10.1016/j.livsci.2011.03.012.

8.Gerber PJ, Steinfeld H, Henderson B, et al. Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Rome: Food and Agriculture Organization of the United Nations (FAO); 2013.

9.Hurley AM, Lopez-Villalobos N, McParland S, et al. Characteristics of feed efficiency within and across lactation in dairy cows and the effect of genetic selection. J Dairy Sci. 2018;101:1267–1280. https://doi.org/10.3168/jds.2017-12841.

10.Kenny DA, Fitzsimons C, Waters SM, McGee M. Improving feed efficiency of beef cattle –the current state of the art and future challenges. Animal. 2018;12(9):1815–1826. doi:10.1017/S175173111800097.

11.Kiggundu N, Ddungu SP, Wanyama J, et al. Greenhouse gas emissions from Uganda's cattle corridor farming systems. Agric Syst. 2019;176:102649. https://doi.org/10.1016/j.agsy.2019.102649.

12.Kongphitee K, Sommart K, Phonbumrung T, Gunha T, Suzuki T. Feed intake, digestibility and energy partitioning in beef cattle fed diets with cassava pulp instead of rice straw. Asian-Australas J Anim Sci. 2018;31(9):1431–1441. https://doi.org/10.5713/ajas.17.0759.

13. Ministry of Water and Environment of the Government of Uganda. Updated Nationally Determined Contribution. 2022.
14. Mwangi FW, Charmley E, Gardiner CP, et al. Diet and Genetics Influence Beef Cattle Performance and Meat Quality Characteristics. Foods. 2019;8:648. doi:10.3390/foods8120648.
15. Ndao S. Analysis of Inputs Parameters Used to Estimate Enteric Methane Emission Factors Applying a Tier 2 Model: Case Study of Native Cattle in Senegal. Anim Feed Sci Nutr. 2021. DOI: http://dx.doi.org/10.5772/intechopen.99810.
16. Seré C, Steinfeld H, Groenewold J. World Livestock Production Systems: Current Status, Issues and Trends. FAO animal production and health paper. Issue 127. FAO. 1996. ISSN 0254-6019. FAO corporate document repository.
17. Steinfeld H, Wassenaar T. The Role of Livestock Production in Carbon and Nitrogen Cycles. Annu Rev Environ Resour. 2007;32:271–94. doi: 10.1146/annurev.energy.32.041806.143508.
18. The Intergovernmental Panel on Climate Change (IPCC). 2006 IPCC Guidelines for National Greenhouse Gas Inventories – A primer, Prepared by the National Greenhouse Gas Inventories Programme. Eggleston HS, Miwa K, Srivastava N, Tanabe K (eds). Published: IGES, Japan. 2008.
19. Uganda Bureau of Statistics. 2022 Statistical Abstract.