



Local feeding practices as mitigation option for low-carbon livestock systems in Sub-Saharan Africa

Assouma, MH^{1,3}; Gbenou, GX²; Sib, O^{1,3}; Bastianelli, D³; Bonnal, L³; Martin, C⁴; Dossa, LH²

¹ CIRAD, UMR SELMET, Bobo Dioulasso, Burkina Faso

² Laboratoire des Sciences Animales, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, 526 Cotonou, Bénin

³ SELMET, Univ Montpellier, CIRAD, INRAE, Institut Agro, Montpellier, France

⁴ Université Clermont Auvergne, INRAE, VetAgro Sup, UMR 1213 Herbivores, 63122 Saint-Genès-Champanelle, France

Key words: Crop residues; legume trees; supplementary feeding; ruminants; enteric methane; Africa

Abstract

Enteric methane emissions (eCH₄) from ruminants are the main source of greenhouse gas (GHG) from the livestock sector in sub-Saharan Africa (SSA). The SSA countries face significant challenges in assessing their climate commitments in the livestock sector, particularly in terms of mitigation measures due to the lack of accurate GHG data obtained through *in vivo* measurements. The objective of this study was to directly measure and analyze eCH₄ in pastoral and agropastoral systems using an advanced methodology: the GreenFeed[®] system. Different ruminant feeding strategies were tested with the aim to identify those that contribute to the reduction of absolute emissions, emission yield, and emission intensity. Cattle were fed natural rangeland fodder, cultivated forage (green and hay), and combinations of grass with main crop coproducts or legume tree forage. Data collection lasted 2.5 years and included 35 trials (diets). Each trial lasted 3 weeks and was split into 2 weeks of diet adaptation and 1 week of data collection. The dry matter (DM) intake in animals was 20±2.4 (12 to 29 g/kg of body weight per head), the DM digestibility, 48±4.6 (30 to 70 %), and the eCH₄ emissions, 70±17.8 (28 to 114 g/d per head). Green herbaceous forage and tanniferous forage, such as legume tree forage and legume crop co-products, showed good potential to increase livestock productivity and reduce eCH₄ emissions yield by up to 33%. These results will help policymakers promote clean technologies and sustainable livestock practices in SSA, and help implement the IPCC Tier 2 methodology to accurately estimate emission factors by cattle categories and breeds.

Introduction

In extensive livestock farming (pastoral and agropastoral) in Sub-Saharan Africa (SSA), animal productivity is low, resulting in higher emission intensities (mass per unit of product) and yields (mass per unit of intake). Depending on the type of ruminant livestock system, enteric methane (eCH₄) can contribute up to 61% of total carbon emissions from a livestock system (de Figueiredo et al. 2017). According to Gbenou et al. (2024a), the hot dry season has the greatest potential for eCH₄ mitigation because it is the period when eCH₄ yields are very high.

The low quantity and quality of feed resources during this season on rangeland that prevents the rumen from functioning optimally is one of the causes.

Feeding strategies suggested in the international literature on GHG mitigation, in particular eCH₄, are often not adapted to the SSA context because they involve costly inputs that are inaccessible locally. Furthermore, they sometimes are in competition with animal productivity and are technically complex to apply. In contrast to these literature strategies, SSA's livestock farmers have access to a variety of crop coproducts, tree legumes, and agro-industrial byproducts, which they use for feeding their animals in agropastoral systems (Gbenou et al., 2024b). The aim of this study was to test the eCH₄ mitigation potential of these locally available and accessible feed resources with the goal to promote low-carbon livestock system in SSA.

Methods

The study was carried out at an experimental station in South-Western Burkina Faso. The study involved ten Sudanese Fulani zebu steers of 2.7±0.1 years and 138.4±10.1 kg average, kept in a barn. Grasses, such as *Panicum maximum* C1 (hay and green), *Andropogon gayanus* (hay), and *Brachiaria ruziziensis* (hay), and rangeland fodder (hay or green), according to seasons were used to feed the steers. Cattle were also supplemented with the most commonly used livestock feed, selected from a survey of farmers: cereal coproducts (maize, sorghum, millet and rice straws), legume coproducts (cowpea and peanut haulms), and tree legumes (*Gliricidia sepium* and *Leucaena leucocephala* dry leaves). The animals were fed at an intake level of 3.2% or 2.3% of their body weight (BW) in dry matter (DM). The grasses and rangeland fodder were provided as stand-alone control diets (100%) or mixed with crop coproducts or LEGTREE legume in constant proportions (75:25 on a DM basis, experimental diets). Access to lick stone and water was *ad libitum*. Data collection lasted 2.5 years and included 35 trials (diets). Each trial corresponded to a diet and lasted 3 weeks split into 2 weeks of diet adaptation and 1 week of data collection. The diets were grouped into four categories: 1) grass diets (diets with 100% *P. maximum* C1, *A. gayanus*, *B. ruziziensis*, or rangeland fodder - GRASS), 2) cereal coproduct diets (mixed diets containing grass and cereal coproduct at 75:25 ratio - CEREAL), 3) legume coproduct diets (mixed diets containing grass and legume coproduct at 75:25 ratio - LEGUME), and 4) tree legume diets (mixed diets containing grass and leaves of tree legume at 75:25 ratio - LEGTREE).

Table 1: Average chemical composition of diets offered to Sudanese Fulani zebu steers.

Item	GRASS	CEREAL	LEGUME	LEGTREE	SEM	P-value
DM (g/kg diet)	96.1	92.2	92.5	94.6	0.01	0.074
OM (g/kg DM)	823.8 ^B	806.5 ^D	817.0 ^C	909.6 ^A	0.09	<0.001
CP (g/kg DM)	26.9 ^C	29.0 ^C	61.8 ^B	99.9 ^A	0.14	<0.001
NDF (g/kg DM)	689.7 ^A	645.9 ^C	598.5 ^D	658.5 ^B	0.35	<0.001
ADF (g/kg DM)	429.5 ^A	400.5 ^C	386.1 ^D	408.3 ^B	0.18	<0.001
GE (MJ/kg DM)	16.5	16.2	16.5	19.1	0.04	0.103

GRASS: diets with 100% *P. maximum* C1, *A. gayanus*, *B. ruziziensis*, or rangeland fodder; CEREAL: mixed diets containing grass and a cereal coproduct at 75:25 ratio; LEGUME: mixed diets containing grass and a legume coproduct at 75:25 ratio; LEGTREE: mixed diets containing grass and leaves of tree legume at 75:25 ratio; DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; ADL: acid detergent lignin; GE: gross energy

A,B,C Values within a row with different superscripts differ significantly at $P < 0.05$

Daily individual DM intake was calculated as the difference between the quantities offered and refused. Daily excreted faeces were collected from faecal bags fitted to each animal for apparent digestibility calculation. Individual representative samples of feed (offered and refused) and faeces were collected daily, and their chemical compositions were determined using NIRS (CIRAD laboratory, Baillarguet, France), as described by Gbenou et

al. (2024a, 2024c). The eCH₄ emissions were measured using a GreenFeed® (GF) unit (ID: 252, C-Lock Inc., SD, USA). Measurement times were tailored to the feeding behaviour of the animals, with random access to the GF unit at 6:30 am (overnight fast), 10 am (immediately after feed intake), 2 pm (during rumination) and 6 pm (immediately after feed intake and at sunset). On the 7th day (last day) of each trial, an additional measurement was performed at 00:00 (during total rest). The total number of visits was 29 per animal per feeding condition, exceeding the minimum number of 20 visits recommended by Manafiazar et al. (2017). Each animal spent an average of 3 min±02s (2min20s to 4min15s) at the GF unit per visit.

All statistical analyses were performed using R software version 4.1.2. (R Core Team 2021). The DM intake, apparent digestibility, and eCH₄ emissions were analyzed using the general linear model (GLM) procedure. The least squares means and their SEM presented a table were compared using the duncan.test (de Mendiburu 2023) in the event of a significant difference (P<0.05). The statistical model used for the variance data analysis was $Y_{ij} = \mu + C_i + (1 | A_j) + \epsilon_{ij}$, where Y_{ij} = variable of interest; μ = overall average; C_i = fixed effect representing the different diet categories; A_j = random effect representing individual variations among animals; and ϵ_{ij} = residual error.

Results

Chemical composition of diet categories

The CP contents in LEGUME and LEGTREE were twice and three times those of GRASS or CEREAL, respectively (Table 1). Fiber content was lower in all categories of mixed diets (P<0.001).

Diet intake and digestibility

The highest intake was obtained with LEGUME and LEGTREE. No significant difference in DM digestibility was observed between diets (Table 2).

Enteric methane emissions

All supplemented diet's categories (CEREAL, LEGUME and LEGTREE) induced eCH₄ yield (g/kg DMI) mitigation from 19% to 47% compared with GRASS (Figure 1). The eCH₄ mitigation in %GEI followed the same patterns in diet's categories (Table 2).

Table 2: Dry matter intake, feed apparent digestibility, and eCH₄ emissions by Sudanese Fulani zebu steers fed different diet categories

Item	GRASS	CEREAL	LEGUME	LEGTREE	SEM	P-value
DMI (g/kg LW)	16.4 ^B	18.0 ^B	25.5 ^A	26.2 ^A	0.31	0.006
DMd (g/kg DMI)	46.0	48.1	49.7	48.8	0.00	0.092
eCH ₄ (g/kg DMI)	30.6 ^A	24.8 ^B	22.3 ^{BC}	20.0 ^C	0.53	<0.001
eCH ₄ (% GEI)	9.3 ^A	7.9 ^B	6.8 ^{BC}	5.8 ^C	0.17	<0.001

GRASS: diets with 100% *P. maximum* C1, *A. gayanus*, *B. ruziziensis*, or rangeland fodder; CEREAL: mixed diets containing grass and cereal coproduct at 75:25 ratio; LEGUME: mixed diets containing grass and legume coproduct at 75:25 ratio; LEGTREE: mixed diets containing grass and leaves of tree legume at 75:25 ratio; DMI: dry matter intake, DMd: dry matter digestibility; eCH₄: enteric methane, GEI: gross energy intake

A,B,C Values within a row with different superscripts differ significantly at $P < 0.05$

Discussion and Conclusion

This study investigated local feeding practices with the aim of identifying mitigation options for low-carbon livestock systems in Sub-Saharan Africa (SSA). The feeding practices tested are among the most widely available in West Africa and the most commonly used by livestock farmers (FAO 2014; Sib et al. 2019). GRASS can provide

sufficient quantities above the daily required CP (7% DM) recommended by NRC (2000) for ruminant maintenance. LEGUME and LEGTREE presented high nutritional quality (CP) compared with GRASS and CEREAL due to the nutritional quality of different resources used to supplement animals. In fact, legume crop coproducts are more nutritious than cereal crop coproducts (Jarial et al. 2020), and legume trees are more nutritious than legume crop coproducts (INRA 2018).

DMI varied according to diet categories. The highest intake obtained with LEGUME and LEGTREE was associated with their highest CP content (Gaviria-Urbe et al. 2020). There were no significant differences between GRASS and CEREAL intake, which had similar nutritional qualities (CP, NDF and ADF). There was no significant difference in DMd between the four diet categories despite the intake improvement in LEGUME and LEGTREE, possibly due to the effect of anti-nutritional factors (Soltan et al. 2017).

This study's innovative feature is that it demonstrates how local feeding practices in a real-world setting can help design low-carbon livestock systems, specifically by using crop co-products and legume trees. The eCH₄ yield mitigation induced by mixed diet categories was 19, 33 and 47% for CEREAL, LEGUME, and LEGTREE, respectively, and could be explained by the tannin content in those diet categories. The mitigation rates induced by LEGUME and LEGTREE are higher than those obtained with the most promising feed additives (Red seaweed and 3-nitrooxypropanol - Bovaer®) in ruminants (EPLM 2024). However, the average eCH₄ yield (24.4 g/kg DMI) recorded across all diet categories (20 – 31 g/kg DMI) was similar to that reported by IPCC (2019) Tier 2 for SSA cattle. The rate of loss of GEI in the form of eCH₄ (Y_m - 15 to 52%) that CEREAL, LEGUME, and LEGTREE prevent could be redirected in milk and meat production for improved food security in SSA.

In conclusion, compared with grass-exclusive diets, local feeding practices improve diet quality and influence intake and eCH₄ emissions in livestock. Diets based on cereal and legume co-products, and legume trees resulted in significant eCH₄ yield mitigation and consequently low-carbon livestock systems.

Acknowledgements

This study was supported by the CaSSECS regional project (<https://www.cassecs.org/>) funded by European DeSIRA program, grant agreement No. [FOOD/2019/410-169]. Experimental procedures were approved by the CIRDES Ethics Committee (for application N° 006/Mars/2021/ CE-CIRDES).

References

- de Figueiredo EB, ..., and La Scala Jr N (2017) Greenhouse gas balance and carbon footprint of beef cattle in three contrasting pasture-management systems in Brazil. *Journal of Cleaner Production* 142, 420–431.
- de Mendiburu F. 2023. *Agricolae: Statistical procedures for agricultural research*. R package version 1.3-6. <https://cran.r-project.org/web/packages/agricolae/agricolae.pdf> [Accessed 02 11 2024]
- EPLM (2024) Potential of animal feed additives for methane mitigation. 7p. <https://livestockmethane.com/wp-content/uploads/2024/05/2024-03-Animal-feed-supplements-.pdf>
- FAO (2014) 'Résidus agricoles et sous-produits agro-industriels en Afrique de l'Ouest—Etat des lieux et perspectives pour l'élevage', (FAO Publishing: Rome)
- Gaviria-Urbe, X., Bolivar, D. M., Rosenstock, T. S., Molina-Botero, I. C., Chirinda, N., Barahona, R., Arango, J., 2020. Nutritional quality, voluntary intake and enteric methane emissions of diets based on novel cayman grass and its associations with two leucaena legume trees. *Frontiers Veterinary Science* 7:579189
- Gbenou GX, Assouma MH, ..., and C, Dossa LH (2024a) Enteric methane emissions from zebu cattle are influenced by seasonal variations in rangeland fodder quality and intake. *Animal* 18(10), 101320
- Gbenou GX, Assouma MH, ..., and C, Dossa LH (2024b) Adapted methods to quantify, predict and mitigate enteric methane in sub-Saharan Africa. *INRAE Productions Animales* 37:7648
- Gbenou GX, Assouma MH, ... and C, Dossa LH (2024c) Supplementing zebu cattle with crop co-products helps to reduce enteric emissions in West Africa. *Archives of Animal Nutrition*, 1-17.
- INRA (2018) 'INRA feeding system for ruminants: Specific feeding of ruminant in hot regions', (Quæ Publishing: Versailles)

- IPCC (2019) '2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories', (IPCC Publishing: Switzerland)
- Jarial, S., Blummel, M., Prasad, K. V. S. V., Ravi, D., 2020. Crop residues comparative price and quality analysis in West Africa - A case from Niger. *Plant Archives* 20:2, 6181-6186
- Manafiazar G, Zimmerman S, Basarab JA (2017) Repeatability and variability of short-term spot measurement of methane and carbon dioxide emissions from beef cattle using GreenFeed emissions monitoring system. *Canadian Journal of Animal Science* 97, 118–126
- NRC (2000) 'Nutrient requirements of beef cattle', (7th Rev. ed. Natl. Acad. Press Publishing: Washington)
- R Core Team. 2021. R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. URL <https://www.R-project.org/> [Accessed 31 10 2024]
- Sib O, Vall E, Bougouma-Yameogo VMC, Blanchard M, Navarro M, Gonzalez-Garcia E (2019) Establishing high-density protein banks for livestock in Burkina Faso (West Africa): agronomic performance under contrasting edaphoclimatic conditions. *Agrofor. Syst.* <https://doi.org/10.1007/s10457-019-00394-4>
- Soltan, Y. A., Morsy, A. S., Lucas, R. C., Abdalla, A. L. 2017. Potential of mimosine of *Leucaena leucocephala* for modulating ruminal nutrient degradability and methanogenesis. *Animal Feed Science and Technology* 223:30–41