Overview of CSU AgNext research using GreenFeed to assess gas flux from beef cattle

Sara Place, PhD

March 4, 2026 | 2026 C-Lock Symposium

AgNext®

COLORADO STATE UNIVERSITY

SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

Facility overview

Confinement “Climate Smart Research” facility at CSU ARDEC
Current setup: 6 pens each with 5 SmartFeed and 1 GreenFeed units (30 SmartFeed; 6 GreenFeed total)

Facility overview

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

Concrete bunks within each pen to facilitate adaptation to SmartFeed units, typically 2-week adaptation upon arrival

Stocking rates:

SmartFeed: Max, 10 head per bunk

- Requires careful attention to feed calling to prevent high competition at feeding times

GreenFeed: Max, 50 head per unit

- Have achieved 100% use rate; however, typically 90-95% depending upon group/temperament of cattle

Facility overview

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS
FOR ANIMAL AGRICULTURE

Since Nov. 2022:

- 16 experiments or trials completed or ongoing
- 2,165 individual animal records

Facility overview

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

Grazing capability:

- Intensive grazing at ARDEC & extensive grazing at John E. Rouse Beef Improvement Center (Saratoga, WY) & Eastern Colorado Research Center (Akron, CO)
- Two GreenFeed on trailers
- Collaborations with USDA-ARS to expand capacity


Summary of research
AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS
FOR ANIMAL AGRICULTURE

Determination of test duration

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

- Collection of phenotypes to assess animal variability & impacts of variation requires understanding test length period
- Building upon, Dressler et al. (2023), this work attempted to understand # spot samples required

Translational Animal Science, 2024, **8**, txae056
https://doi.org/10.1093/tas/txae056
Advance access publication 8 April 2024
Environmental Animal Science

Determination of gas flux and animal performance test duration of growing cattle in confined conditions

Juan de J. Vargas, Maya Swenson, and Sara E. Place[1,]
Department of Animal Sciences, Colorado State University, Fort Collins, CO 80523, USA
[1]Corresponding author: sara.place@colostate.edu

Determination of test duration

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

Data

- **Experiment 1:** 213 crossbreed animals (Angus: 105 steers, 43 heifers, and 15 bulls; Hereford: 20 heifers and 25 bulls; Wagyu: 3 heifers and 2 bulls)
- **Experiment 2:** 169 Angus steers
- **Experiment 3:** 64 Angus steers

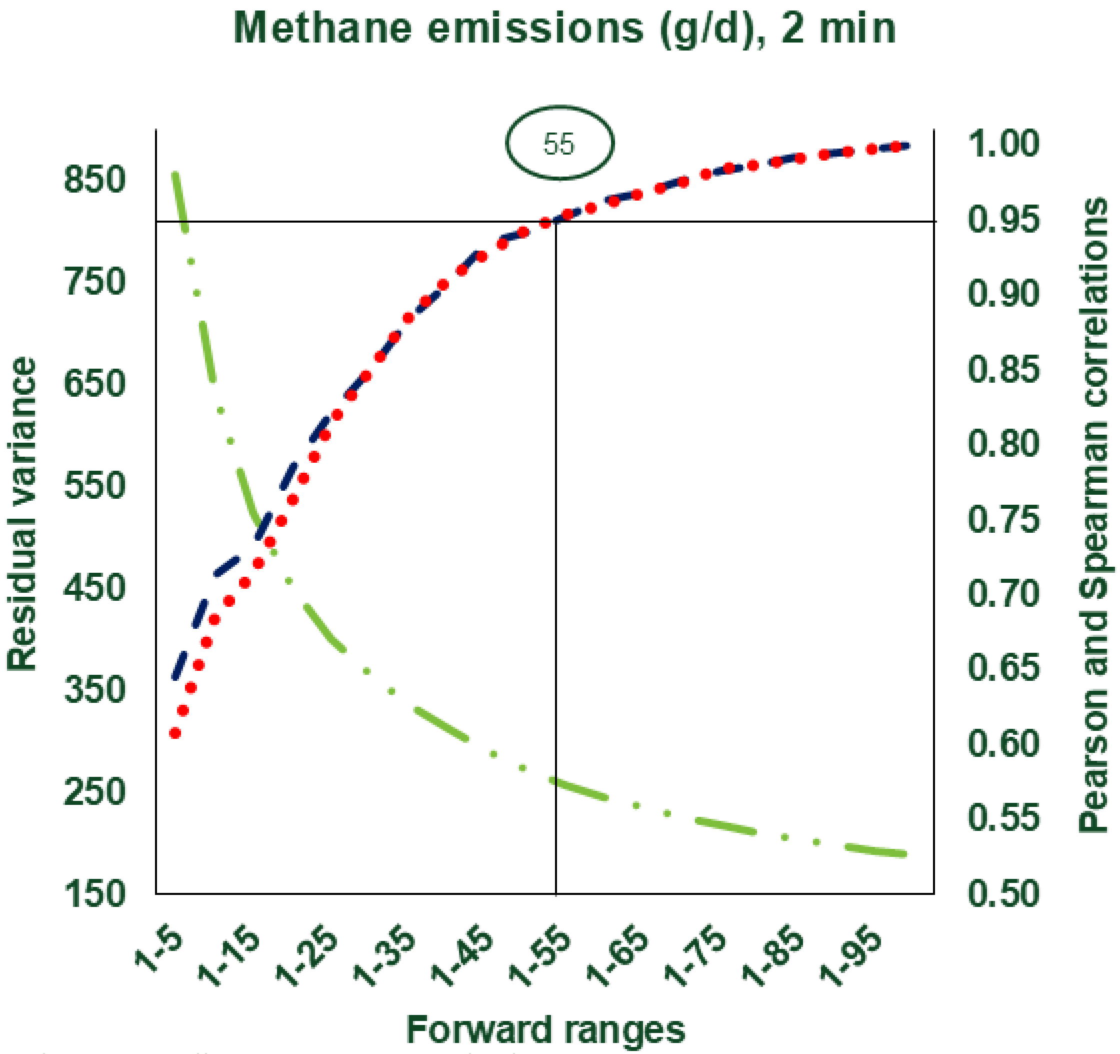
Evaluated variables

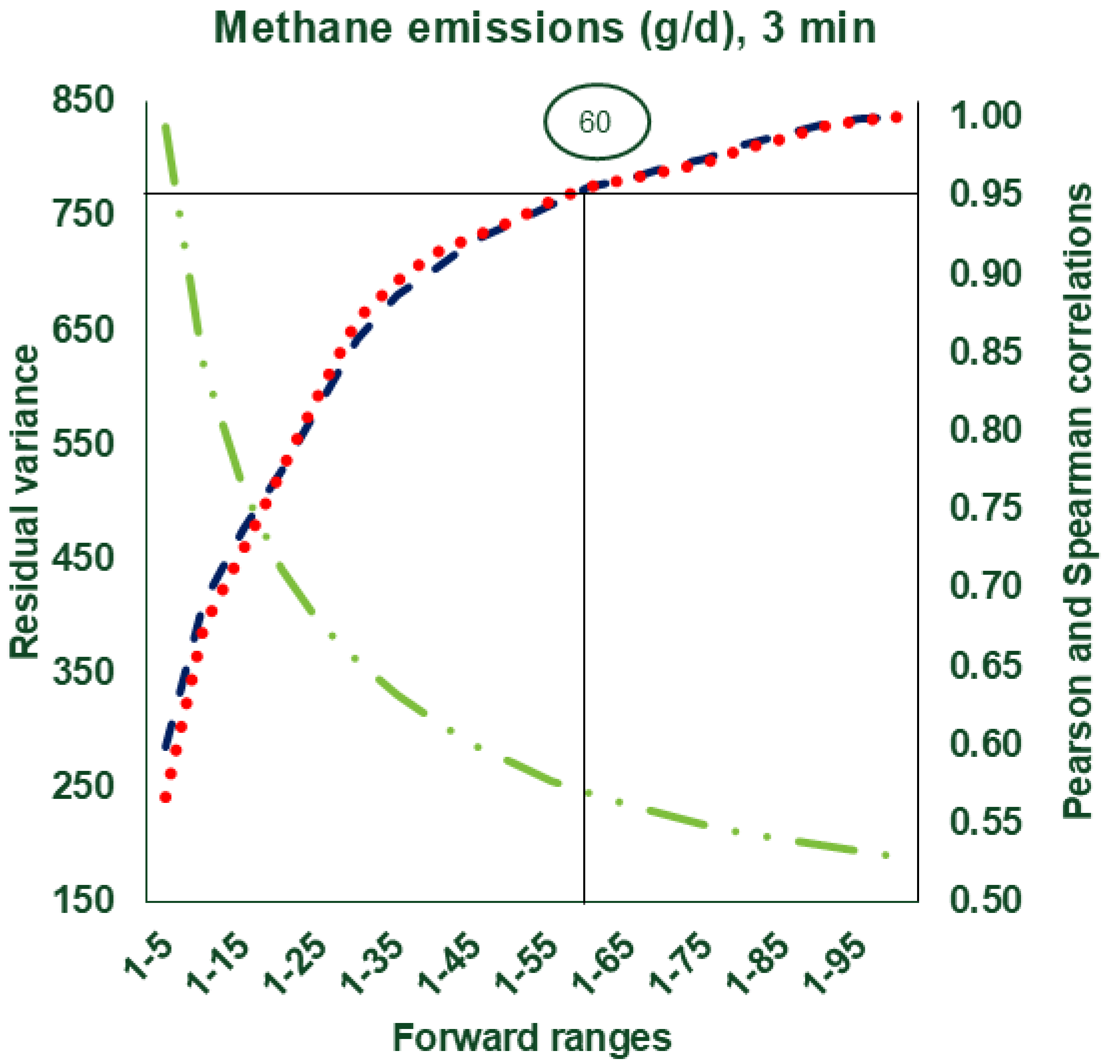
- Gas flux from the first 100 visits with > 2 or > 3 min

Statistical analyses

- Definition of 5-visit intervals until 100 visits with animals visiting > 2 or > 3 min
- Residual variance, $Y_{ij} = \mu + Interval_i + Animal_j + \varepsilon_{ij}$
- Pearson and Spearman correlation among 5-visit intervals

Methane determination requires between 55 to 60 visits





Vargas et al., 2024; https://doi.org/10.1093/tas/txae056

Visitations – how many are required for methane measurement?

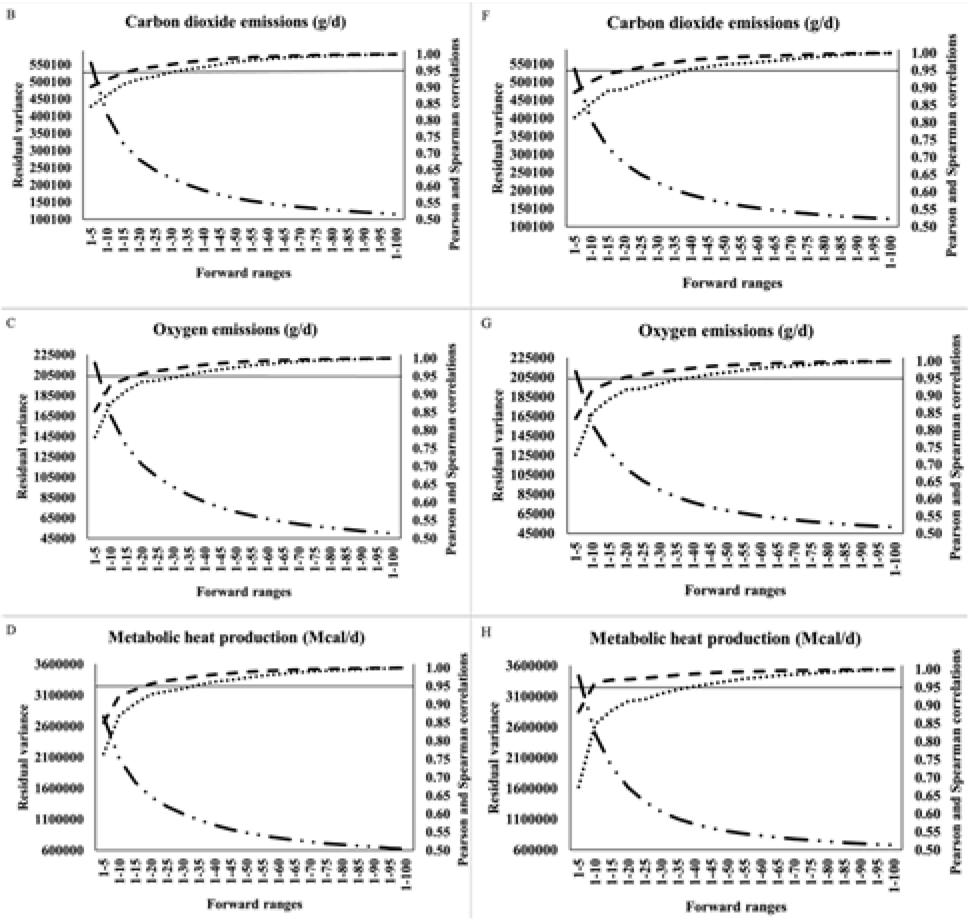
AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

Source	Environment	Minimum recommendation
Gunter and Beck, 2018	Grazing	35
Arthur et al., 2017	Confinement	30
Dressler et al., 2023	Grazing	38
Beck et al., 2024	Grazing and confinement	30 – 40
Vargas et al., 2024b	Grazing	45 – 70
Vargas et al., 2024a	Confinement	55

Numbers of days dependent upon visitation frequency

Carbon dioxide, oxygen fluxes & metabolic heat production require fewer visits than methane flux

AgNext®
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE



2 minutes

3 minutes

Vargas et al., 2024; https://doi.org/10.1093/tas/txae056

Evaluating cattle across production phases

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

Backgrounding diet in confinement

CH_4 emissions, g/d:	161
ADG, kg/d:	1.18
CH_4 intensity, g/kg ADG:	137
BW, kg:	251

Grazing shortgrass steppe

CH_4 emissions, g/d:	218
ADG, kg/d:	0.61
CH_4 intensity, g/kg ADG:	377
BW, kg:	429

Finishing diet in confinement

CH_4 emissions, g/d:	198
ADG, kg/d:	2.55
CH_4 intensity, g/kg ADG:	80
BW, kg:	624

CSU BIC steers, 2023 calf crop means

Classifying cattle according to residual methane emissions

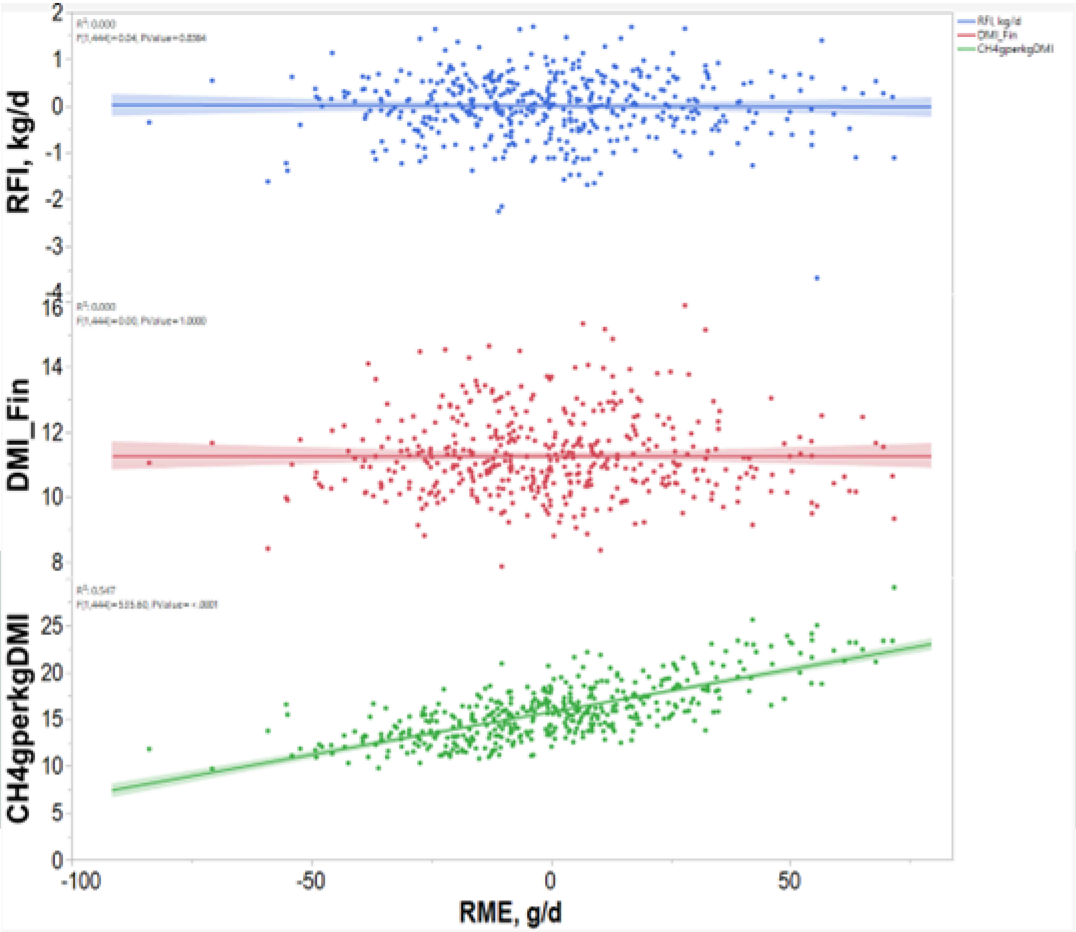
Item	Low	High	SE	*P* value
N	10	10		
Dry matter intake, kg/d	7.8	8.11	0.51	0.68
Average daily gain, kg/d	1.52	1.56	0.09	0.81
Mid body weight, kg	271	283	9.9	0.40
Methane emissions, g/d	192	260	8.9	<0.01
Residual methane emissions, g/d	-28	31	2.4	<0.01

35% difference in methane emissions with similar animal performance fed backgrounding diet

2024 CSU BIC calf crop steers

Phenotypical relationship of residual methane with other traits in cattle fed finishing diet

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE



- No relationship between RME and RFI, DMI, ADG
- Cattle with higher RME produce more methane per unit of feed consumed

Data available at: https://datadryad.org/dataset/doi:10.5061/dryad.qnk98sfsn

Classification of methane emissions

If animals are low emitters on high forage diets, do they remain so on finishing diets?

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

Data

- **Backgrounding phase:** 46 Angus steers (244 ± 11 kg)
- **Finishing phase:** 23 implanted and 23 non-implanted Angus steers (540 ± 9 kg)

Animal classification

- Methane production (g/d), methane yield (g/kg DMI), methane intensity (g/kg ADG), residual methane
- Low (≤ percentile 0.25), medium (between 0.25 and 0.75 percentile), and high (≥ percentile 0.75)

Evaluated variables

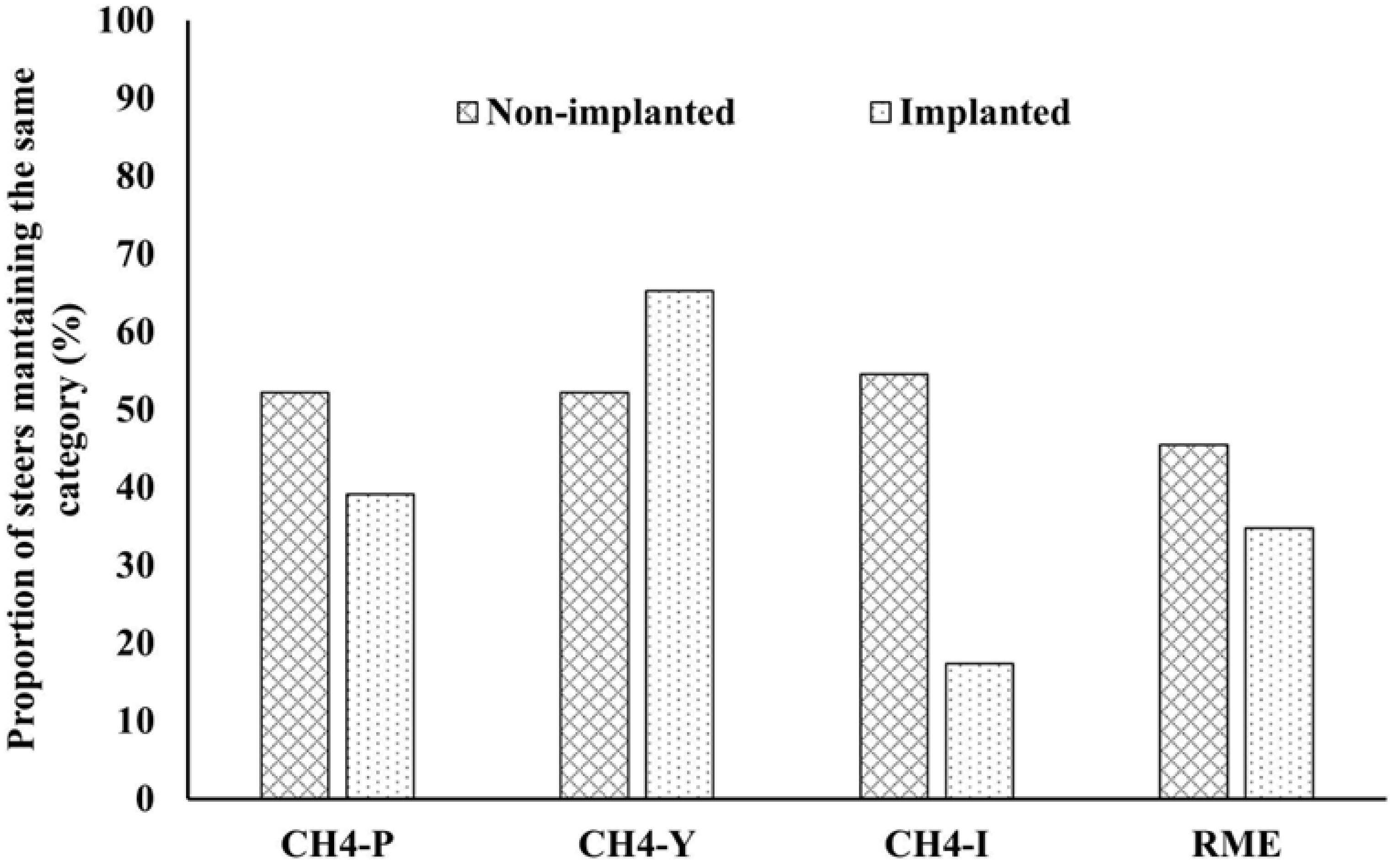
- Gas flux (> 55 visits and > 2 min)

Statistical analyses

- A mixed model with classification as a fixed effect and animal as an experimental unit
- Fisher's exact test to evaluate the relationship between backgrounding and finishing classification

Classification of methane emissions

If animals are low emitters on high forage diets, do they remain so on finishing diets?

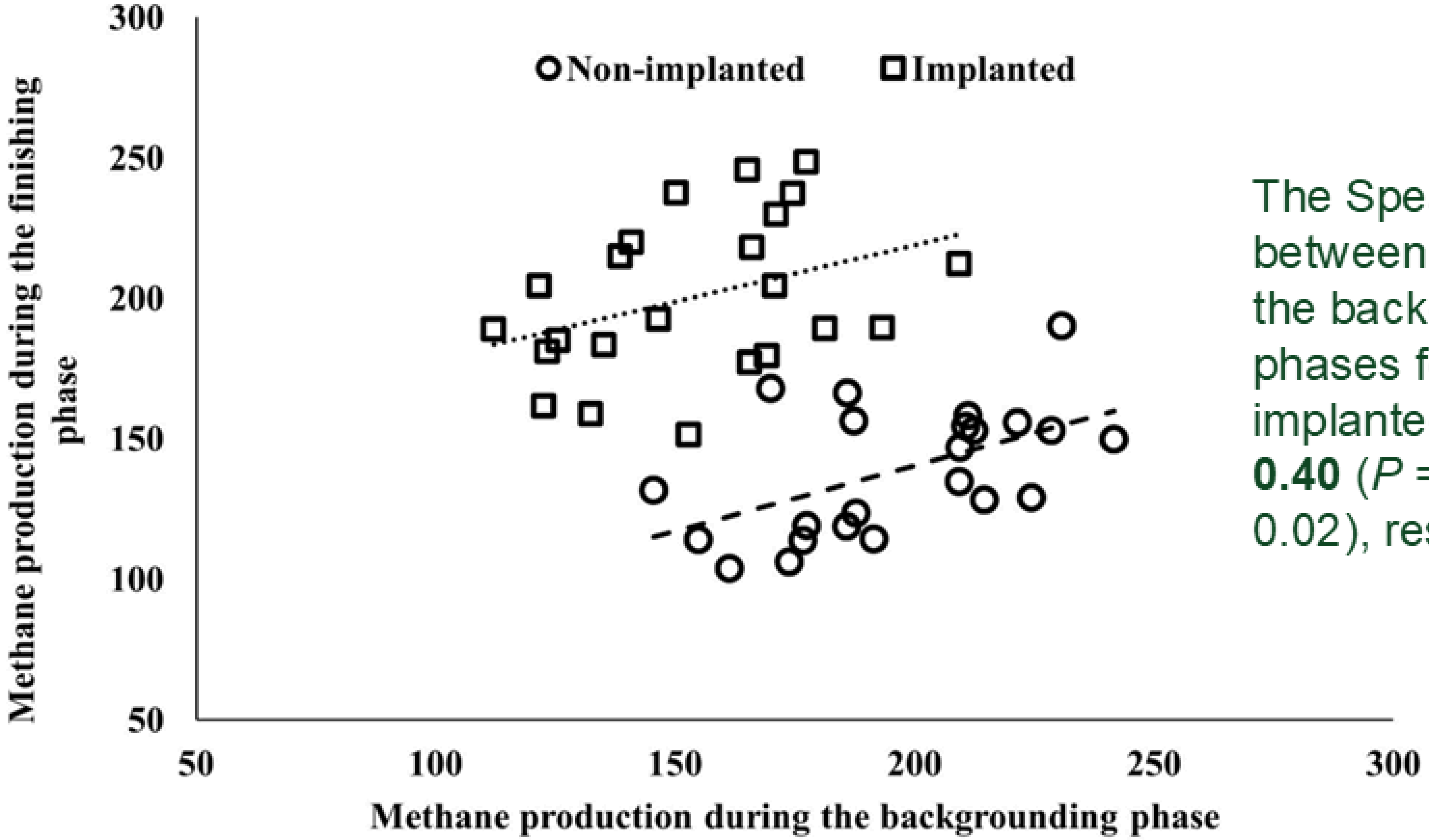


Between **35** and **83%** of the steers **re-ranked** according to CH_4 (g/d, g/kg DM, g/kg ADG) and RME classification from the backgrounding to the finishing phase.

Vargas et al., 2025. https://doi.org/10.1093/jas/skaf046

Classification of methane emissions

If animals are low emitters on high forage diets, do they remain so on finishing diets?



The Spearman correlation between CH_4 production during the backgrounding and finishing phases for implanted and non-implanted steers varied between **0.40** (*P* = 0.05) and **0.48** (*P* = 0.02), respectively.

Vargas et al., 2025. https://doi.org/10.1093/jas/skaf046

Predicting dry matter intake from gas flux

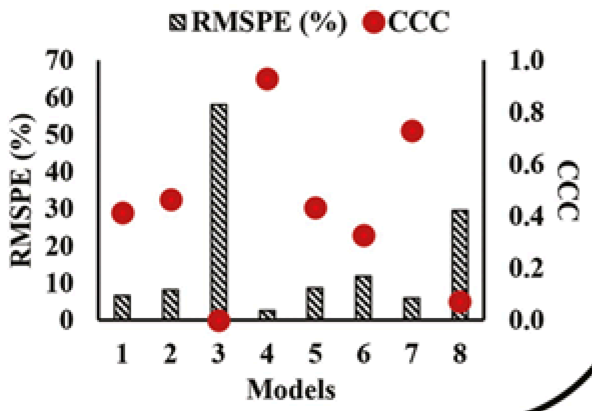
Can gas flux be a useful tool to predict DMI in forage-fed cattle?

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

Gas flux is related to dry matter intake (**DMI**). The relationship of DMI, animal growth performance, and gas flux was evaluated in 130 growing steers fed a backgrounding diet

The production of CO_2 and one retrieved equation had adequate and excellent agreement with the observed DMI, respectively. The use of CO_2 production has the potential to be used for predicting DMI in growing steers

Six equations retrieved from the literature and two new equations using CO_2 and CH_4 production were evaluated for predicting DMI using an independent database of growing steers fed a forage-based diet



Vargas et al., 2025 https://doi.org/10.1093/tas/txaf111

Impacts of breed & technology use on growth performance & gas flux

Comparing Bos indicus vs Bos taurus cattle with or without the use of growth technologies

AgNext®
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS
FOR ANIMAL AGRICULTURE

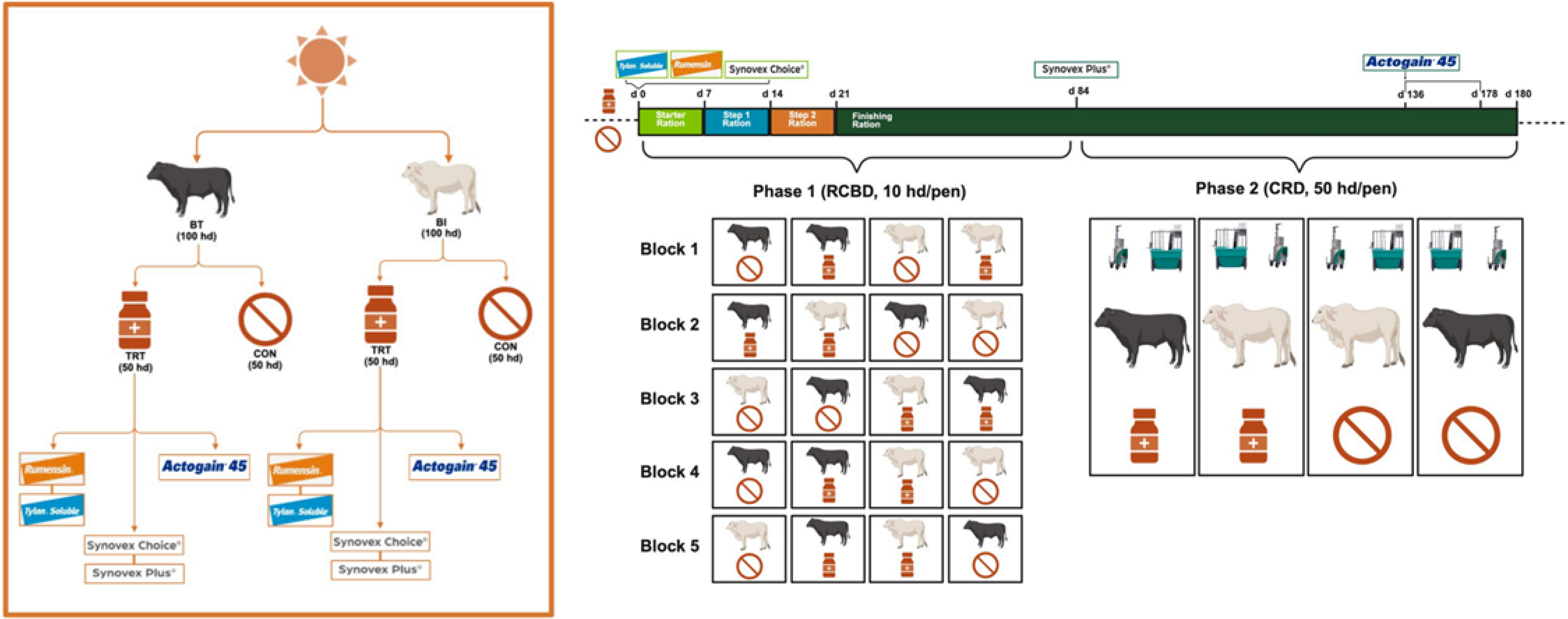


Figure 1. Treatment arrangement, project timeline, and experimental design

Schilling-Hazlett et al., 2025: https://doi.org/10.1093/jas/skaf322

Results- Gas Flux

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

Table 4. Gas flux of finishing *Bos taurus* and *Bos indicus* steers managed with and without the use of growth-promoting technologies during Phase 2 (d 84 to 180) in summer feedlot conditions.

Item[1]	*Bos indicus*		*Bos taurus*		SEM[3]	S[4]	T[4]	S×T[4]
	CON[2]	TRT[2]	CON[2]	TRT[2]				
n, animal	36	42	44	44	-	-	-	-
DMI, kg	7.51	8.33	9.96	10.47	0.198	<0.01	<0.01	0.32
ADG, kg/d	0.97[c]	1.35[b]	1.32[b]	1.93[a]	0.050	<0.01	<0.01	<0.01
CH_4, g/d	123	133	179	180	5.5	<0.01	0.13	0.28
CO_2, g/d	7062	7604	9927	10244	143.0	<0.01	<0.01	0.32
O_2, g/d	5069	5455	6754	7215	92.3	<0.01	<0.01	0.61
H_2, g/d	0.78[c]	1.03[b]	1.45[a]	1.07[bc]	0.076	<0.01	0.22	<0.01
Y_m, % GEI	4.92	4.81	5.43	5.12	0.190	<0.01	0.21	0.52
MY, g CH_4/kg DMI	16.5	16.1	18.1	17.1	0.63	<0.01	0.21	0.53
EI, g CH_4/kg ADG	131.1[a]	101.9[b]	140.7[a]	92.8[b]	5.98	0.05	<0.01	0.05
EI_{CG}, g CH_4/kg carcass gain	1.72[b]	1.47[b]	2.04[a]	1.48[b]	0.084	<0.01	<0.01	0.02

[1]DMI = dry matter intake, kg; ADG = average daily gain, kg; CH_4 = methane, g/d; CO_2 = carbon dioxide, g/d; O_2 = oxygen, g/d; H_2 = hydrogen, g/d; Y_m, CH_4 emitted as a percent of gross energy intake (GEI); MY = methane yield, g CH_4/kg DMI; EI = emissions intensity, g CH_4/kg ADG; EI_{CG} = emissions intensity for carcass gain, g CH_4/kg carcass gain.
[2]Experimental management treatment; CON = managed without the use of growth-promoting technologies, TRT = cattle managed with the use of growth-promoting technologies.
[3]SEM= standard error of the mean.
[4]S = main effect cattle sub-species; T = main effect management treatment; S×T = interaction between cattle sub-species and management treatment.
[a,b,c]Means in the same row within main effect that do not have a common superscript letter differ, $P \leq 0.05$.

Schilling-Hazlett et al., 2025: https://doi.org/10.1093/jas/skaf322

Impacts of breed & technology use on growth performance & gas flux

Comparing Bos indicus (BI) vs Bos taurus (BT) cattle with or without the use of growth technologies (GPT)

COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

- BT steers exhibited greater and more efficient growth performance
- GPT improved efficiency of growth
- BT steers had greater absolute CH_4 emissions than BI steers
- GPT reduced GHG emissions when expressed per unit of gain
- Observations demonstrated that the effect of GPT may differ by sub-species
- BT steers produced more USDA Choice and Prime carcasses than BI steers

Schilling-Hazlett et al., 2025: https://doi.org/10.1093/jas/skaf322

Effect of terminal implant on methane intensity, growth performance, and feeding behavior

62 Angus steers, implanted 52 or 80 days prior to slaughter

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

	Treatment		DOF			*P* value		
Item	CON	IMP	52	80	SEM	Trt	DOF	Trt x DOF
N	31	31	32	30				
Initial BW, kg	551	551	579	522	3.64	0.88	<0.0001	1.00
Final BW, kg	670	709	685	694	4.36	**<0.0001**	0.17	0.46
ADG, kg/d	1.7	2.4	2.0	2.1	0.04	**<0.0001**	0.003	0.38
G:F	0.16	0.21	0.18	0.19	0.005	**<0.0001**	0.13	0.43
DMI, kg/d	10.9	11.3	11.1	11.1	0.11	**0.01**	0.87	0.83
Meal visit, visit/d[1]	6.5	6.4	6.6	6.3	0.10	0.38	0.05	0.97
Session size, g of DM/visit	1704	1778	1723	1759	30.1	*0.08*	0.40	0.81

[1]meal criteria was a 3,972 seconds interval

As expected, the growth implant (200 mg TBA; 20 mg E2; Component TE-200; Elanco Animal Health) **increased ADG**, **DMI**, **final live weight** when fed to common days on feed, and **improved gain: feed**

Effect of terminal implant on methane intensity, growth performance, and feeding behavior

62 Angus steers, implanted 52 or 80 days prior to slaughter

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

	Treatment		DOF			*P* value		
Item	CON	IMP	52	80	SEM	Trt	DOF	Trt x DOF
N	31	31	32	30				
Initial BW, kg	551	551	579	522	3.64	0.88	<0.0001	1.00
Final BW, kg	670	709	685	694	4.36	**<0.0001**	0.17	0.46
ADG, kg/d	1.7	2.4	2.0	2.1	0.04	**<0.0001**	0.003	0.38
G:F	0.16	0.21	0.18	0.19	0.005	**<0.0001**	0.13	0.43
DMI, kg/d	10.9	11.3	11.1	11.1	0.11	**0.01**	0.87	0.83
Meal visit, visit/d[1]	6.5	6.4	6.6	6.3	0.10	0.38	0.05	0.97
Session size, g of DM/visit	1704	1778	1723	1759	30.1	*0.08*	0.40	0.81

[1]meal criteria was a 3,972 seconds interval

As expected, the growth implant (200 mg TBA; 20 mg E2; Component TE-200; Elanco Animal Health) **increased ADG**, **DMI**, **final live weight** when fed to common days on feed, and **improved gain: feed**

Effect of terminal implant on methane intensity, growth performance, and feeding behavior

62 Angus steers, implanted 52 or 80 days prior to slaughter

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

	52 DOF		80 DOF			*P* value		
Item	CON	IMP	CON	IMP	SEM	Trt	DOF	Trt x DOF
GreenFeed visits, n	83	93	100	110	8.71	0.25	0.06	0.96
CH_4, g/d	184[a, b]	182[a, b]	177[a]	199[b]	5.72	*0.06*	0.35	**0.04**
CH_4 as a % of GEI	5.1	5.2	5.0	5.3	0.17	0.33	0.95	0.46
CH_4 yield, g/kg DM	16.9	16.4	16.3	17.6	0.55	0.52	0.60	*0.09*
CH_4 intensity, g/kg ADG	106.7[a]	74.9[b]	102.6[a]	90.4[a, b]	6.68	**0.0001**	0.54	*0.07*

A terminal growth implant can lower methane intensity (g/kg ADG), though that effect may be attenuated by longer DOF as dry matter intake difference between implanted and non-implanted cattle increases

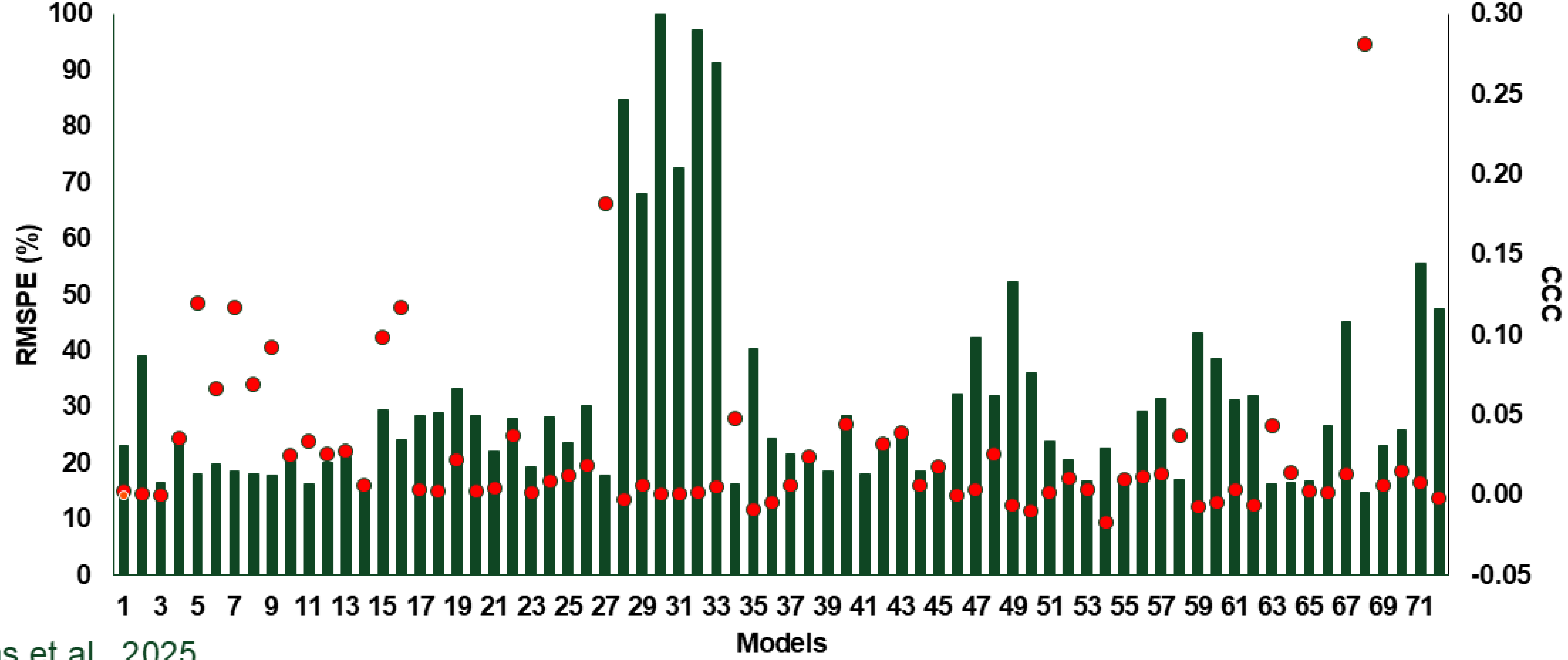
Evaluating existing methane prediction models for finishing cattle

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

- If we need to predict enteric methane in Scope 3 inventories, how well do they perform (accuracy & sensitivity)?
- Data from 448 steers across 5 experiments with 55 visits or greater from the GreenFeed
- Retrieved 72 prediction equations from the literature to evaluate against observed data

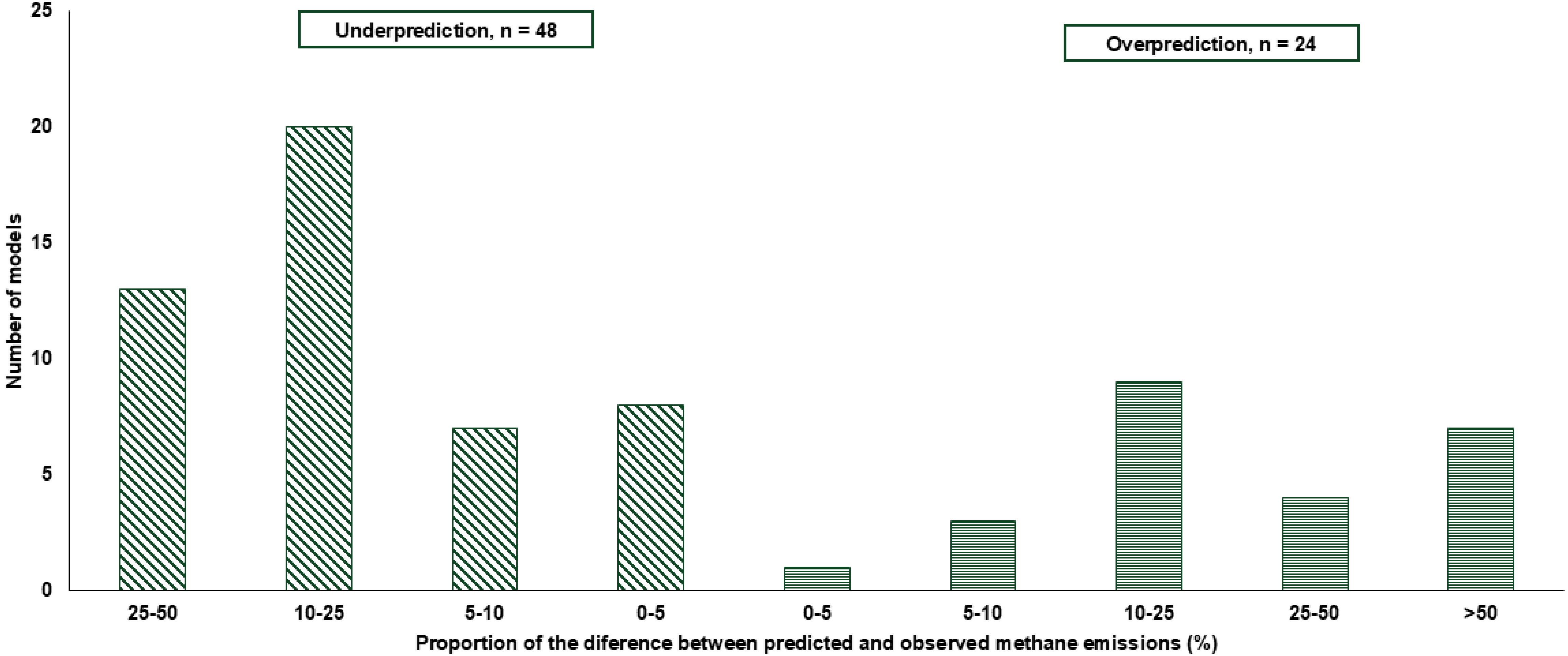
Root mean square prediction error & concordance correlation coefficient of 72 prediction equations

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE



Vargas et al., 2025.
https://doi.org/10.1016/j.animal.2025.101536

Number of models that over and under predicted observed methane emissions



Vargas et al., 2025.
https://doi.org/10.1016/j.animal.2025.101536

Summary and future directions

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

- Individual animal data as collected by C-Lock, Inc. equipment can be powerful for phenotyping cattle & investigating diet & technology impacts
  - Variability across cattle managed similarly is substantial
    - Opportunity for genetic selection; however, care must be taken to avoid negative growth performance & other economically-relevant trait impacts
- Novel application of gas flux data may improve prediction of DM intake in grazing/group housed cattle without individual intake data
  - Further investigations required
- Growth technologies work!
  - What is the "best" metric for methane? Goals often in absolute terms (g/d), but g/kg product may be more relevant)
- Finishing cattle enteric methane prediction models have opportunity to improve
  - However, CSU data is currently limited with regard to diet diversity

- Future and ongoing work:
  - Investigating dietary ingredient/additive and diet formulation impacts on enteric methane emissions & growth performance
  - Continued work towards evaluating & improving enteric methane prediction models

Want to Learn More?

Keep up with us on:

Colorado State University AgNext

@CSUAgNext

@CSUAgNext

AgNext at Colorado State University

Subscribe to the AgNext Newsletter

sara.place@colostate.edu

AgNext
COLORADO STATE UNIVERSITY
SUSTAINABLE SOLUTIONS FOR ANIMAL AGRICULTURE

Listen to the AgNext Podcast