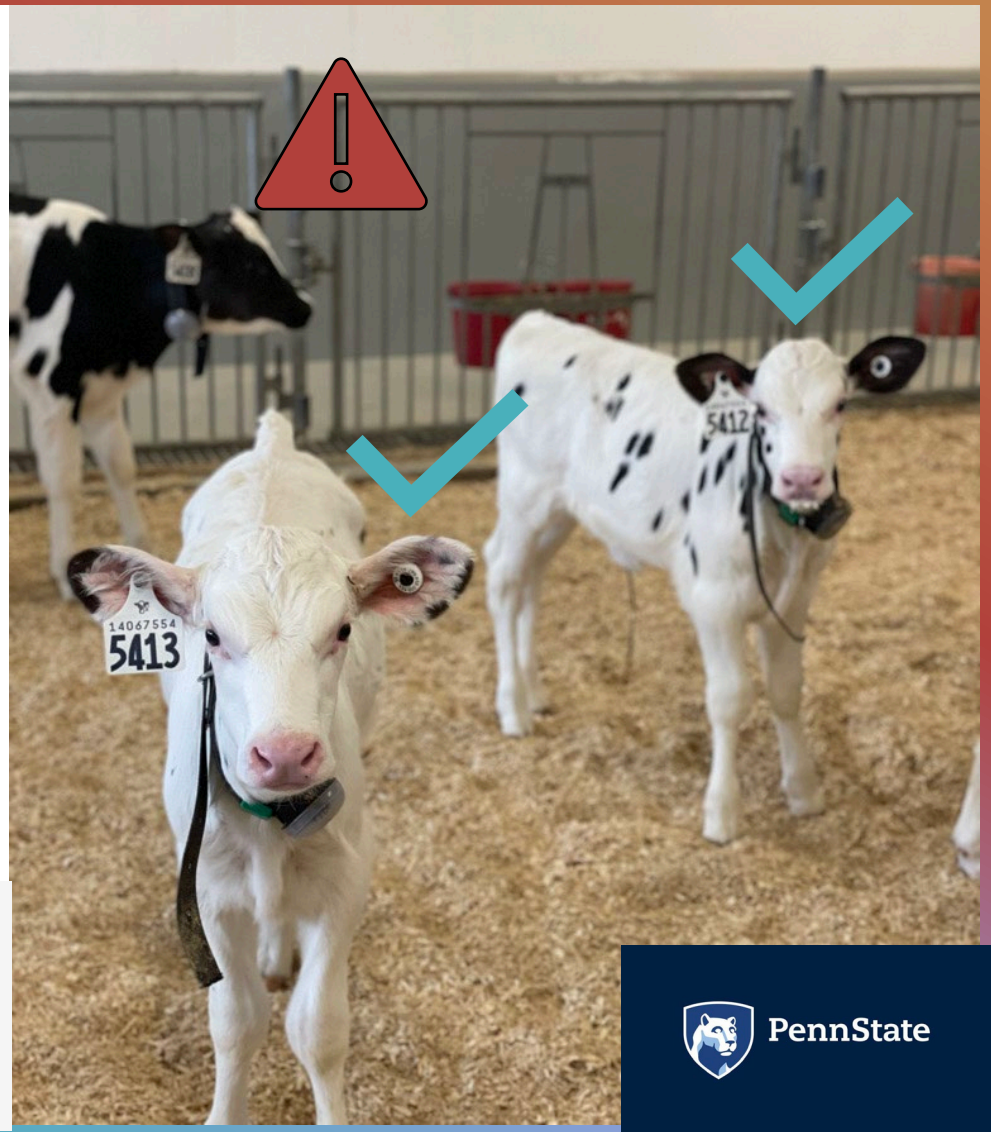
Moo-ving forward: AI and precision livestock farming strategies for dairy calf care

Melissa Cantor, Ph.D., MSc.
Assistant Professor Precision Dairy Science
Penn State University
EAAP 2024



A thank you to key collaborators

DAIRY at GUELPH
CANADA'S DAIRY UNIVERSITY

University of Kentucky

The UNIVERSITY of VERMONT

PennState

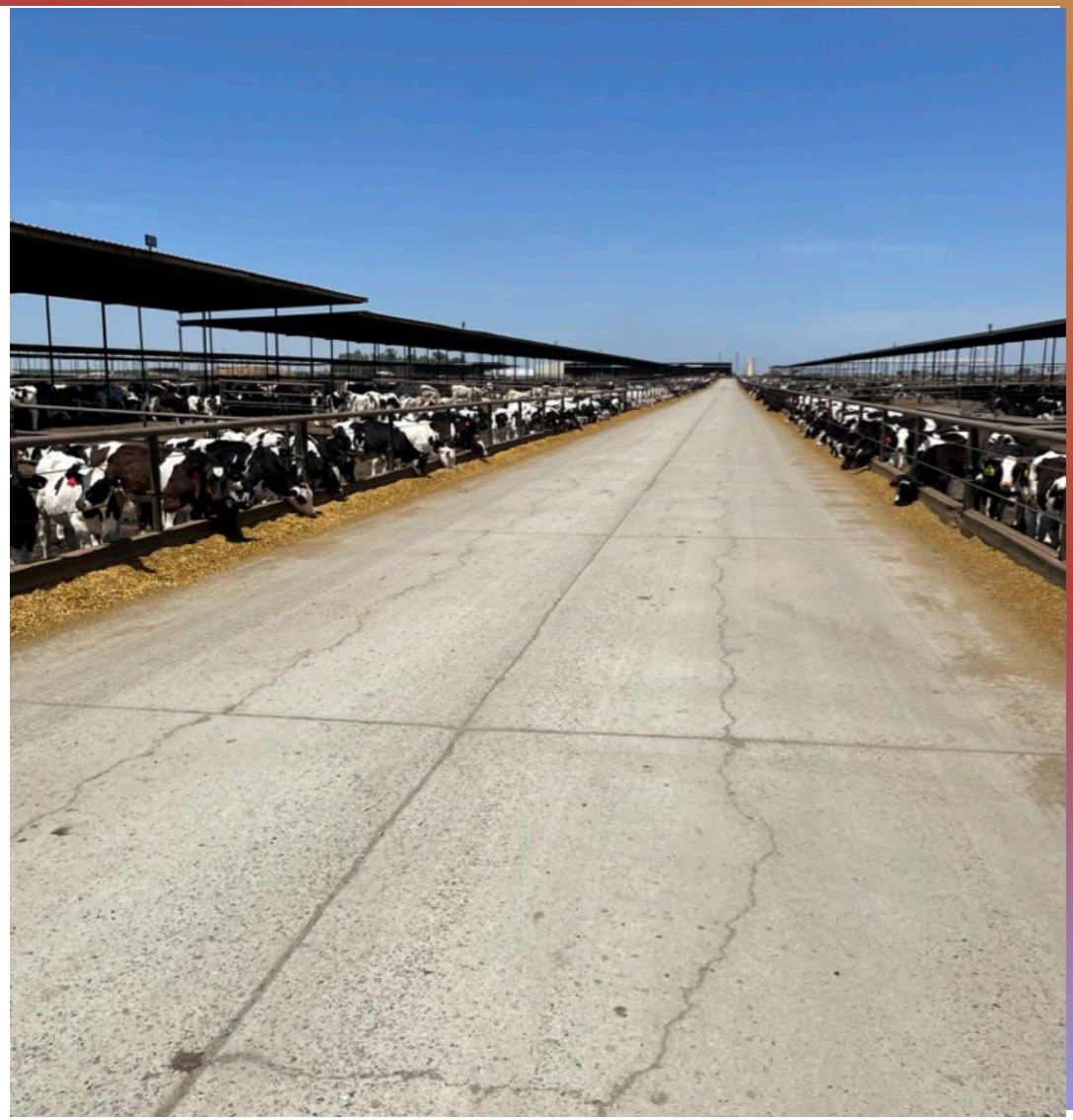
Outline

- Why tech for cattle?
- Is behavior correlated with disease?
- Who is better AI or humans?

Why are we talking about tech for dairy calf management?

In the USA...

+ Farms are fewer, larger
+ Less skilled laborers
+ Higher input costs
+ Increased emphasis on efficiency



Opportunities: Robotic grain and milk feeders

- Promote growth[1-5]
- Feed more milk [1-5]
- Customize how calves are weaned from milk

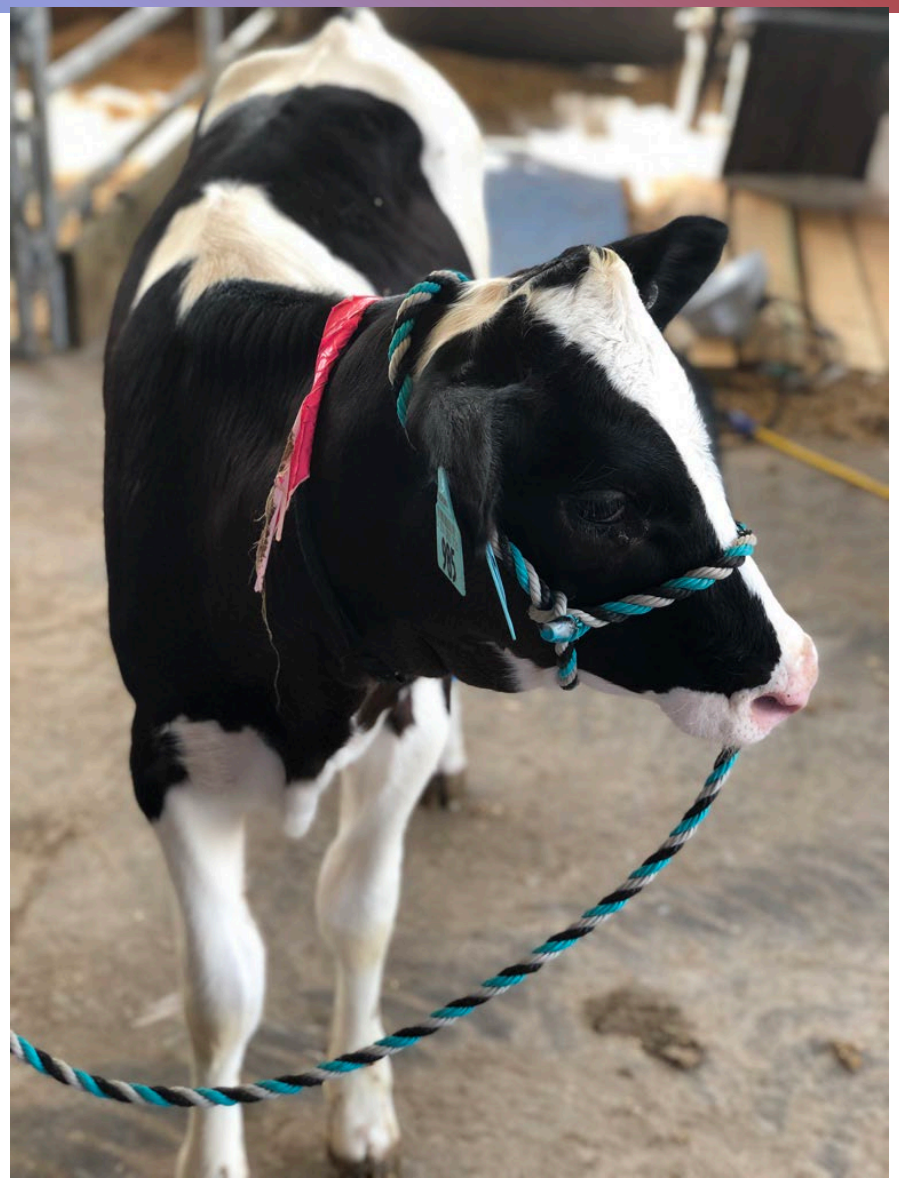
1 De Paula Vierera et al., 2010
2 Pempek et al., 2016
3 Benneton et al., 2018.
4 Welk et al., 2022
5 Cantor et al., 2019

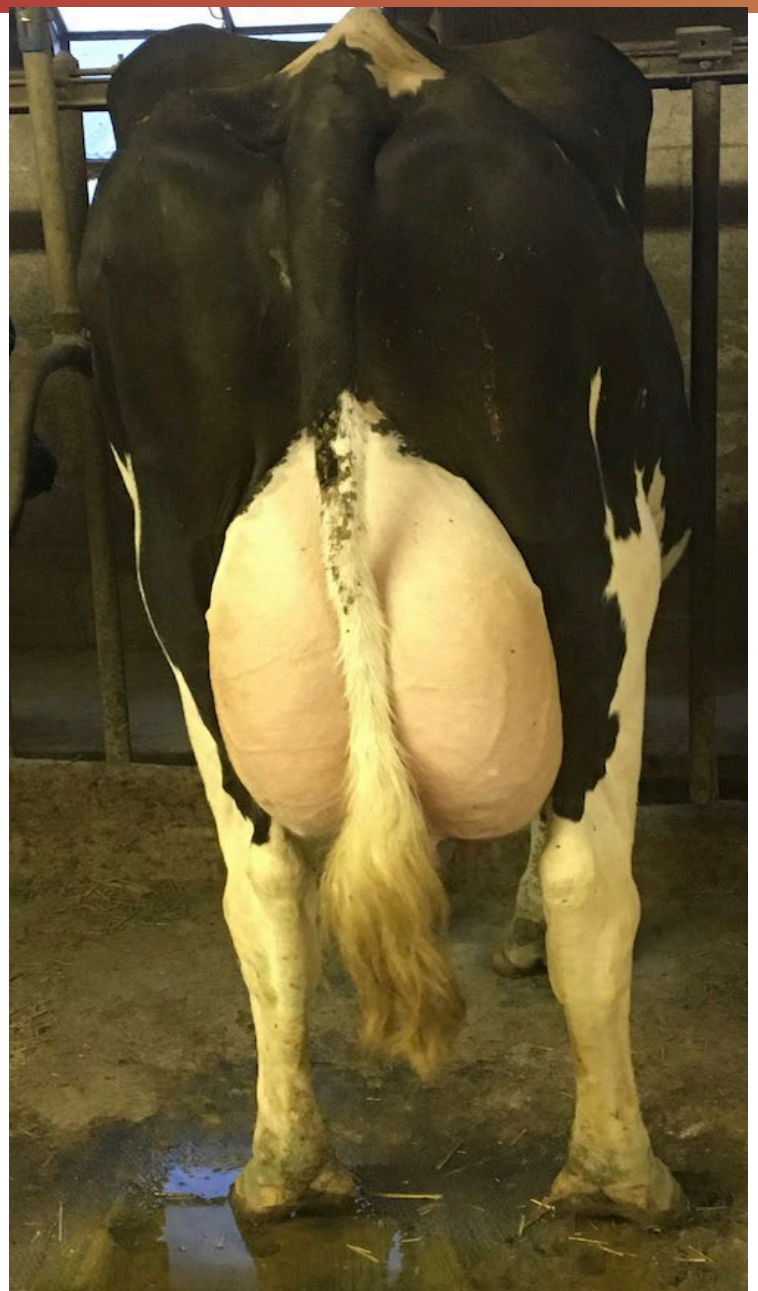
Pedometers and automated milk feeders

- Milk intake
- Drinking speed
- Visits

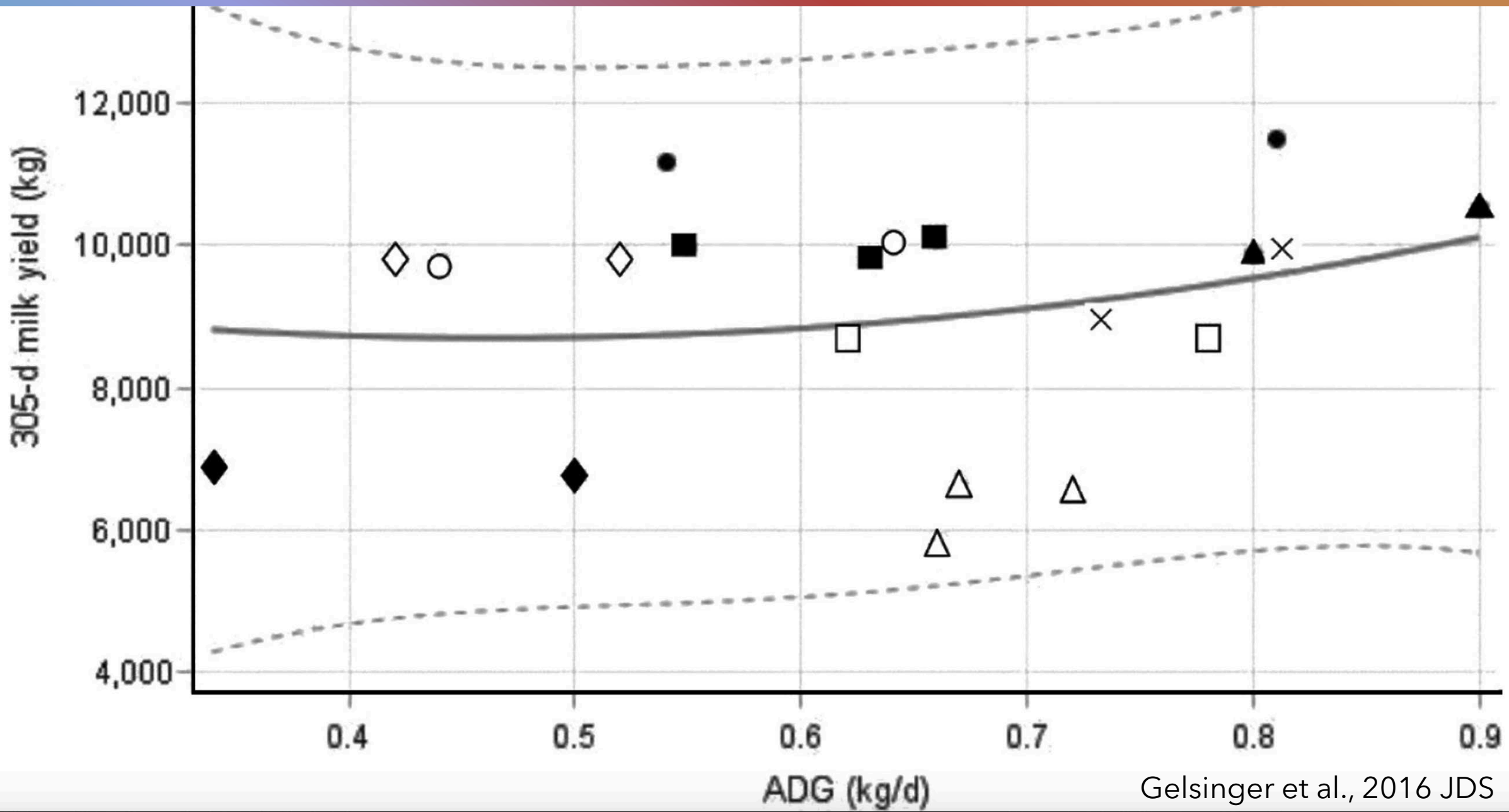
- Lying time
- Lying bouts
- Steps
- Activity index

Early growth preweaning= more milk first lactation



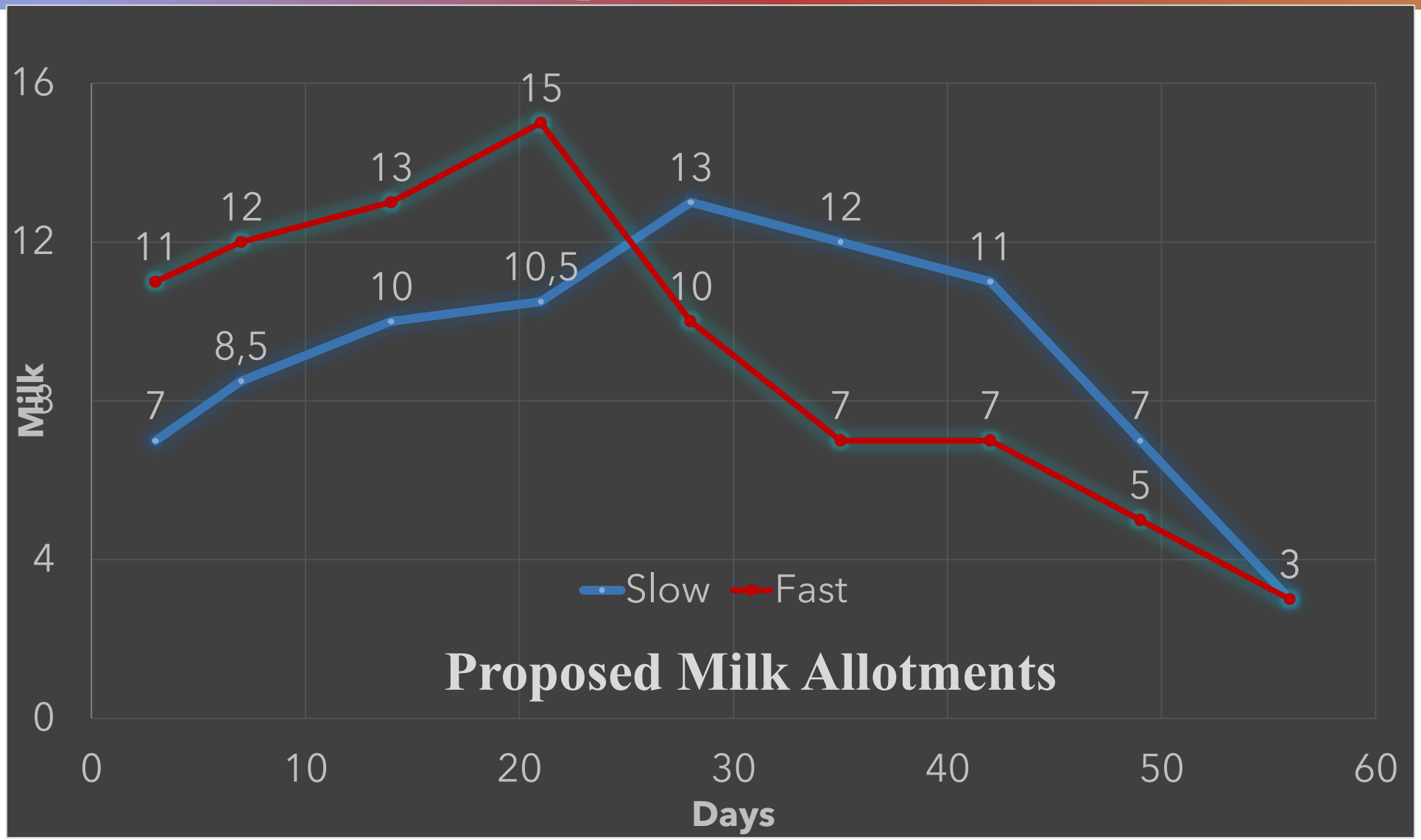


Early growth preweaning= more milk first lactation



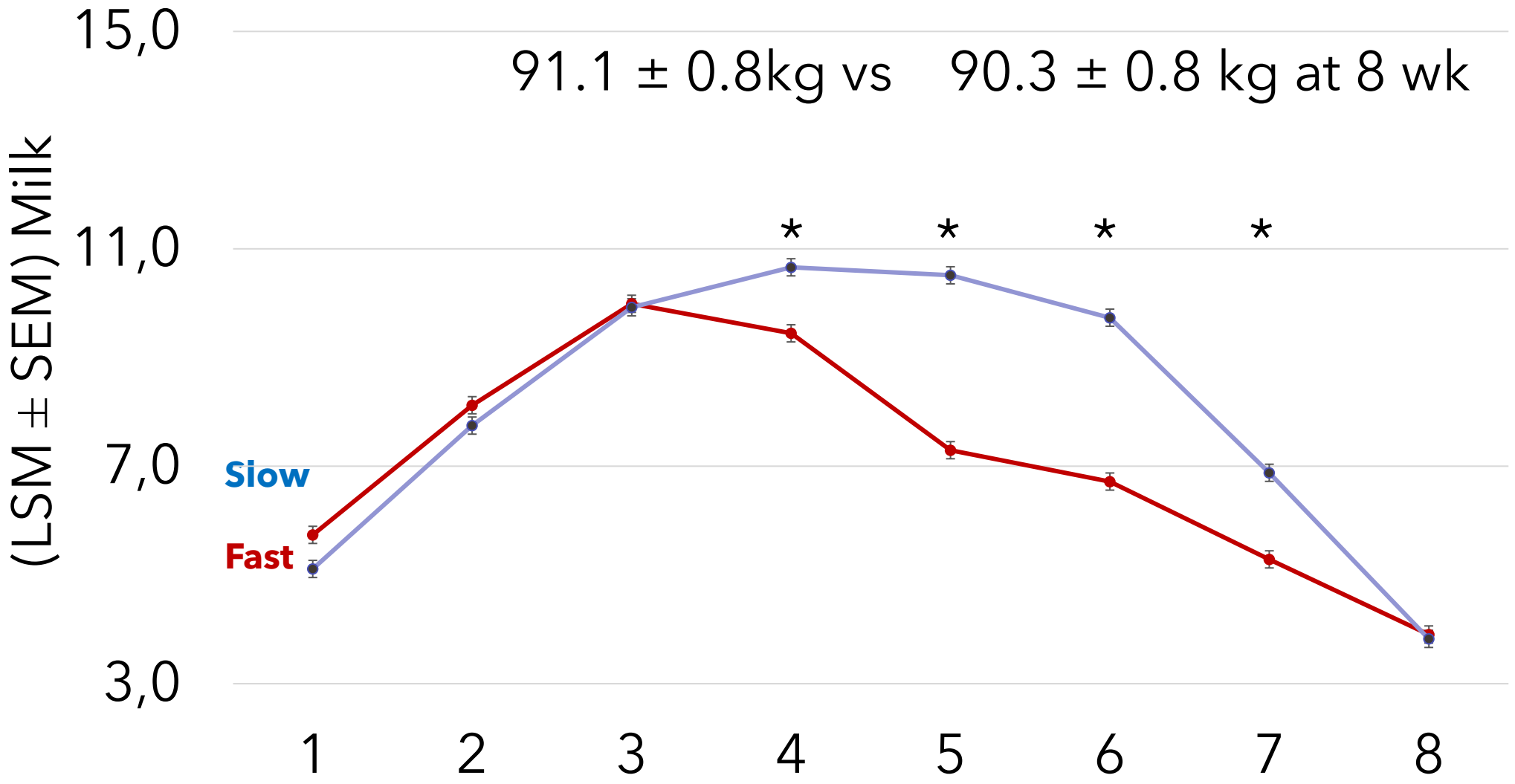
Gelsinger et al., 2016 JDS

Robotic feeders provide calves a choice



1 Adapted from Cantor et al., 2019

Robotic feeders maximize growth

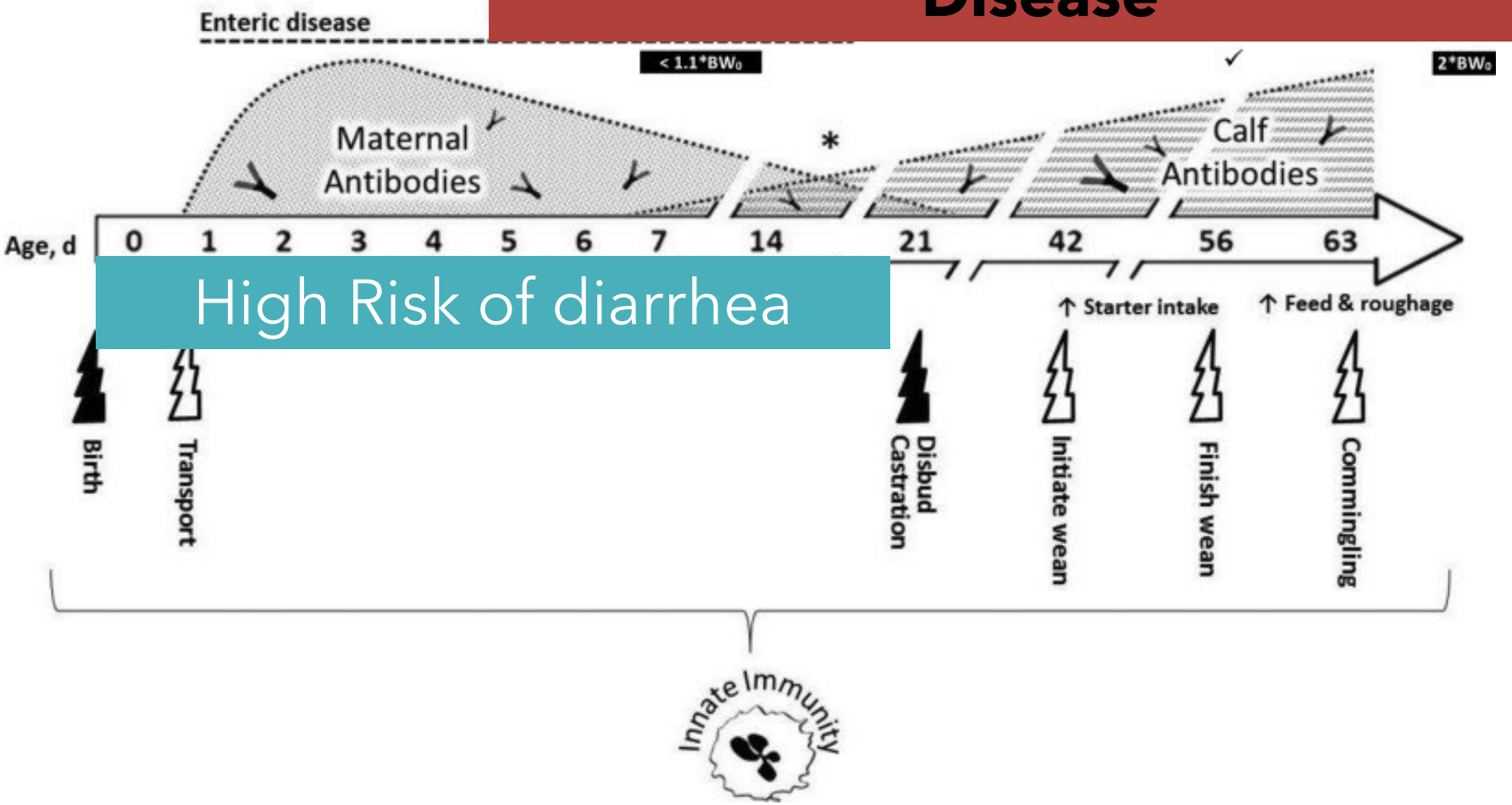


1 Adapted from Cantor et al., 2019

BUT finding sick calves in group housing is challenging

Dairy calves lack immunocompetence

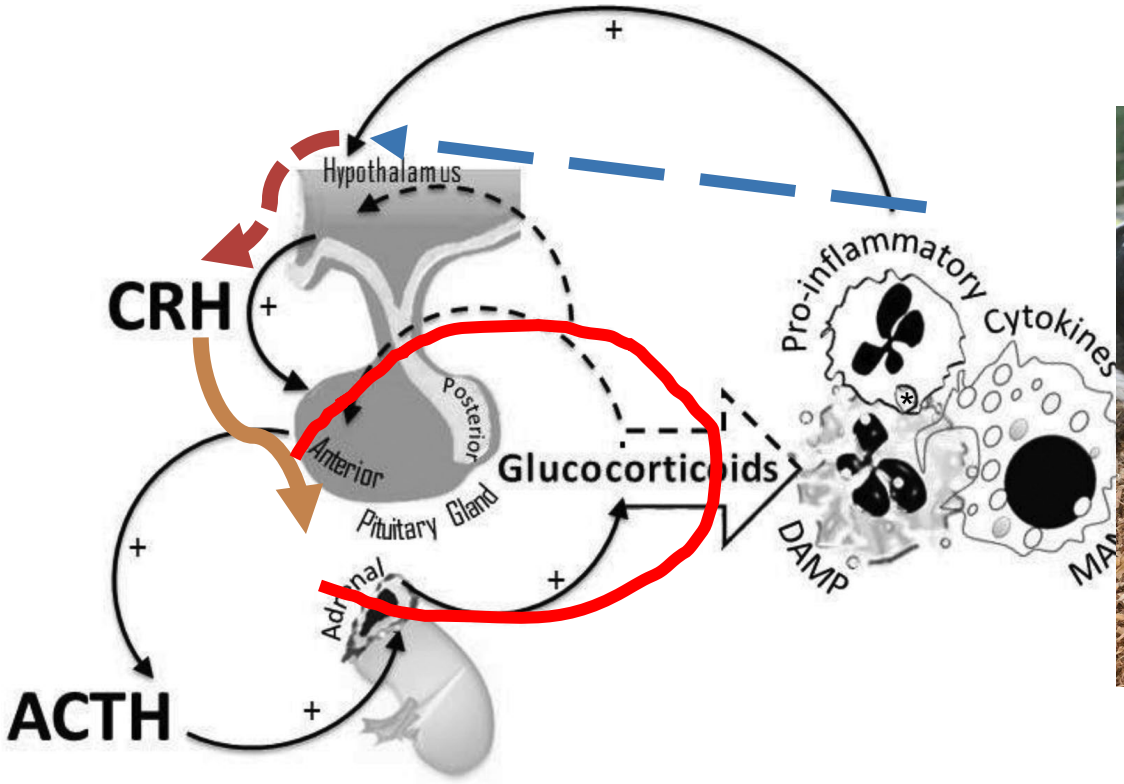
High Risk of Bovine Respiratory Disease

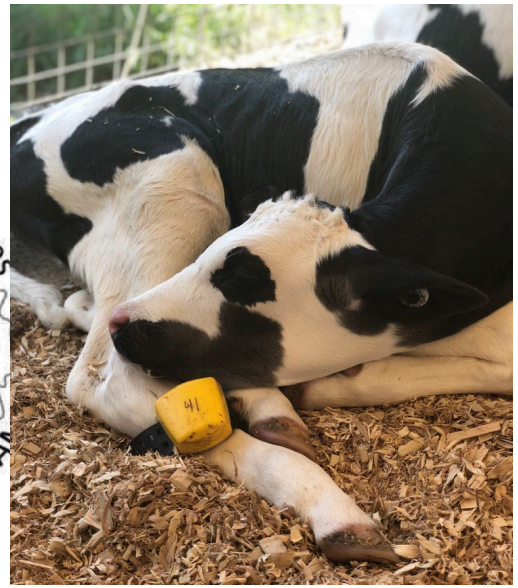


Cortese, 2009


Precision technology can help us!

Sickness behavior is a biological process

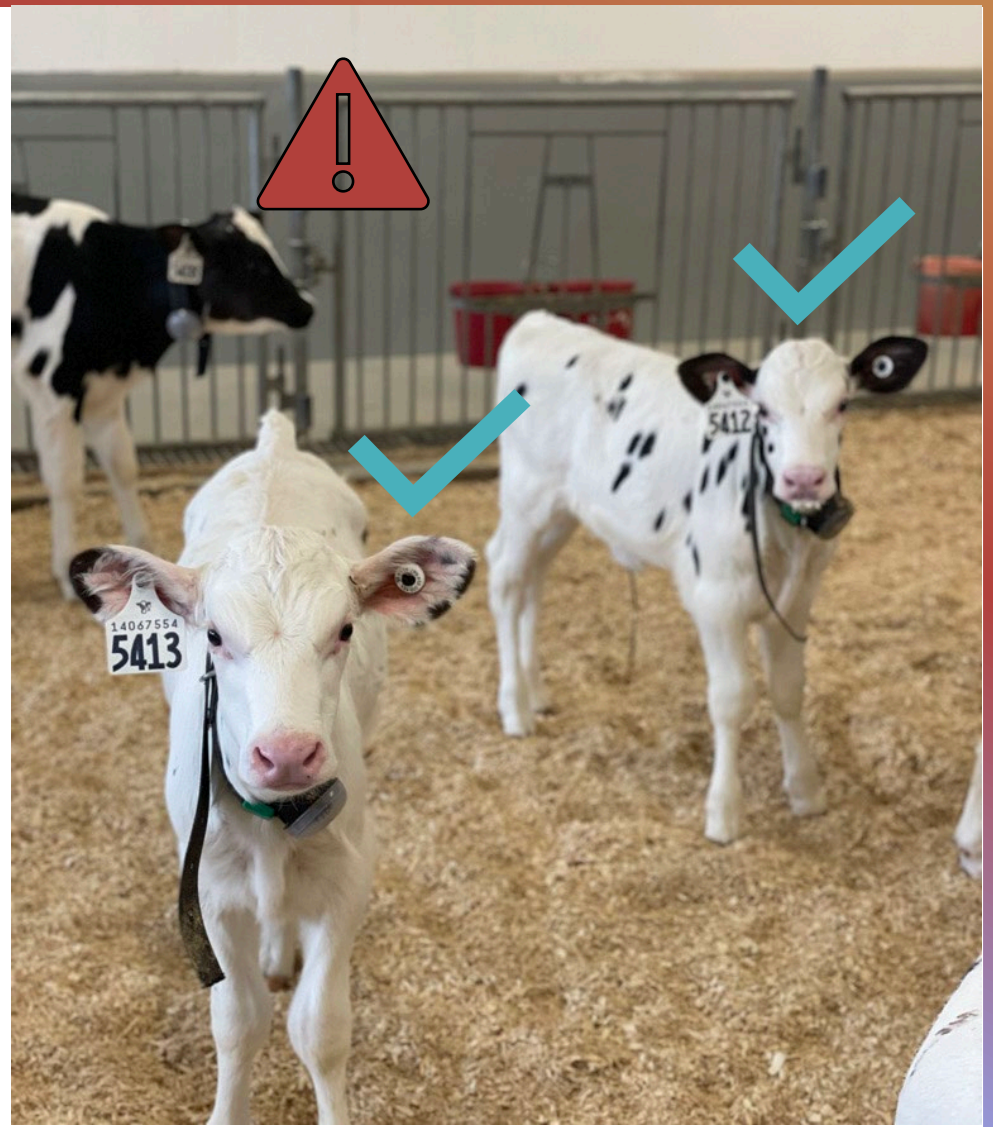




Hulbert et al., 2016

What is precision livestock farming {PLF}?

- ✓ Sensor + software[1]
- ✓ Monitors baseline for changes[1-5]
- ✓ PLF = sensor + software + alert for decision making[5-6]



1 Review Costa et al., 2021
2 Cantor et al., 2021
3 Cantor and Costa, 2022
4 Cantor et al., submitted
5 Casella et al., submitted
6 Cantor et al., 2022

Back to calves: A precision livestock farming story

Scours or diarrhea is commonplace

Leading cause of morbidity[1]

33% of calves had diarrhea (USDA 2018)

Leading cause of mortality[1]

Leading cause 50% of deaths (USDA 2018)

4 USDA, 2018

Consequences of diarrhea in calves

- ✓ Causes metabolic acidosis, low blood sugar, dehydration[1]
- ✓ Reduces average daily gain[2]
- ✓ Might affect first lactation milk[3]

1 Trefz et al., 2016, 2017
2 Pardon et al., 2022
3 Abutarish et al., 2021
4 USDA, 2018

Simple: Correlation diarrhea with behavior in calves

Journal of Dairy Science
Volume 106, Issue 12, December 2023, Pages 9366-9376

Research

Activity behaviors and relative changes in activity patterns recorded by precision technology were associated with diarrhea status in individually housed calves

D. Guevara-Mann [1], D.L. Renaud [1], M.C. Cantor [1 2]

Show more

animals

MDPI

Article

Associations between feeding behaviors collected from an automated milk feeder and neonatal calf diarrhea in group housed dairy calves: a case-control study

M.H. Conboy[1], C.B. Winder[1], M.C. Cantor[1], J.H.C. Costa[2], M.A. Steele[3], C. Medrano-Galarza[1,4], T. E. von Konigslow[1], A. Kerr[5] and D. L. Renaud[1*]

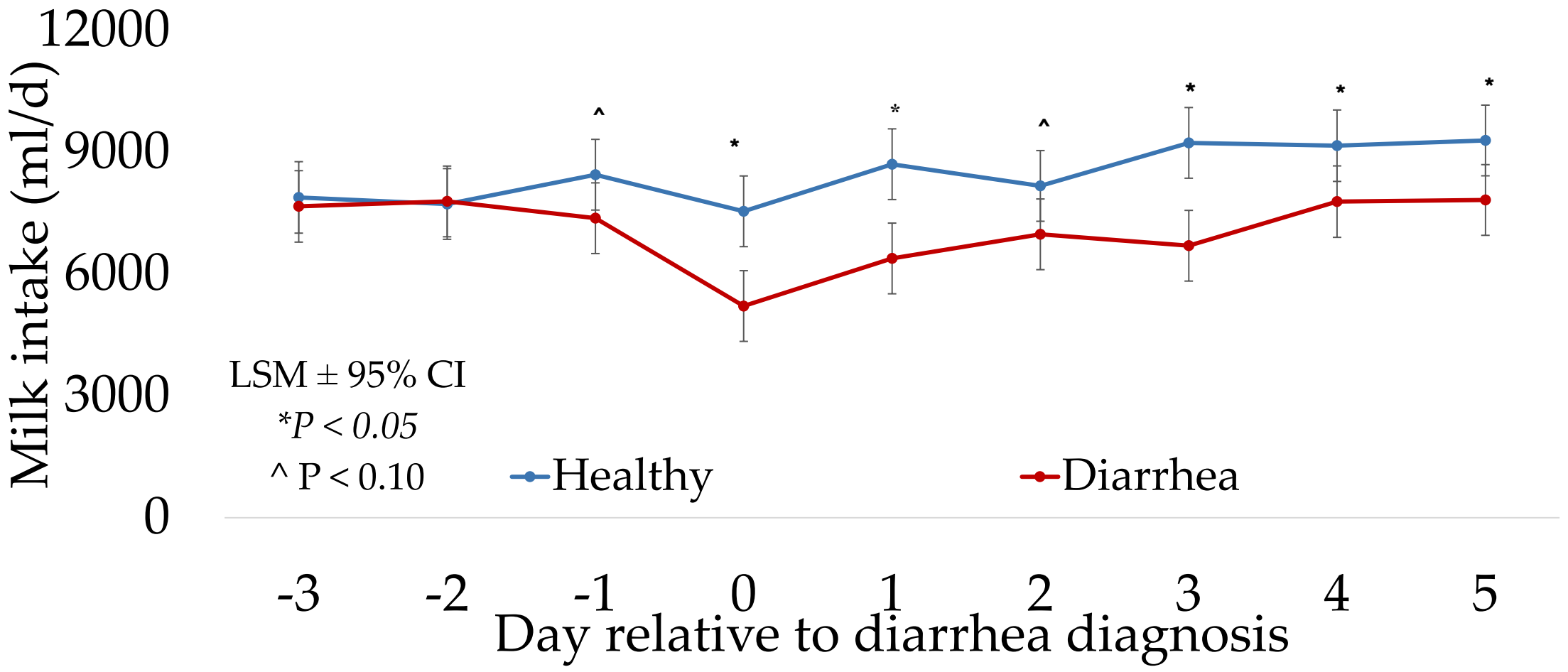
[1] Department of Population Medicine, University of Guelph, Guelph, ON, Canada, N1G 2W1

PennState

DAIRY at GUELPH
CANADA'S DAIRY UNIVERSITY

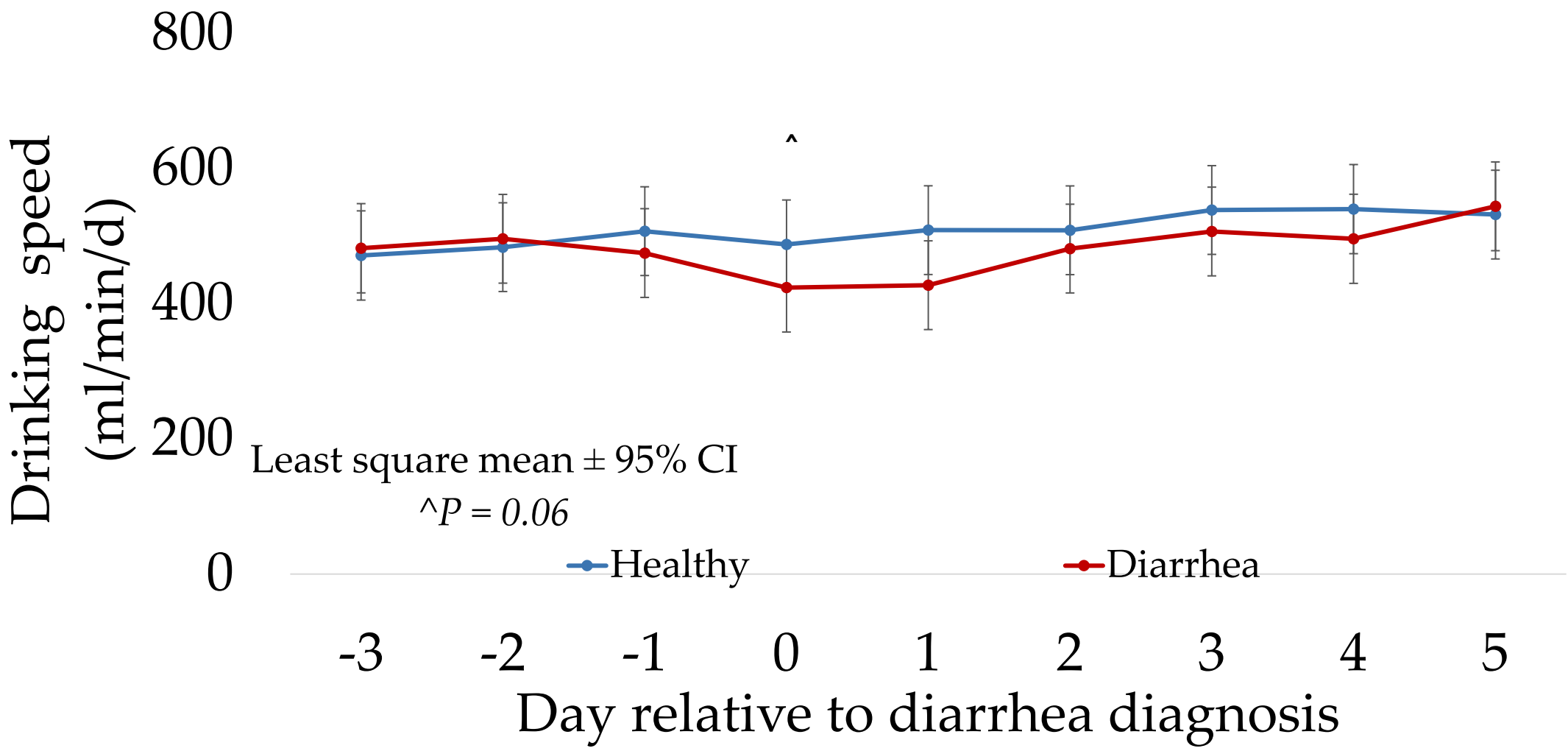
Is feeding behavior correlated with calf diarrhea?

Calves drink less milk surrounding diarrhea



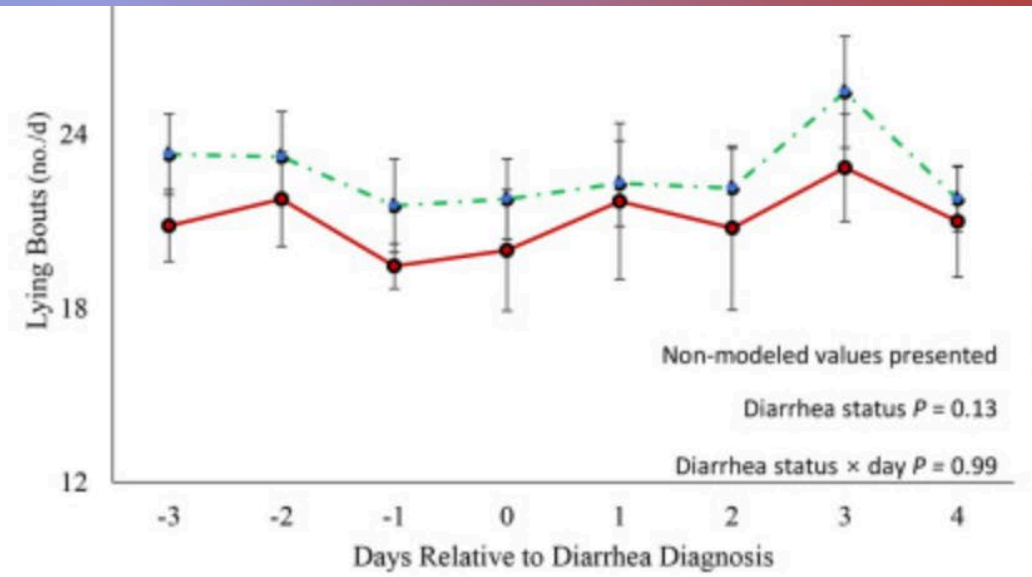
1 Adapted from Conboy et al., 2022

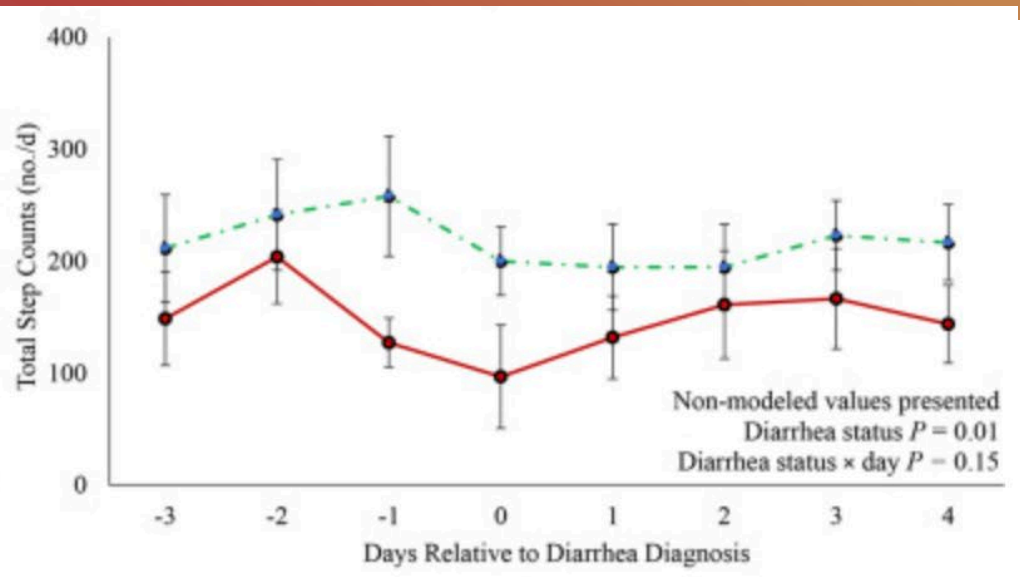
Calves tend to drink slowly during diarrhea

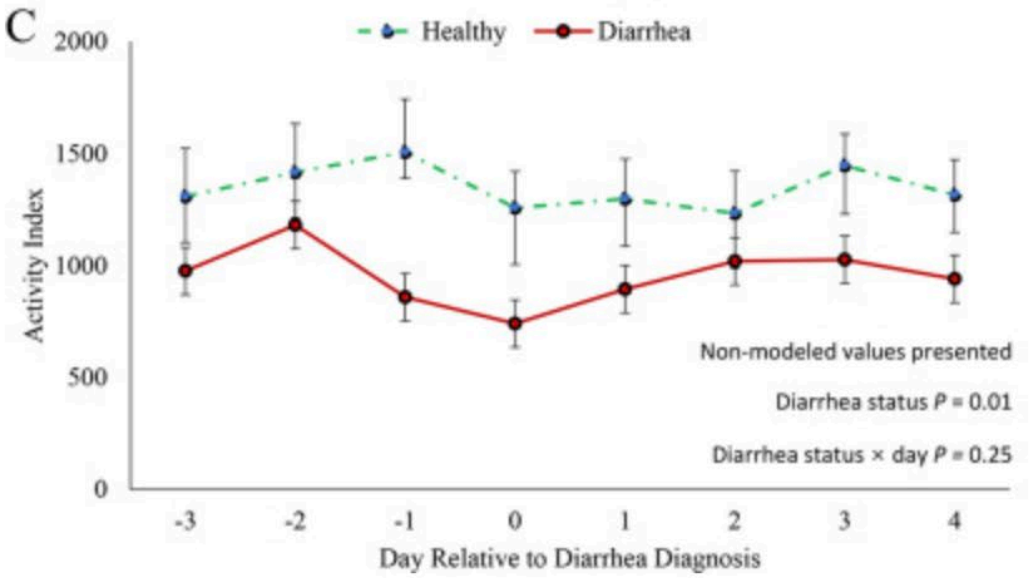


1 Adapted from Conboy et al., 2022

Sick calves are less active

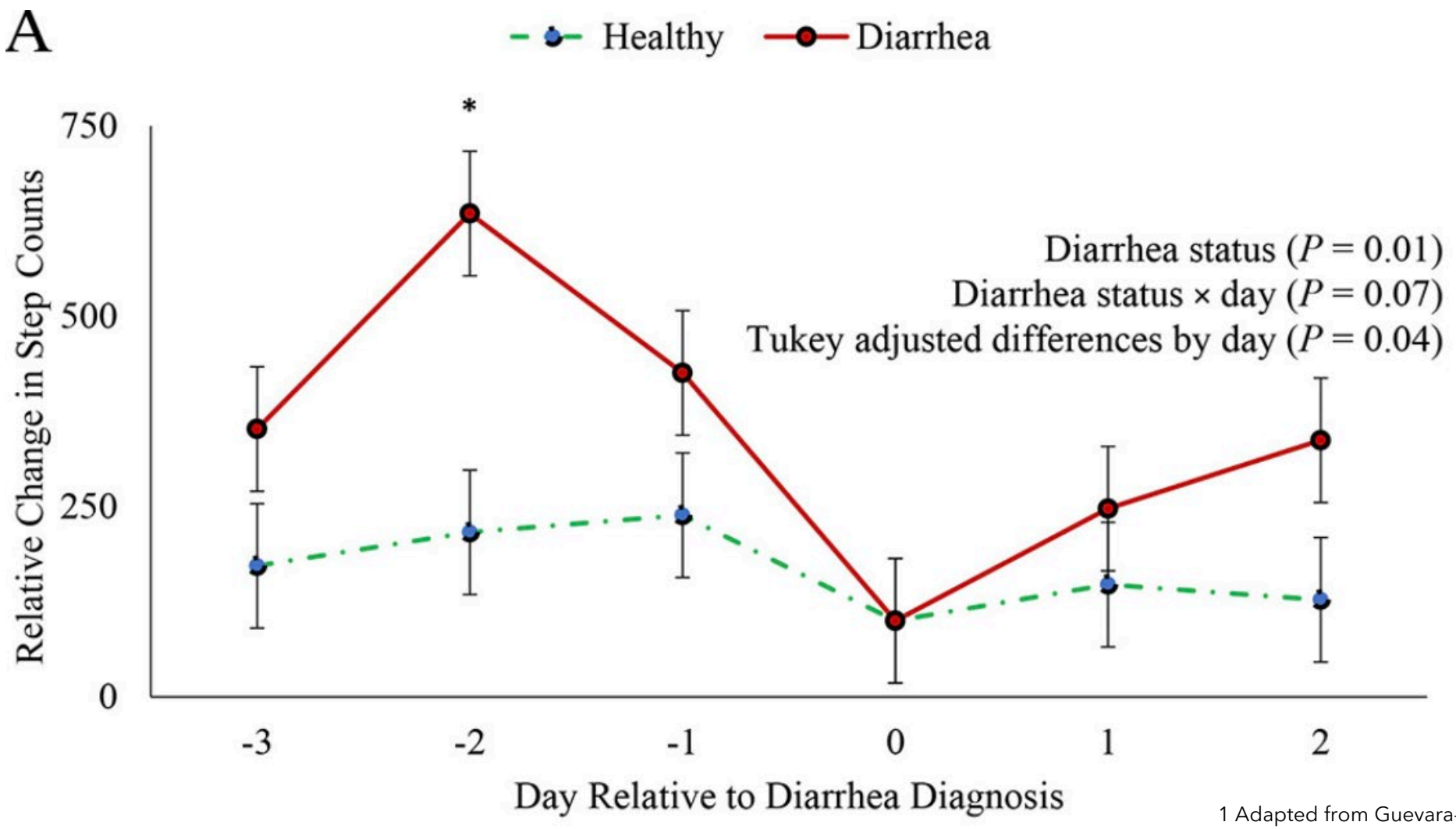






1 Adapted from Guevara-Mann et al., 2023

Steps and index useful for -2 d alert



1 Adapted from Guevara-Mann et al., 2023

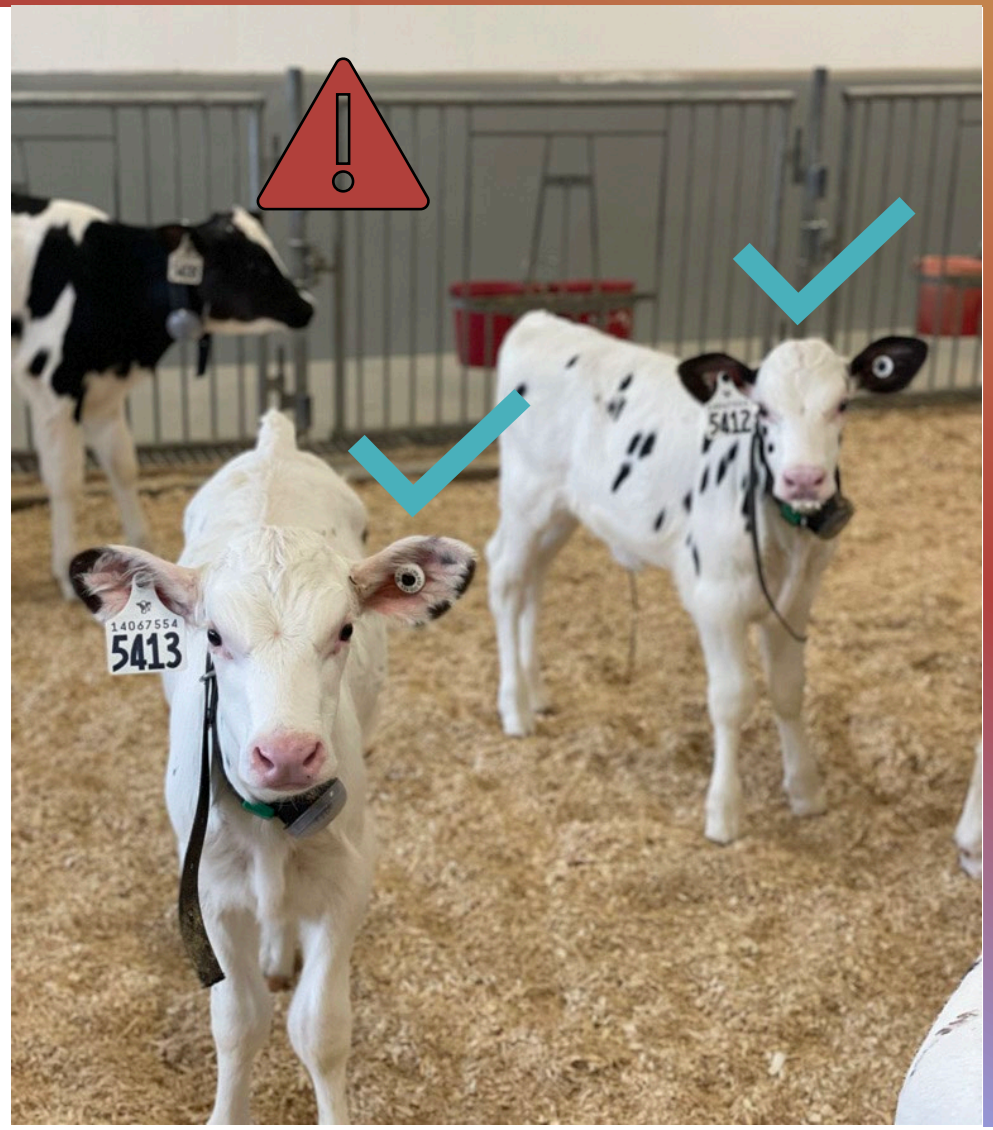
Using collective feeding behavior had poor sensitivity

Feeding behavior	Optimal cutpoint	Sensitivity	Specificity	Area under ROC curve
Milk intake (mL)	6025	0.44	0.28	0.36
Rewarded visits (/d)	11	0.34	0.69	0.52

1 Adapted from Conboy et al., 2022

So how do we find the sick calf?

Objective: Use robotic data to create algorithm for diarrhea



ELSEVIER

Journal of Dairy Science
Available online 9 November 2023
In Press, Journal Pre-proof What's this?

The development, and validation of a milk feeding behavior alert from automated feeder data to classify calves at-risk for a diarrhea bout: A diagnostic accuracy study

M.C. Cantor [2], A.A. Welk [2], K.C. Creutzinger [1 4], M. M. Woodrum Setser [5], J.H.C. Costa [3], D.L. Renaud [2]

Show more

Alert steps: create, test, validate

N=259 calves w complete data

Daily health records

Milk, speed, rewarded visits tested

Relative change, rolling dividends

Cantor et al., 2024


10 L/d
VS.
15 L/d

Alert steps: create relative change alert

$$\text{Milk intake relative change today} = \frac{(previous\ day\ \ milk - \text{day before yesterday milk})}{\text{day } before\ yesterday\ milk}$$

Cantor et al., 2024

Alert steps: create rolling dividends alert

$$\text{Milk intake rolling dividends today} = \frac{previous\ day\ \ milk}{\text{day } before\ yesterday\ milk}$$

Cantor et al., 2024

Alert test: Diagnostic accuracy

AUC ROC curve > 70%
Sensitivity > 80%
Precision > 90%
Accuracy > 80%

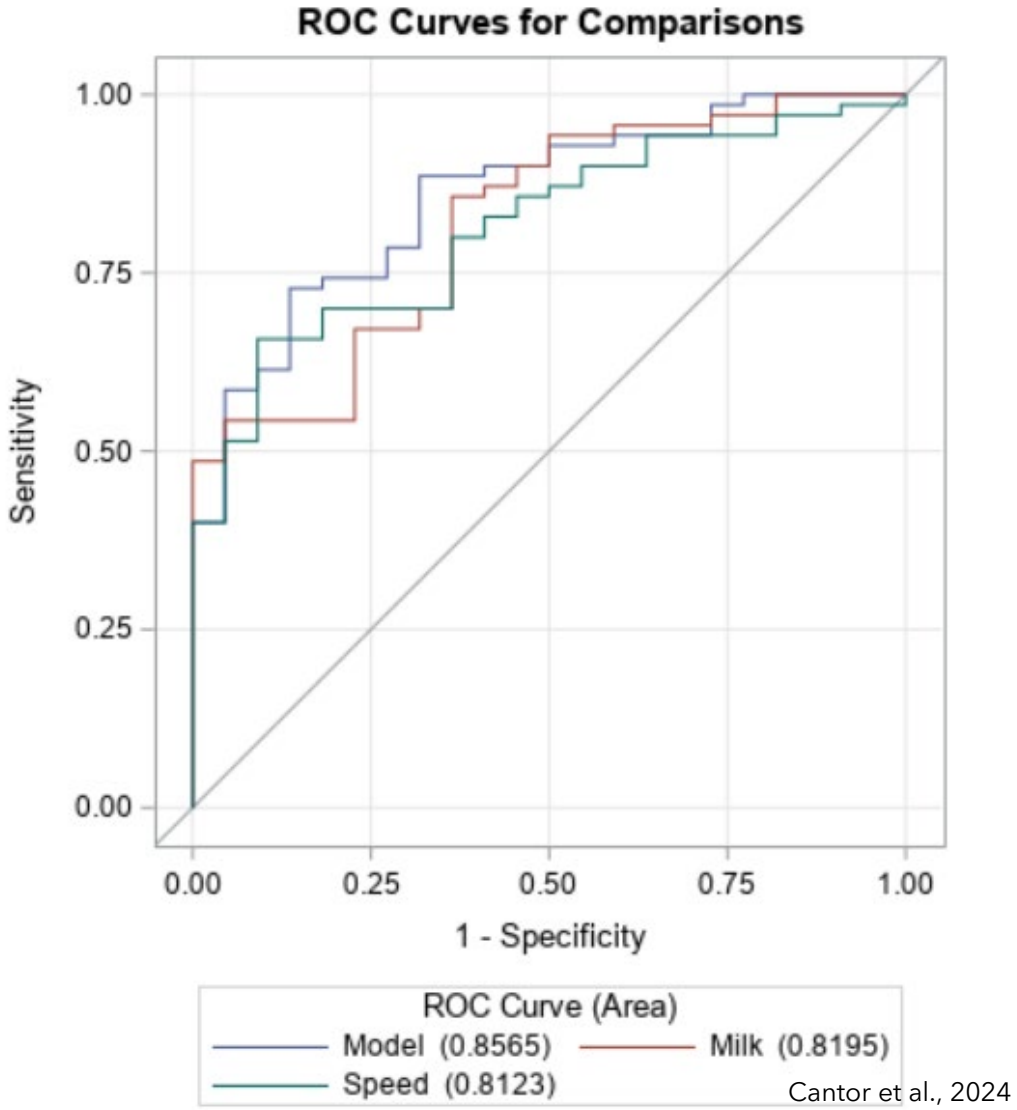
Cantor et al., 2024

Results

Alert works! dividends milk + drinking speed

15 L/d calves

- ✓ Threshold ≤ 0.60
  Sensitivity 91% 32/35
- ✓ Accuracy 82% 39/46
- ✓ Precision 89% 32/36
- ✓ Specificity 73% 8/11



Cantor et al., 2024

Alert test failure: rolling dividend milk

10 L/d

No diagnostic accuracy

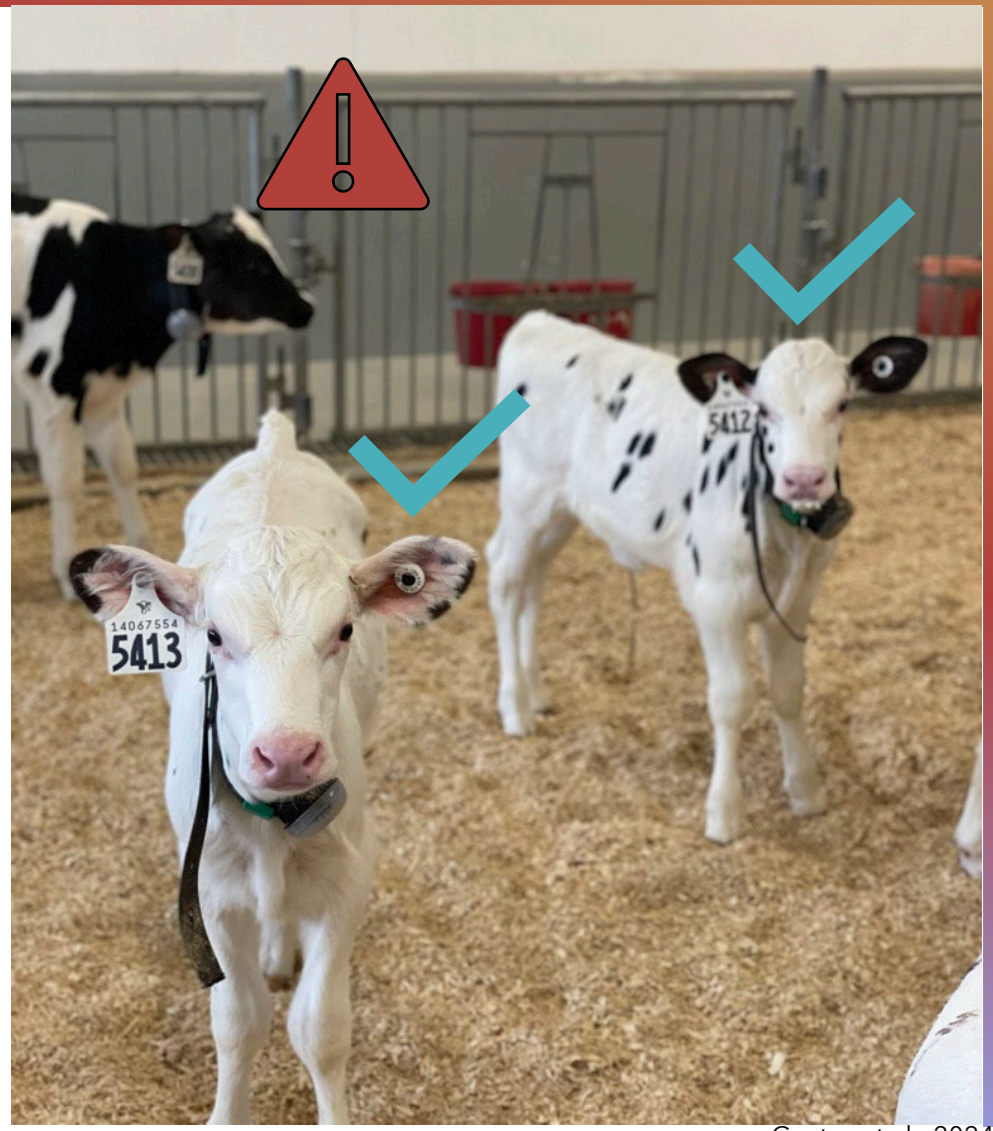
Threshold 0.71

Sensitivity 48% 36/75

Accuracy 52% 45/86

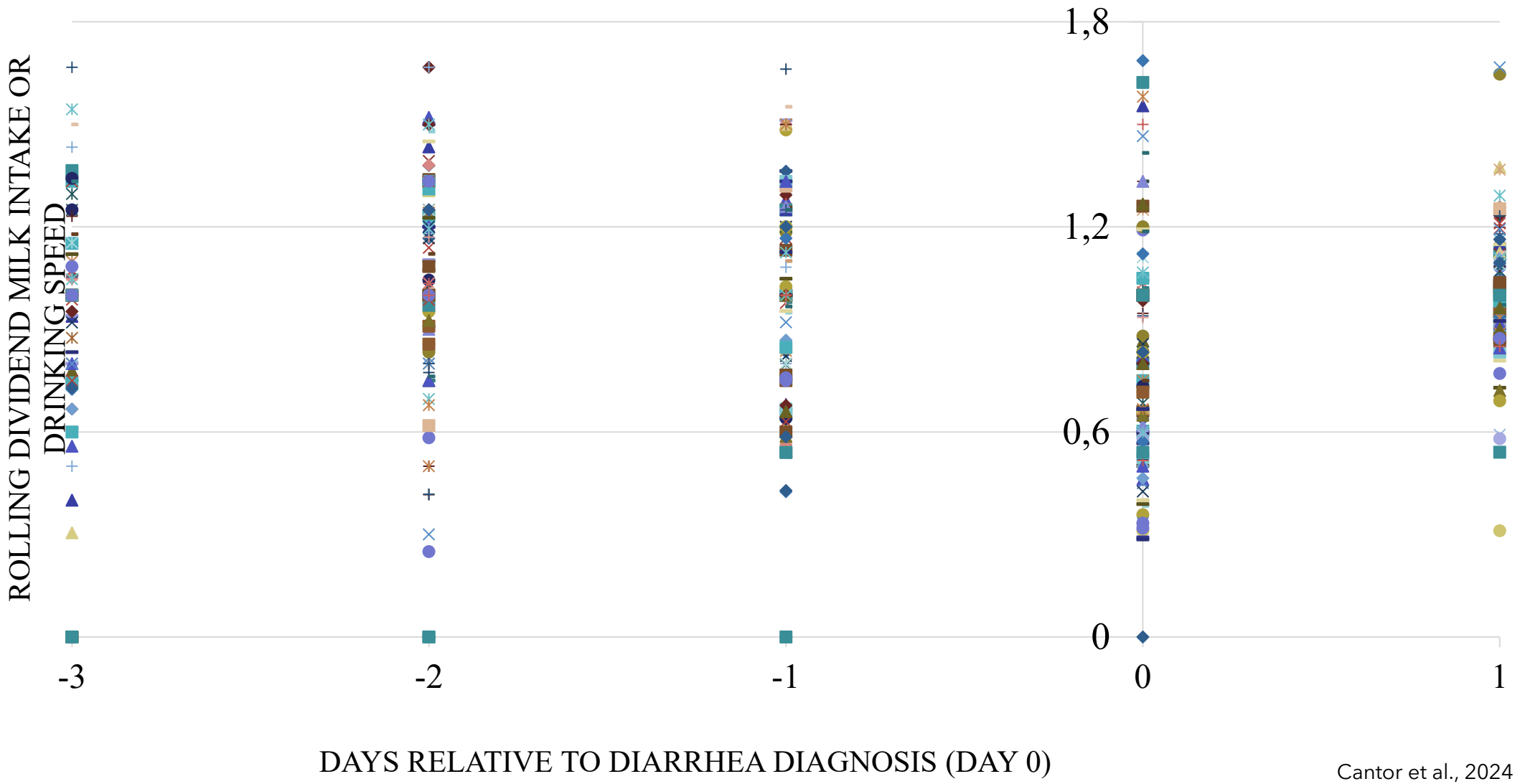
Precision 96% 36/38

Specificity 82% 9/11



Cantor et al., 2024

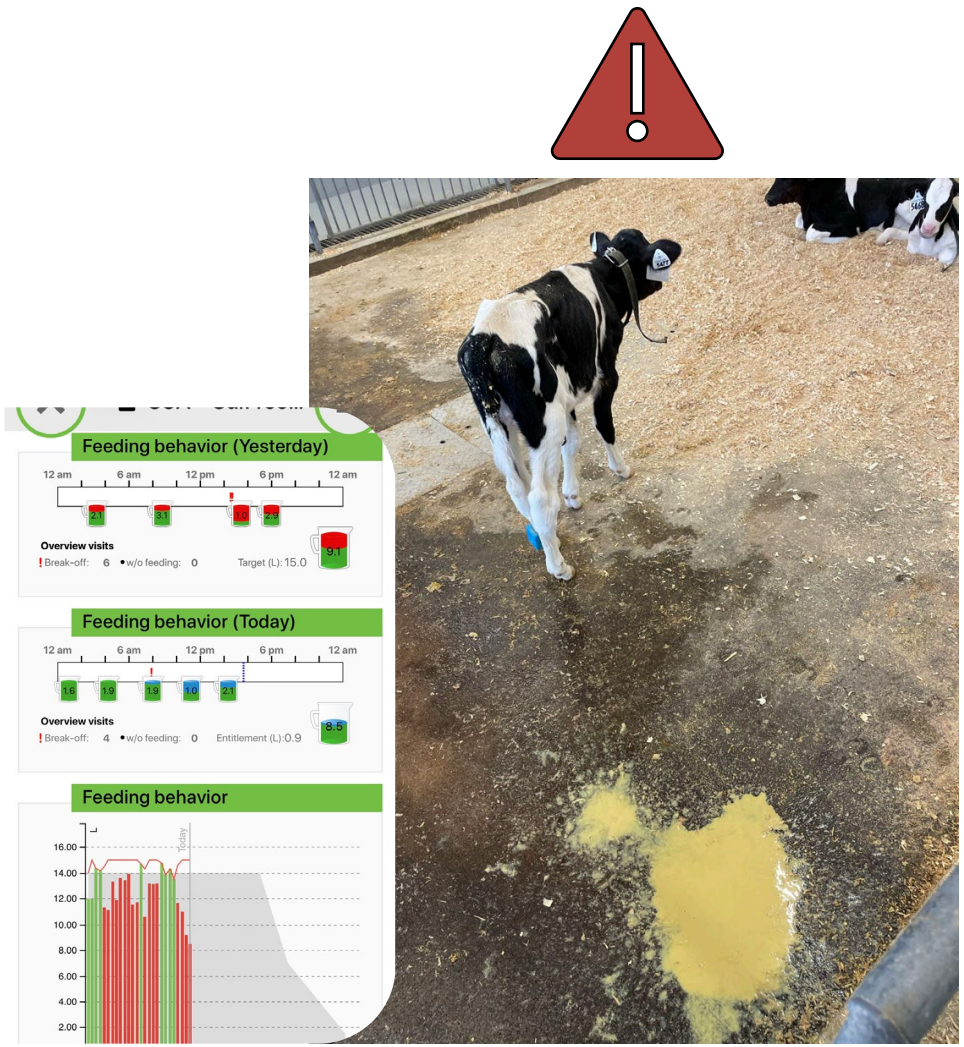
Summary: calves are individuals



Cantor et al., 2024

Where should we go?

- ✓ Test alert with real time data[1]
- ✓ Test potential of different [1-3] interventions



1 Welk et al., in review
2 Cantor et al., 2021
3 Carter et al., 2022

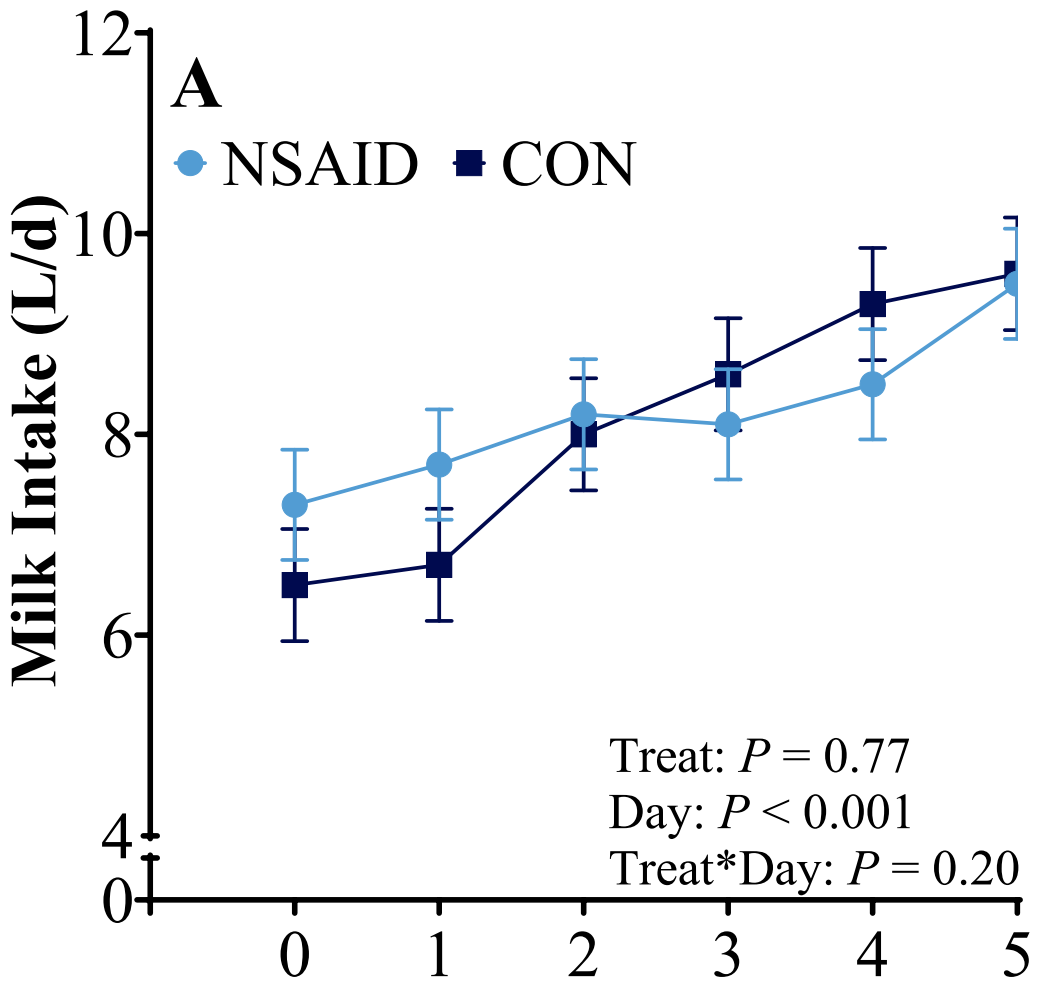
PennState
College of Agricultural Sciences

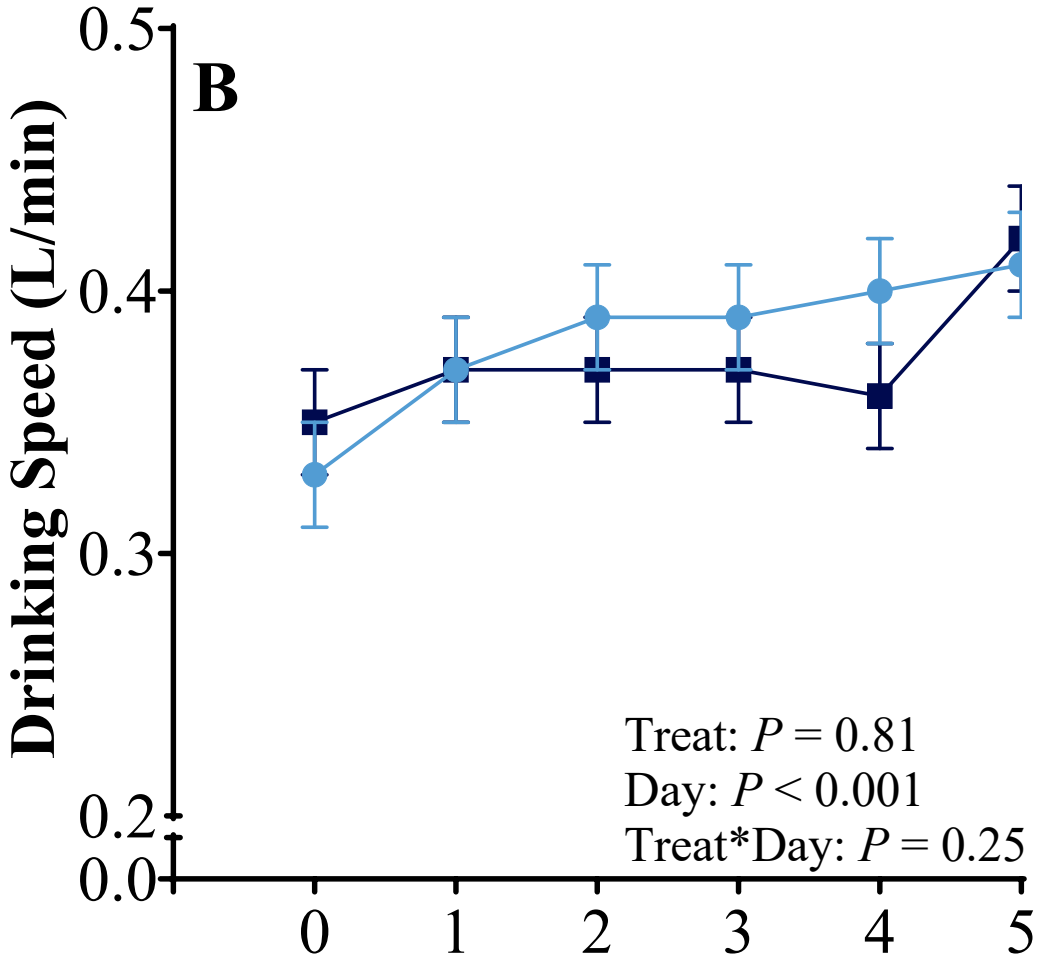
2024- Test "Smart" robotic algorithm

DAIRY at GUELPH
CANADA'S DAIRY UNIVERSITY

What do you think does an NSAID work for improving calf behavior?

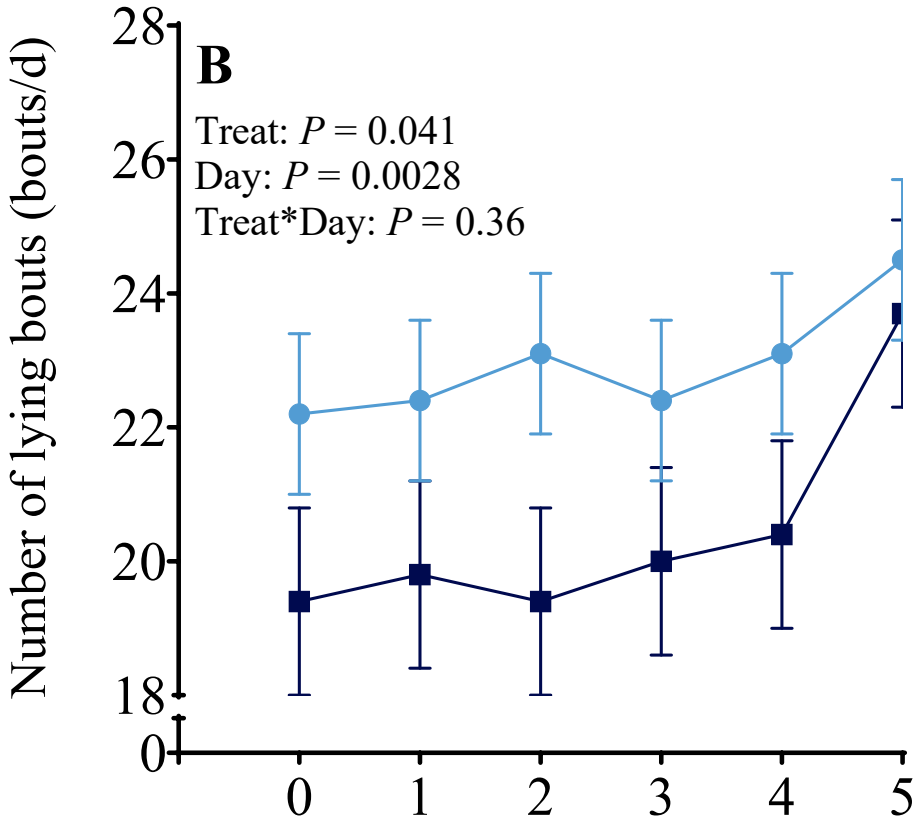
Milk intake, drinking speed not affected (n=61)

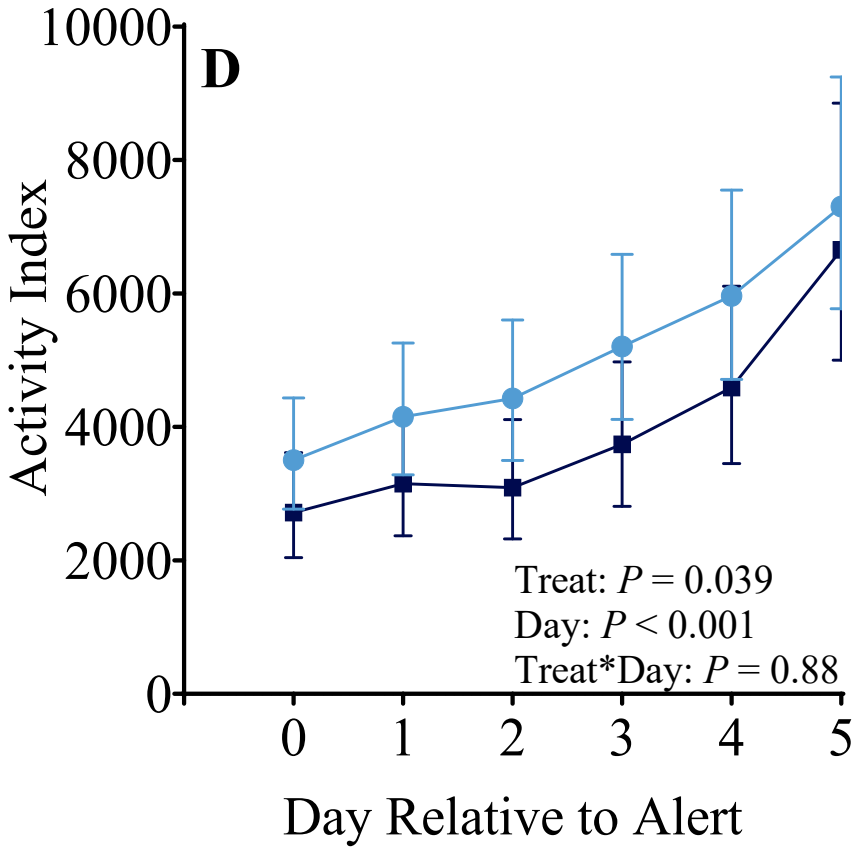




Welk et al., submitted

Locomotor activity greatly affected (N=32)

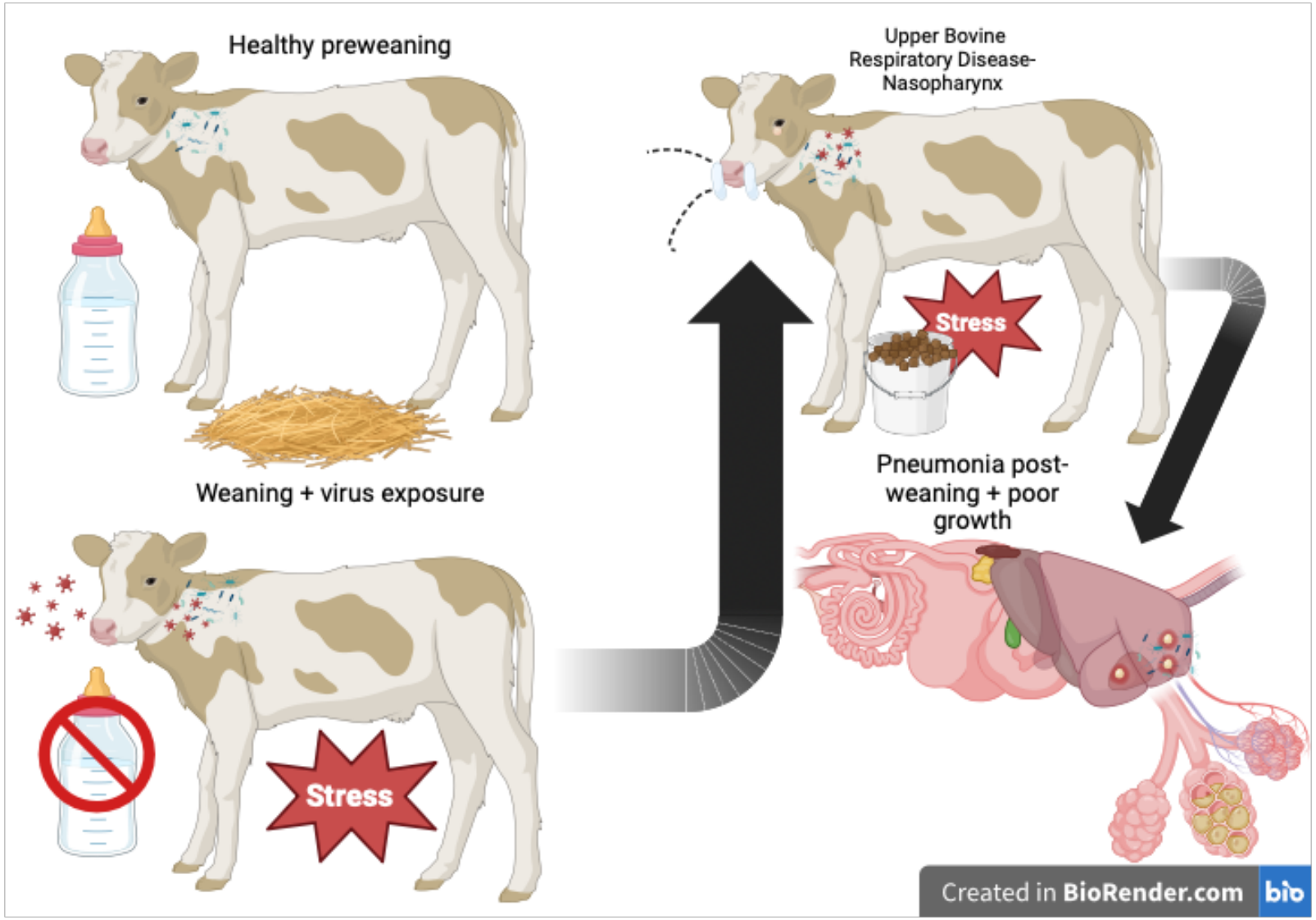




Welk et al., submitted

What about pneumonia?

Bovine Respiratory Disease Complex (BRD)

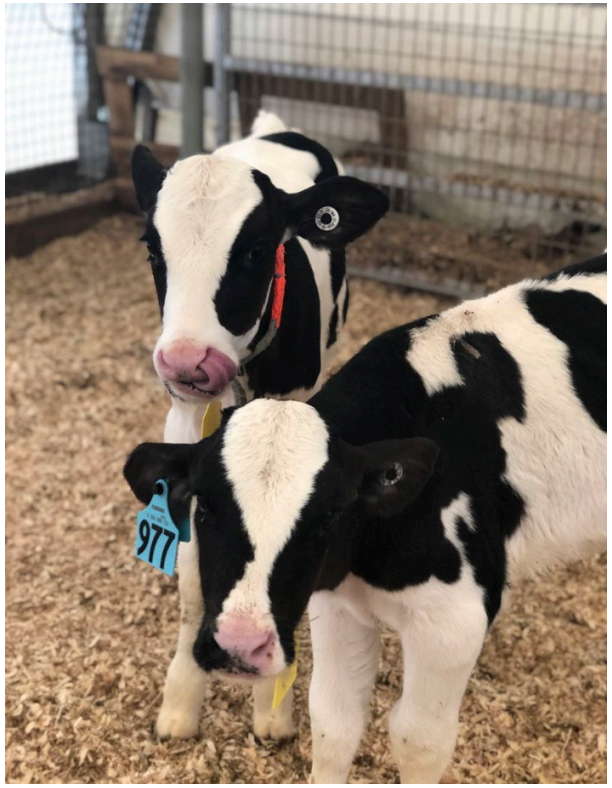


Urie et al., 2018
Benaraek et al., 2014
Welling et al., 2020,
USDA, 2018
Dubrovsky et al., 2019

BRD is a leading killer of dairy replacements

- Second leading killer of preweaned calves
- Leading killer of postweaned calves
- Potentially underdiagnosed[5]
  - One study found 40% of BRD cases missed

?



Urie et al., 2018
Benaraek et al., 2014
Welling et al., 2020,
USDA, 2018
Dubrovsky et al., 2019

The correlation of BRD with feeding and activity

ELSEVIER

Journal of Dairy Science

Volume 105, Issue 7, July 2022, Pages 6070-6082

Research

Daily behavioral measures recorded by precision technology devices may indicate bovine respiratory disease status in preweaned dairy calves

M.C. Cantor [1, 2], J.H.C. Costa [1]

Show more

+ Add to Mendeley Share Cite

University of Kentucky

https://doi.org/10.3168/jds.2021-20798

Get rights and content

Open access

Feed intake decreases surrounding BRD

ITEM DAILY	HEALTHY [95% CI]	BRD [95% CI]	SEM	F-VALUE DEGREES FREEDOM	BRD STATUS[1]	TREAT* DAY
Milk intake L	9.41 [9.07-9.75]	8.58 [8.24-8.91]	0.16	$13.00_{1,31}$	0.001	0.66
Drinking speed (L/min)	0.89 [0.80-0.98]	0.96 [0.86-0.11]	0.04	$1.03_{1,31}$	0.32	0.57
Rewarded visits	3.57 [3.36-3.78]	3.71 [3.50-3.91]	0.10	$0.96_{1,32}$	0.33	0.54
Unrewarded visits[2]	2.23 [1.58-2.95]	1.95 [1.32-2.64]	NA	$0.36_{1,32}$	0.55	0.05
Starter intake[2] g	69.93 [50.34-95.88]	42.34 [29.54-59.28]	NA	$4.72_{1,31}$	0.03	0.12

Cantor and Costa, 2022

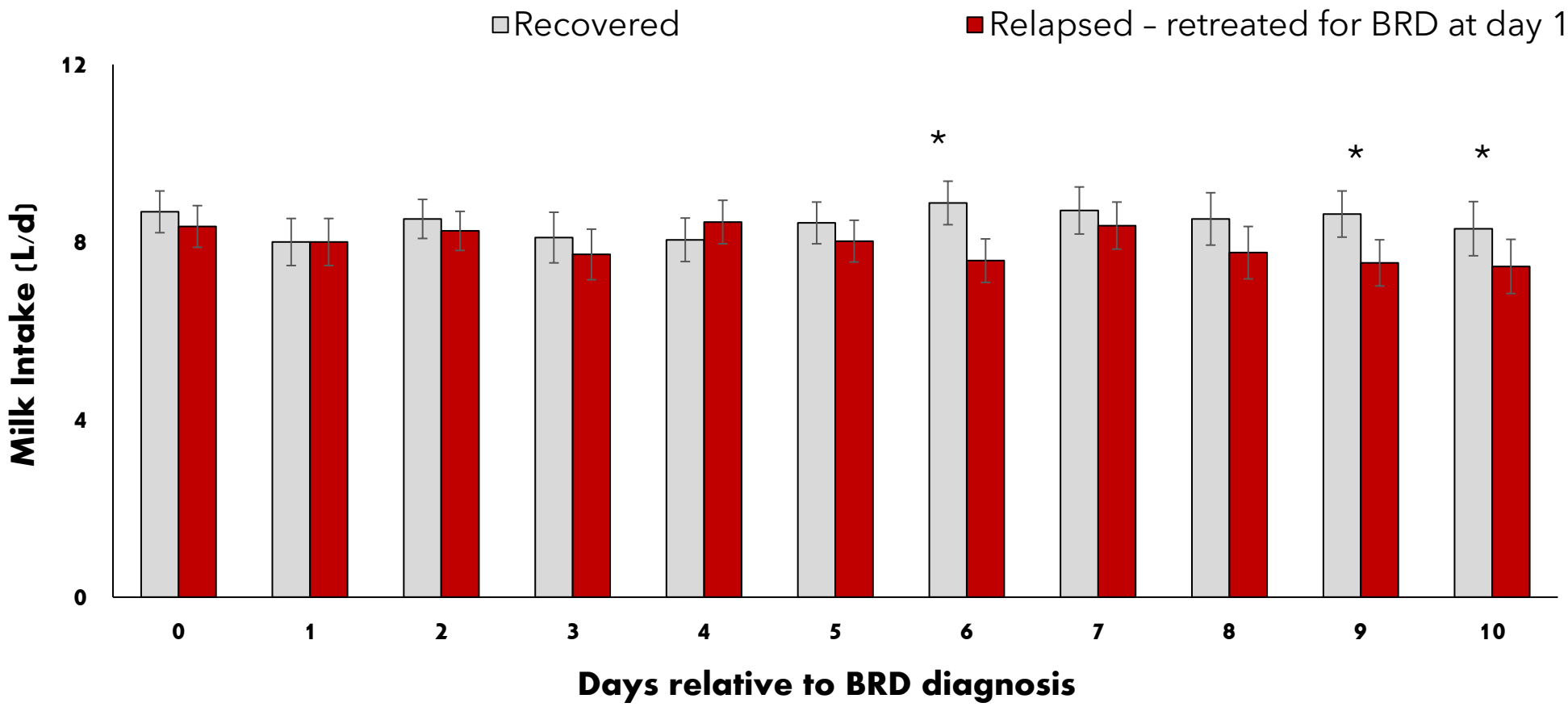
BRD calves show lethargic behavior

ITEM DAILY	HEALTHY [95% CI]	BRD [95% CI]	SEM	F-VALUE DEGREES FREEDOM	BRD STATUS[1]	TREAT* DAY
Lying time	17.05 [16.79-17.31]	17.72 [17.46-17.97]	0.13	$14.24_{1,30}$	< 0.001	0.18
Lying bouts	21.07 [19.81-22.34]	18.51 [17.25-19.77]	0.62	$8.91_{1,31}$	0.01	0.60
Step count	645.97 [592.36- 699.58]	428.41 [375.15-481.67]	26.25	$35.94_{1,30}$	< 0.001	0.87
Activity index[1]	3504.94 [32271.71- 3788.18]	2444.62 [2162.48- 2726.76]	134.48	$31.11_{1,29}$	< 0.001	0.88

Cantor and Costa, 2022


Even calves who relapse from antibiotics change their behavior!

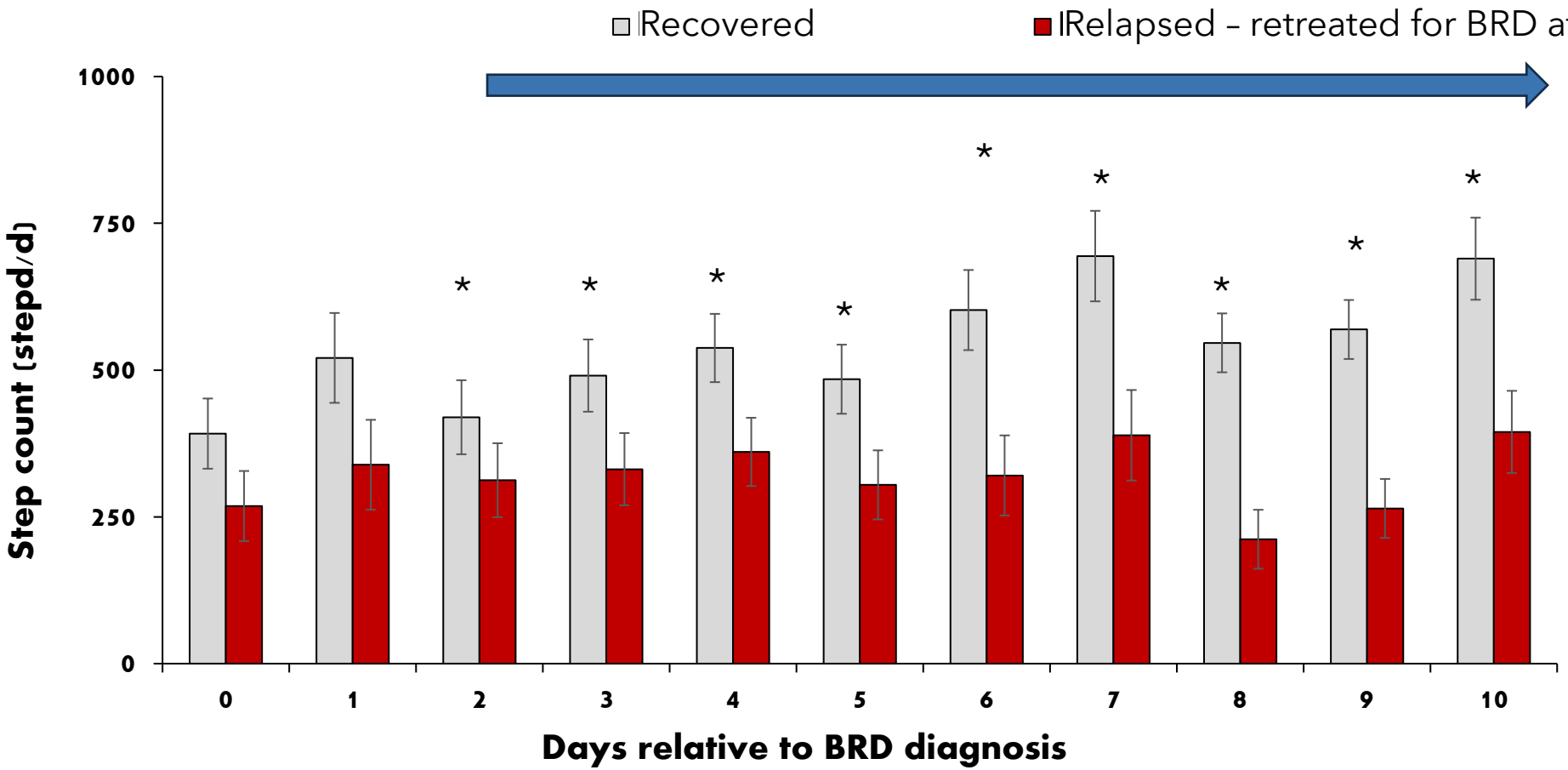
Calves decrease milk, and grain surrounding relapse with BRD



Grain intake (51 v. 138 g/d) was also lower in relapsed calves

Cantor et al., 2022. Sci. Reports

A calf's activeness is also useful for monitoring for recovery from treatment



Cantor et al., 2022. Sci. Reports

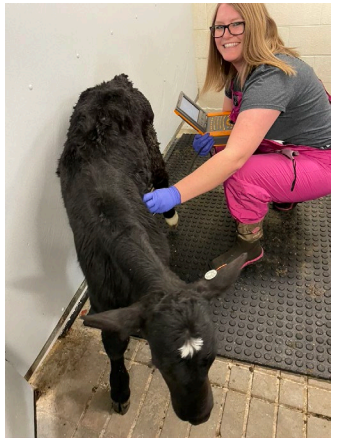

Can we use machine learning to find sick calves?

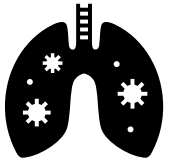
Which performs better: Tech or exams?

Automatic

Manual

Healthy

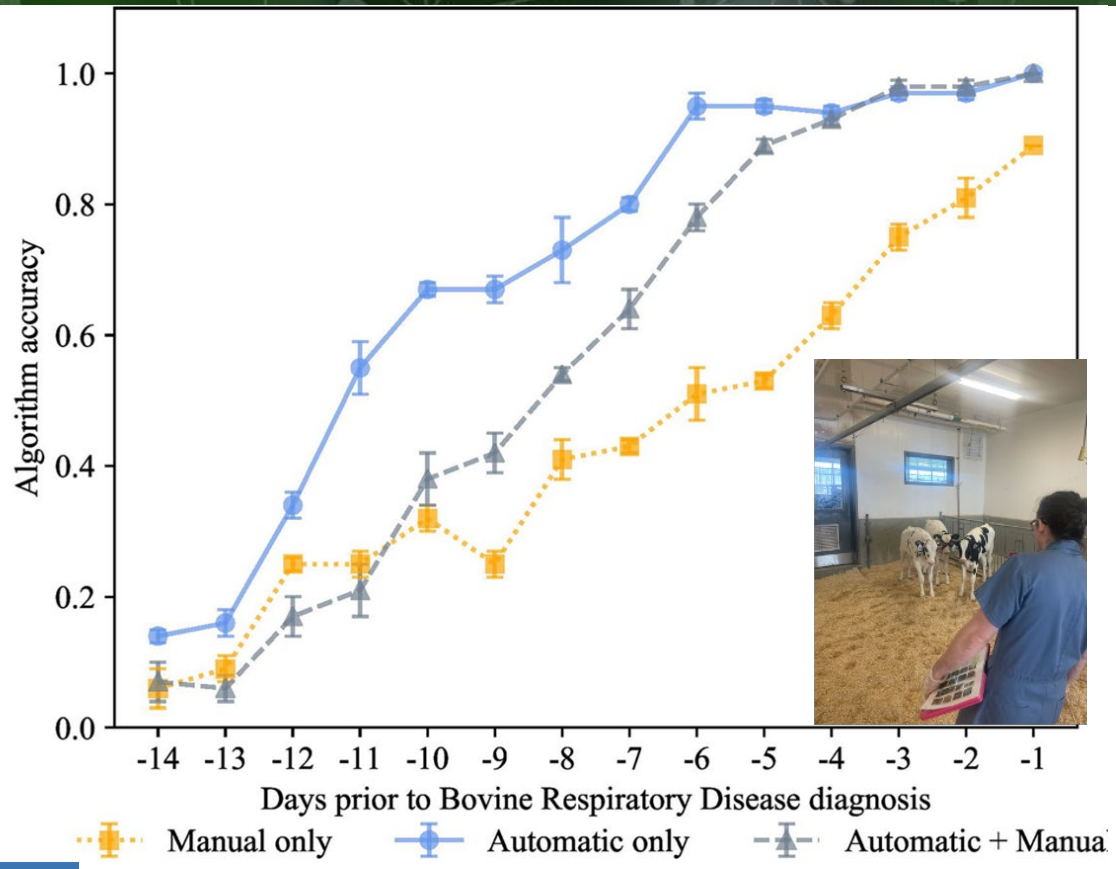




54 BRD

PennState
College of Agricultural Sciences

2021-2023 Artificial intelligence= pneumonia 96% accuracy w robotics



REPORT A CONCERN GIVE APPLY MORE

This is Penn State + Academics + Admission + Tuition and Aid Research Athletics News +

Precision technology, machine learning lead to early diagnosis of calf pneumonia

Wearable sensors, automatic feeders yield clues about onset of bovine respiratory disease

That's nice but is it economical?

Journals & Magazines > IEEE Access > Volume: 11

A Machine Learning and Optimization Framework for the Early Diagnosis of Bovine Respiratory Disease

Datasets Available

Publisher: IEEE Cite This PDF

Enrico Casella ; Melissa C. Cantor ; Megan M. Woodrum Setser ; Simone Silvestri ; Joao H. C. Costa ... **All Authors**

610 Full Text Views

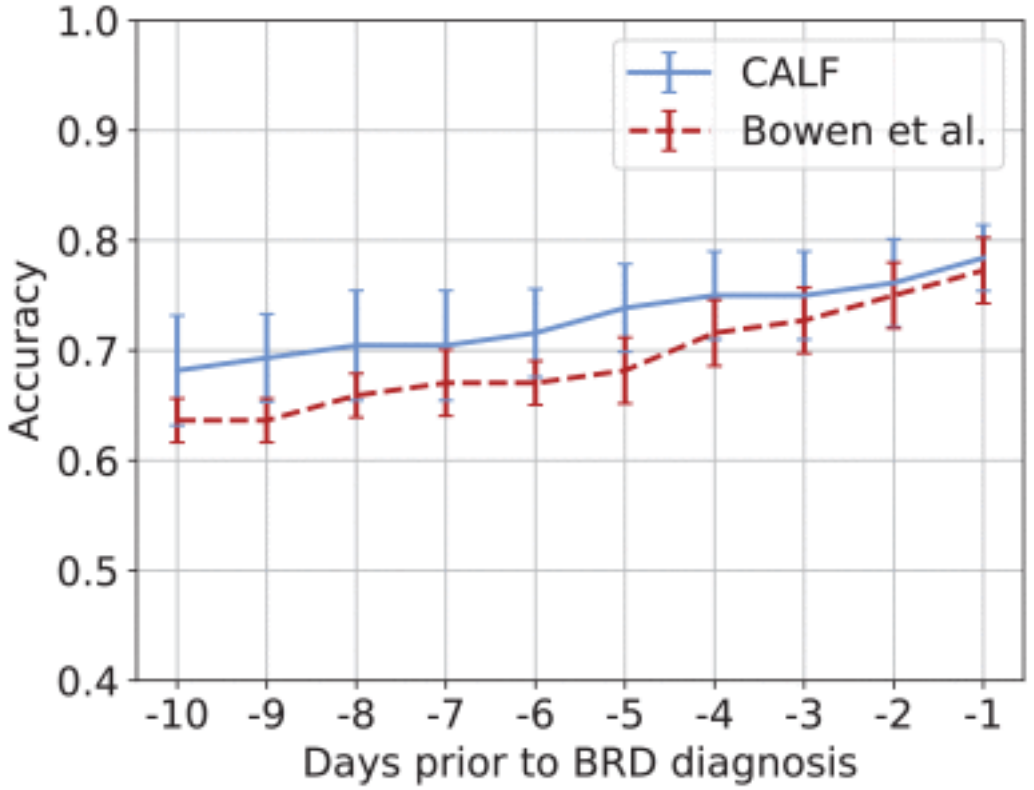
Open Access Comment(s)

University of Kentucky

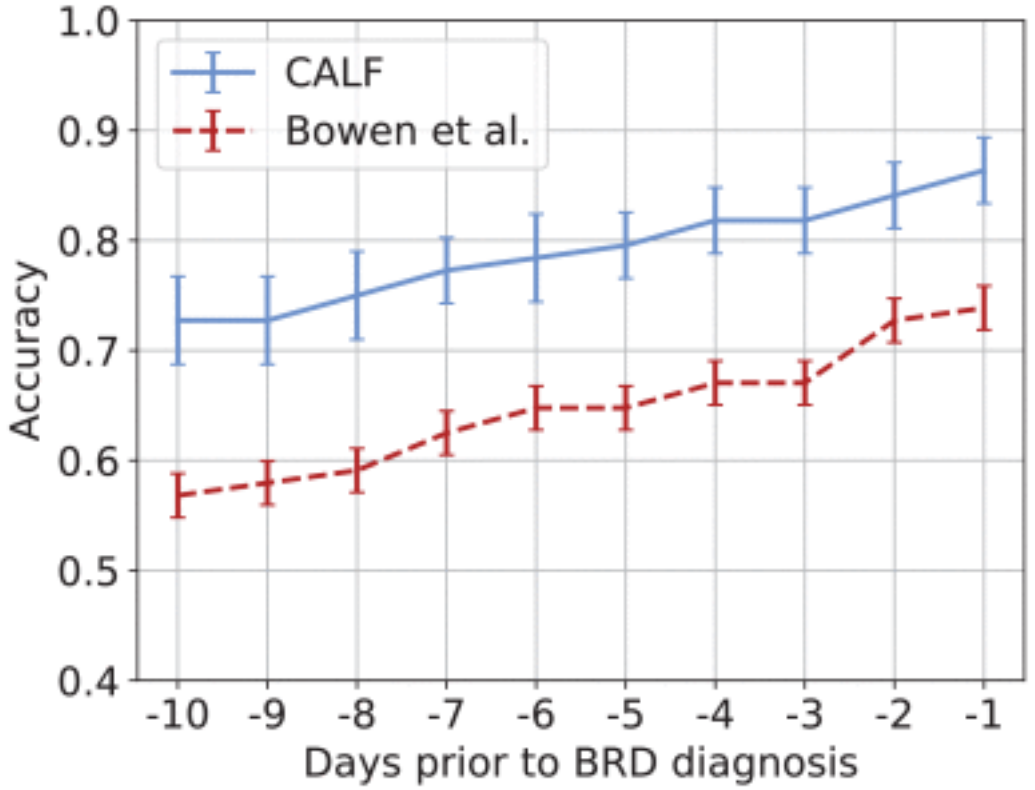
PennState

The UNIVERSITY of VERMONT

Accuracy 80% -6 d with budget constraints



(a) Low-budget scenario

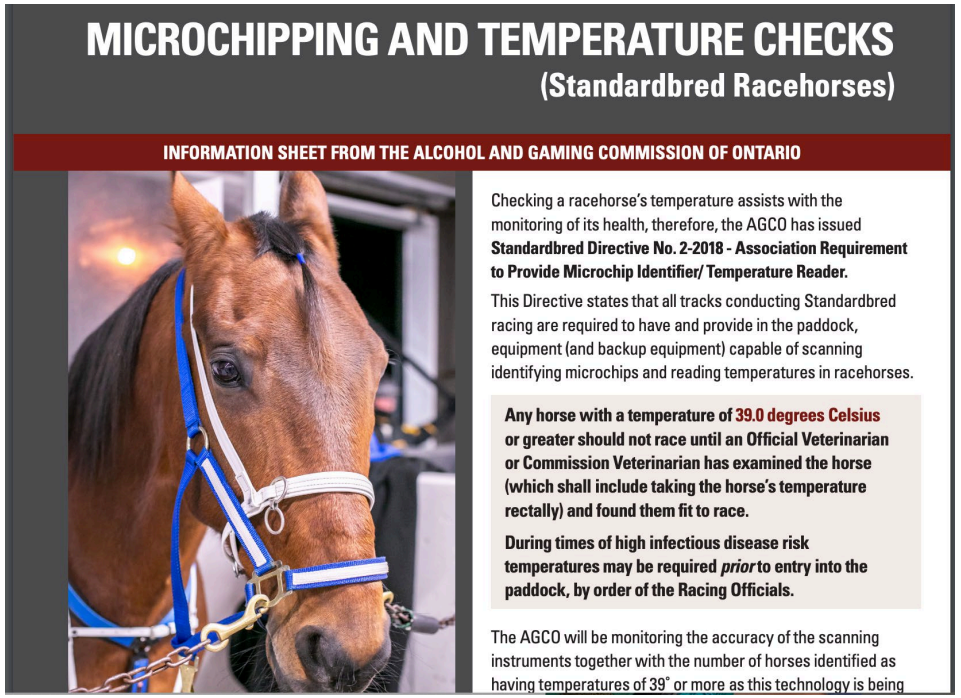


(b) High-budget scenario

The cons to Precision Dairy Technologies

Word of caution

- Most commercial technologies are lab validated
- These “validations” can affect industry regulatory changes
- But, do they work in animal conditions?



MICROCHIPPING AND TEMPERATURE CHECKS
(Standardbred Racehorses)

INFORMATION SHEET FROM THE ALCOHOL AND GAMING COMMISSION OF ONTARIO

Checking a racehorse’s temperature assists with the monitoring of its health, therefore, the AGCO has issued **Standardbred Directive No. 2-2018 - Association Requirement to Provide Microchip Identifier/ Temperature Reader.**

This Directive states that all tracks conducting Standardbred racing are required to have and provide in the paddock, equipment (and backup equipment) capable of scanning identifying microchips and reading temperatures in racehorses.

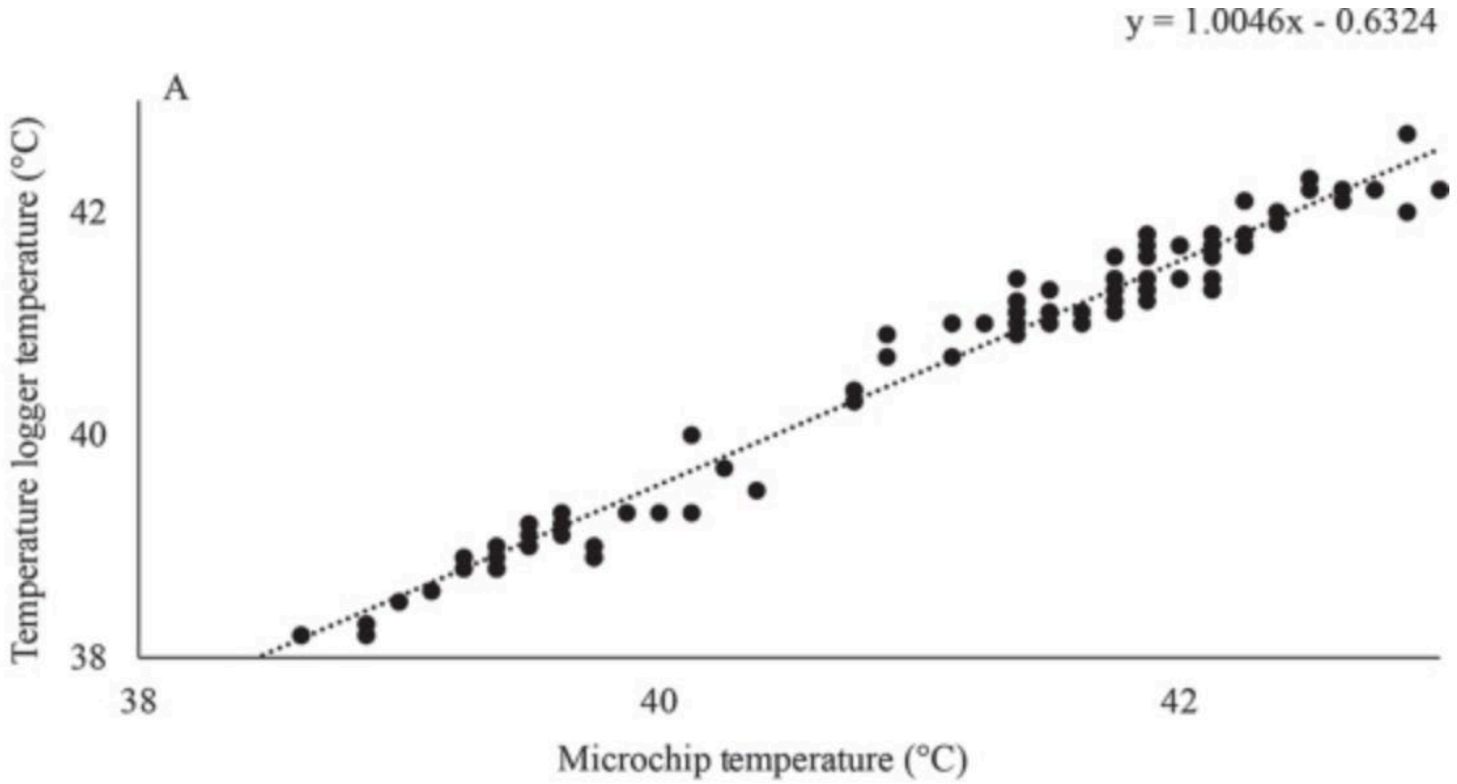
Any horse with a temperature of 39.0 degrees Celsius or greater should not race until an Official Veterinarian or Commission Veterinarian has examined the horse (which shall include taking the horse’s temperature rectally) and found them fit to race.

During times of high infectious disease risk temperatures may be required *prior* to entry into the paddock, by order of the Racing Officials.

The AGCO will be monitoring the accuracy of the scanning instruments together with the number of horses identified as having temperatures of 39˚ or more as this technology is being

[1]Woodrum Setser et al., 2020
[2]Cantor et al. 2022

The case of the implantable microchips: nearly perfect in a lab setting



University of Kentucky

[1]Woodrum Setser et al., 2020
[2]Cantor et al. 2022

Once implanted in the calf, none could substitute for rectal temperature

Table 1. The median and interquartile range (Q1, Q3) of Pearson correlations for microchip temperature (°C) read once on the hour for 24 h in 12 dairy bull calves[1]

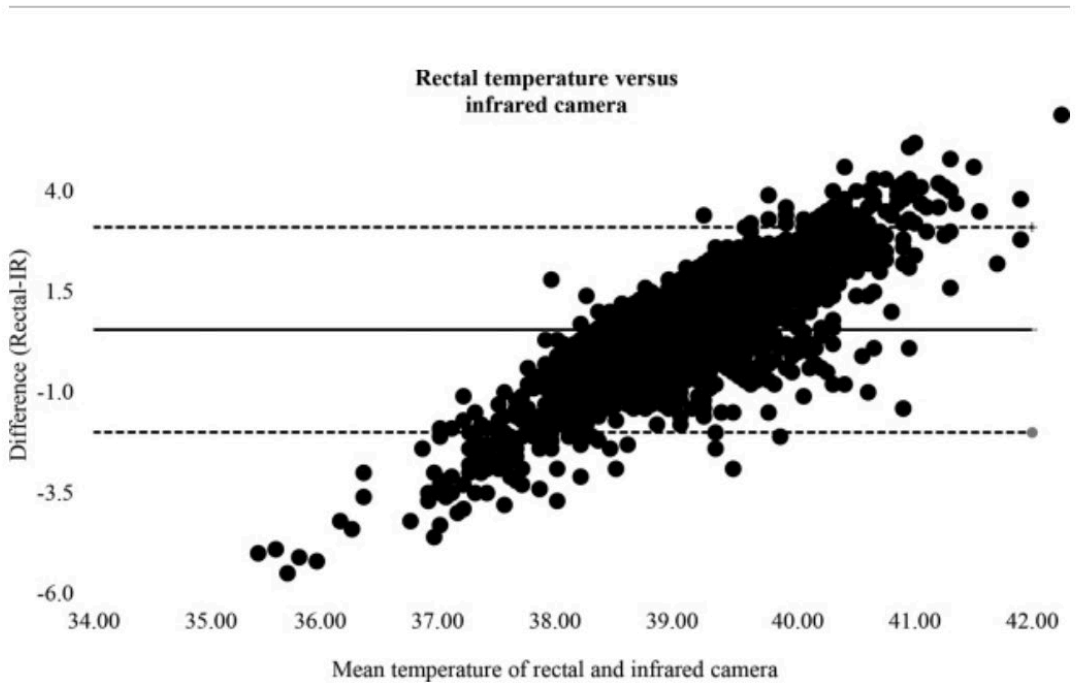
Item	Tympanic–rectal	Ear–rectal	SCAP–rectal	Neck–rectal	Ear–tympanic	SCAP–tympanic	Neck–tympanic	Neck–ear	SCAP–ear	SCAP–neck
Median	0.19	0.10	0.12	0.12	0.4	0.19	0.34	0.78	0.58	0.75
Q1	0.07	0.07	0.10	0.07	0.35	0.1	0.32	0.73	0.45	0.6
Q3	0.22	0.19	0.18	0.19	0.45	0.41	0.44	0.84	0.75	0.84
P-value	≤0.81	≤0.85	≤0.93	≤0.97	≤0.59	≤0.75	≤0.71	≤0.003	≤0.44	≤0.17

1

University of Kentucky

[1]Woodrum Setser et al., 2020
[2]Cantor et al. 2022

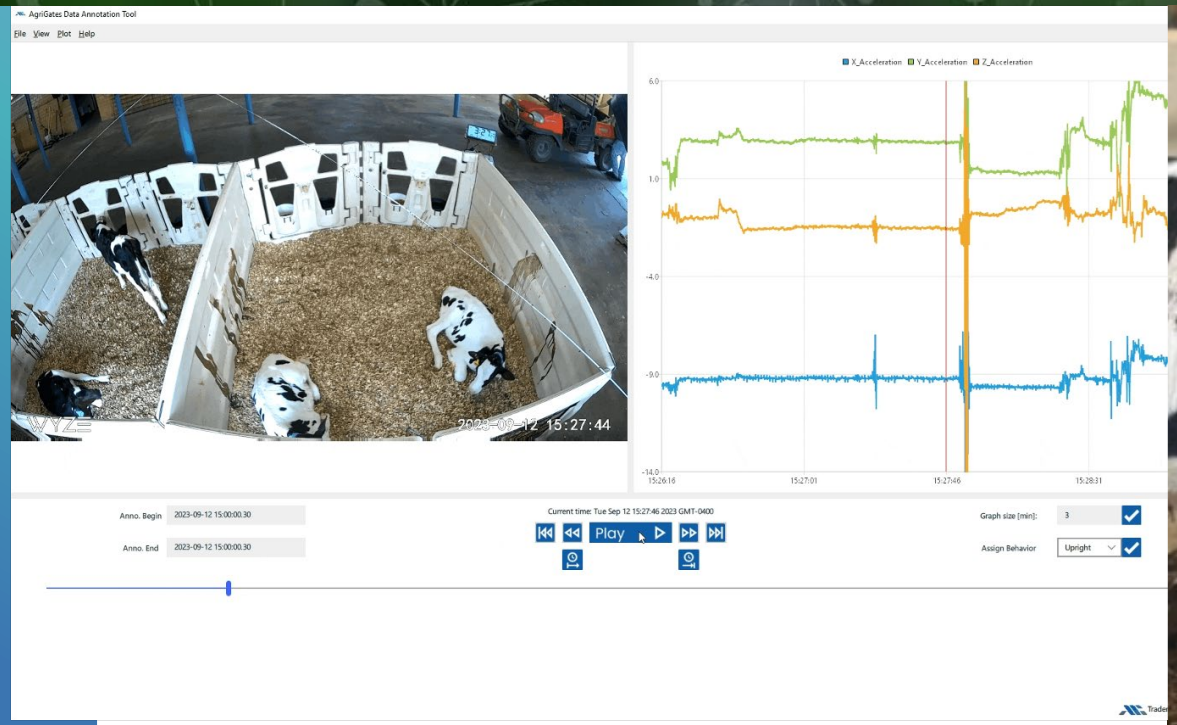
Infrared thermography was also influenced by ambient temperature



[1]Woodrum Setser et al., 2020
[2]Cantor et al. 2022

PennState
College of Agricultural Sciences

2024-Explore techy alternatives to robotics for disease detection



AgriGates

Summary

Sickness behavior is useful

Alert for automated milk feeders
can find calves 15 L/d
Commercial testing needed

Computers find BRD calves sooner

Economical to use the data

Non-antimicrobial alternatives?

AMERICAN DAIRY SCIENCE ASSOCIATION®

Thank you!

PennState

FÖRSTER TECHNIK®

Melissa Cantor, PhD
Assistant Professor
Precision Dairy Science
mmc7081@psu.edu

USDA

Dairy Farmers of Ontario Milk