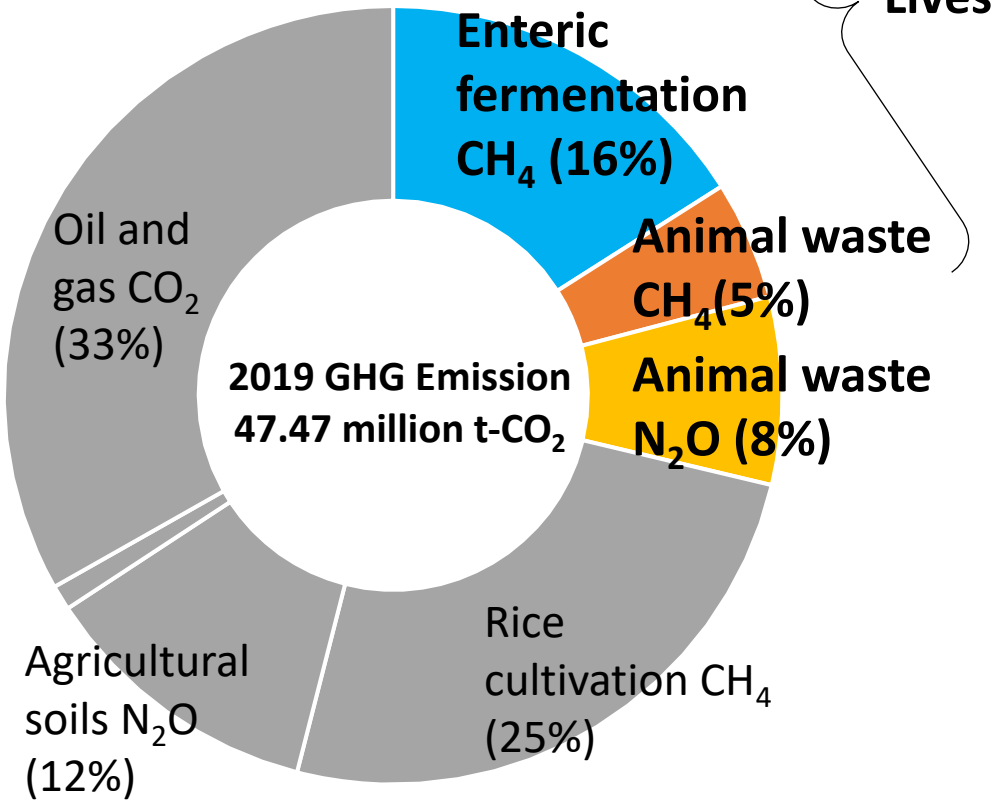
Exploring indicators of genetic selection using the sniffer method to reduce methane emissions from Holstein cows

***Y. Uemoto*[1]**, **T. Tomaru[2], M. Masuda[3], K. Uchisawa[3], K. Hashiba[3], Y. Nishikawa[4], K. Suzuki[4], T. Kojima[4], T. Suzuki[5], F. Terada[6]**

[1]Graduate School of Agricultural Science, Tohoku University, Sendai, Miyagi, 980-8572 Japan
[2]Gunma Prefectural Livestock Experiment Station, Maebashi, Gunma, 371-0103 Japan
[3]Niikappu station, NLBC, Hidaka, Hokkaido, 056-0141 Japan
[4]Head office, NLBC, Nishigo, Fukushima, 961-8061 Japan
[5]Institute of Livestock and Grassland Science, NARO, Nasushiobara, Tochigi, 329-2793 Japan
[6]Institute of Livestock and Grassland Science, NARO, Tsukuba, Ibaragi, 305-0901 Japan

Greenhouse gas (GHG) from agricultural sector in Japan



MAFF in Japan HP (2021)
(https://www.maff.go.jp/j/kanbo/kankyo/seisaku/midori/attach/pdf/team1-153.pdf)

Livestock sector accounts for about 30 % of GHG emission from agriculture

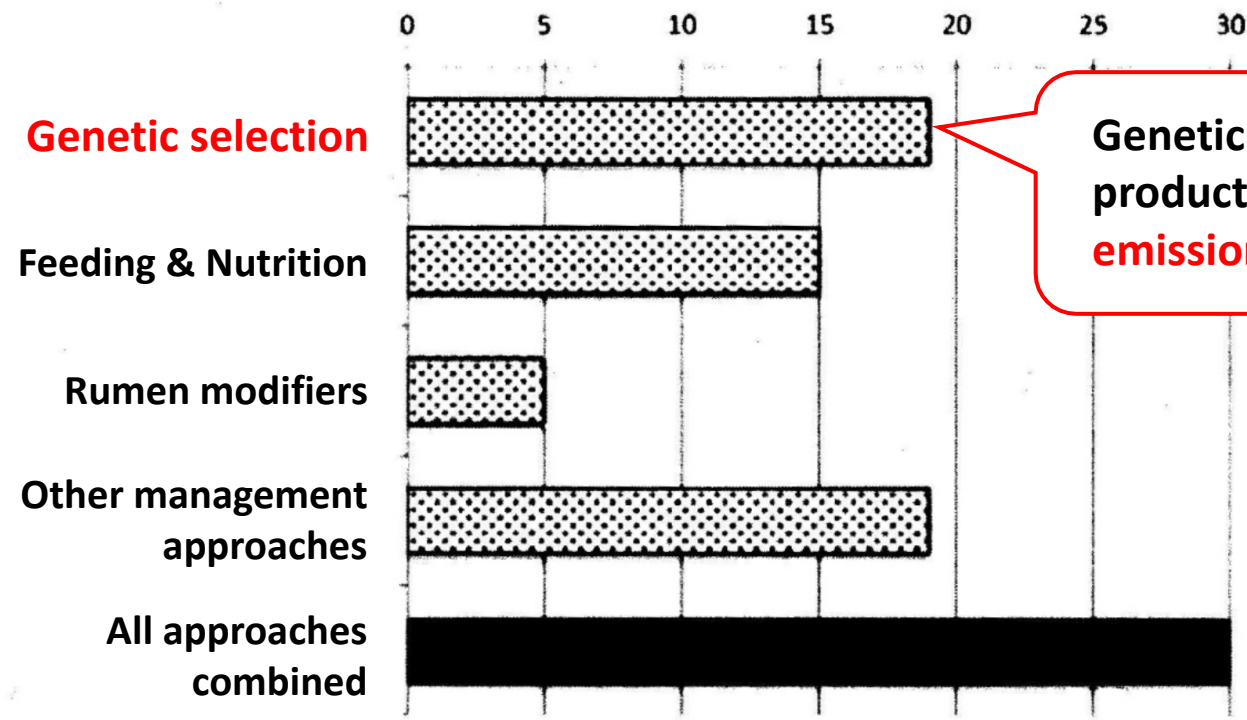
Enteric methane (CH_4) mission from dairy cows are major contributor

Reducing enteric CH_4 emission from cows is important for sustainable livestock production

Introduction: Genetic selection

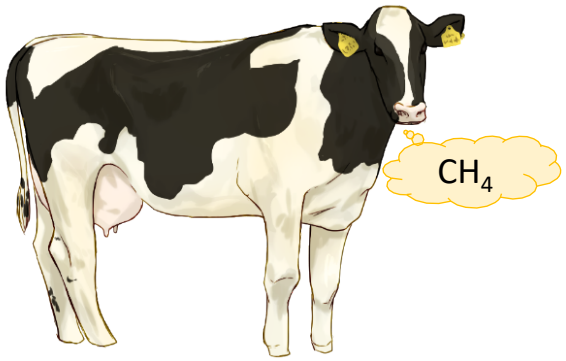
There are several strategies to mitigate enteric CH_4 emission from dairy cows.

Maximum potential reductions in CH_4/energy-corrected milk (ECM) (%)



Knapp et al. (2014)

Genetic selection for increasing productivity and/or decreasing CH_4 emission itself has attracted attention.



Genetic selection is a permanent and cumulative solution for improving the sustainability of the dairy industry, while minimizing additional costs and labor for dairy farmers.

A practical and cost-effective method for measuring CH_4 is required at on-farm level

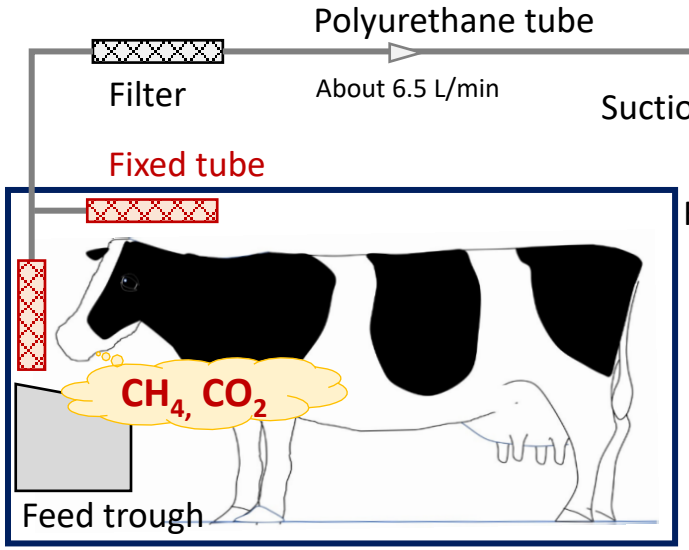
Measuring enteric CH_4 emission from dairy cows

Open-circuit respiration chamber
(=Gold standard method)

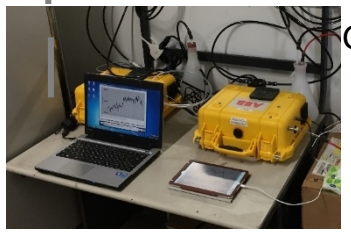
The chamber needs high costs to construct and maintain, and thus only small samples can be measured.

Sniffer method is cost-effective for measuring CH_4

The air near the animal's nostrils is sampled through a fixed tube in a feed trough in an automatic milking system (AMS). Garnsworthy et al. (2012)



Automatic milking system (AMS)



Measuring CH_4, CO_2

Sniffer method can measure CH_4 and CO_2 concentrations simultaneously at the commercial farm level.

CH_4 obtained by using the sniffer method can be used as indicators of genetic selection ?

Introduction: Objectives

Our objective was to evaluate whether CH_4/CO_2 and methane-related traits obtained by the sniffer method can be used as indicators of genetic selection for lower CH_4 emissions in Holstein cows using two farm datasets.

Study 1

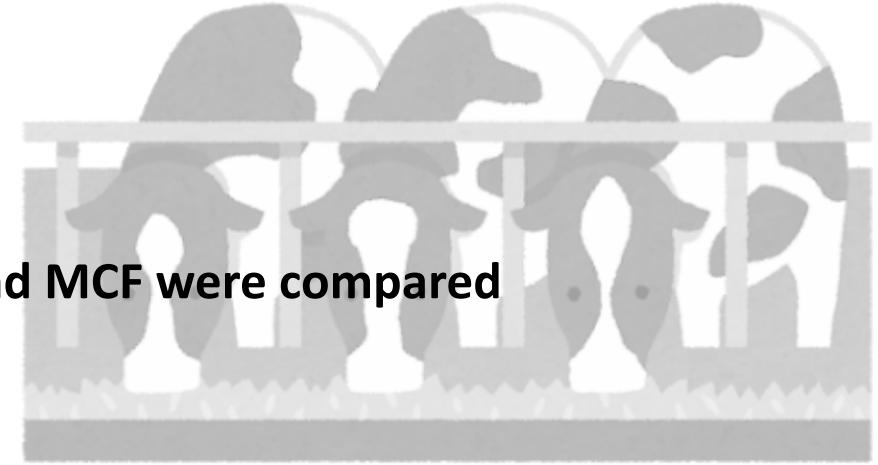
We investigated the impact of the model with and without body weight (BW) on the lactation stage and parity for predicting methane-related traits in the Farm 1 dataset.

Study 2

We estimated heritability for CH_4/CO_2 and methane conversion factor (MCF) in the Farm 2 dataset.

Study 3

The repeatability and environmental effects for CH_4/CO_2 and MCF were compared between the Farm 1 and Farm 2 datasets.



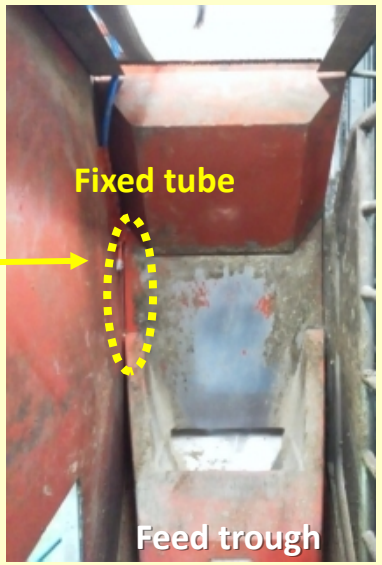
Materials and Methods: Population

The concentrations of CH_4 and CO_2 in the sampled air were measured during milking in each milking box of the AMS (Oikawa et al., 2022), and these data were recorded daily for seven consecutive days.

The average values of CH_4 (ppm) and CO_2 (ppm) per milking were obtained, and CH_4/CO_2 was calculated. Holstein cows with repeatable records were obtained.

A dataset was obtained from two farms with the same gas analyzer

Farm 1 dataset

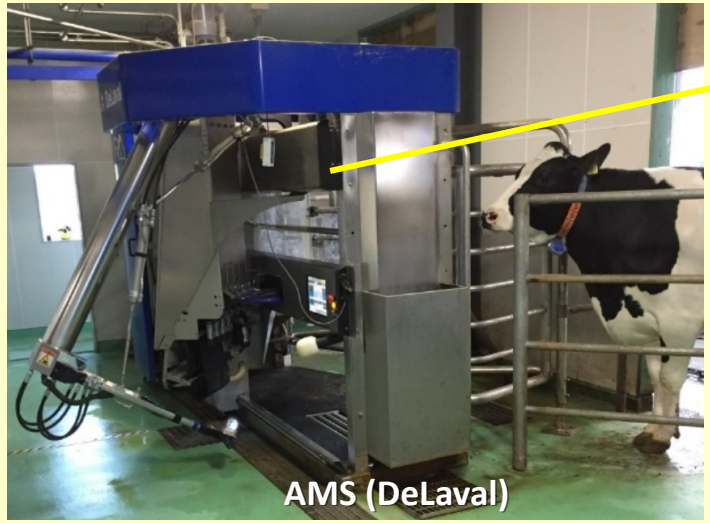


400 records for 74 Holstein cows

in 12 separate periods spanning Oct. 2017 to Mar. 2021.

Obtained traits: Average daily milk yield (AMY), ECM, CH_4/CO_2, BW

Farm 2 dataset



520 records for 182 Holstein cows

in 7 separate periods spanning Jun. 2018 to Apr. 2020.

Obtained traits: AMY, ECM, CH_4/CO_2

(BW records cannot be available for this population)

Materials and Methods: Methane-related traits

The prediction equations for methane-related traits as shown by Suzuki et al. (2021)

Traits	Abbreviations	BW in model	Prediction equations
CH_4 (L/day)	CH4e	-	$-248 + 10.5\times ECM + 5169\times CH_4/CO_2$
	CH4eb	+	$-507 + 0.536\times BW + 8.76\times ECM + 5029\times CH_4/CO_2$
CH_4 per ECM (L/kg)	CH4e/ECM	-	CH4e/ECM
	CH4eb/ECM	+	CH4eb/ECM
MCF (J/100J)	MCFe	-	$2.91 - 0.0498\times ECM + 51.0\times CH_4/CO_2$
	MCFeb	+	$2.546 + 0.000742\times BW - 0.0521\times ECM + 50.83\times CH_4/CO_2$
Residual CH_4 (RM, L/day)	RMe	-	CH4e - (10.26×ECM + 153.46)
	RMeb	+	CH4eb - (9.48×ECM + 224.32)

Farm 1 dataset

Input: AMY, ECM, CH_4/CO_2, BW

Output: CH4e, CH4eb, CH4e/ECM, CH4eb/ECM, MCFe, MCFeb, RMe, RMeb

Farm 2 dataset

Input: AMY, ECM, CH_4/CO_2

Output: MCFe

Materials and Methods: Statistical analyses

Farm 1 A linear mixed model was applied to estimate fixed effects and variance components.

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Za} + \mathbf{e}$$

Study 1

Estimates of the levels for lactation stage, parity

Study 3

Estimates of variance components

$\mathbf{a} \sim N(\mathbf{0}, \sigma_a^2 \mathbf{I})$

$\mathbf{e} \sim N(\mathbf{0}, \sigma_e^2 \mathbf{I})$

Repeatability: $R = \frac{\hat{\sigma}_a^2}{\hat{\sigma}_a^2 + \hat{\sigma}_e^2}$

Farm 2 A single-trait repeatability animal model was applied to estimate fixed effects and variance components.

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Zu} + \mathbf{Wpe} + \mathbf{e}$$

Study 3

Estimates of the levels for lactation stage, parity

Estimates of variance components

$\mathbf{a} \sim N(\mathbf{0}, \sigma_u^2 \mathbf{A})$

$\mathbf{pe} \sim N(\mathbf{0}, \sigma_{pe}^2 \mathbf{I})$

$\mathbf{e} \sim N(\mathbf{0}, \sigma_e^2 \mathbf{I})$

Study 2

Heritability

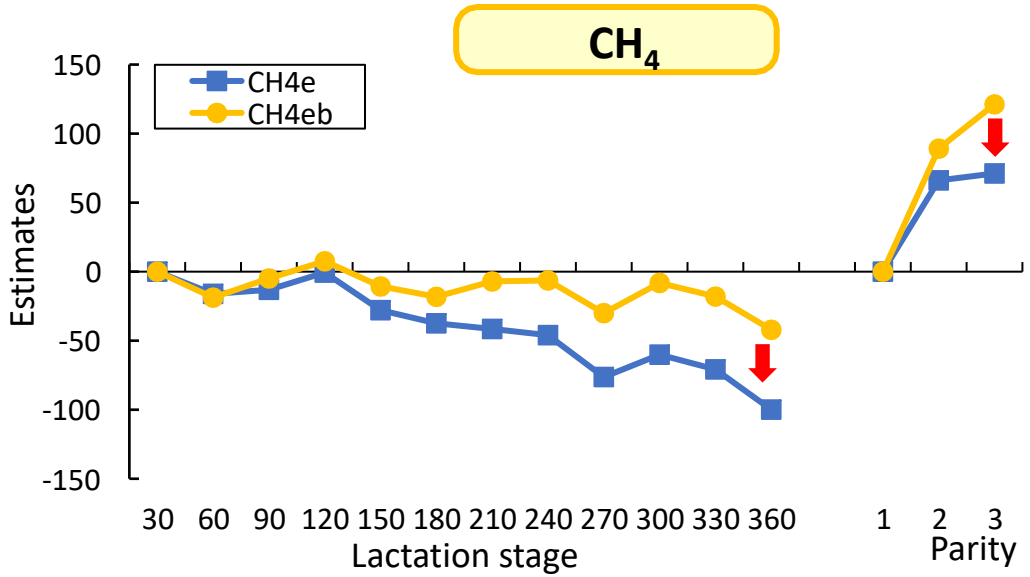
$$h^2 = \frac{\hat{\sigma}_u^2}{\hat{\sigma}_u^2 + \hat{\sigma}_{pe}^2 + \hat{\sigma}_e^2}$$

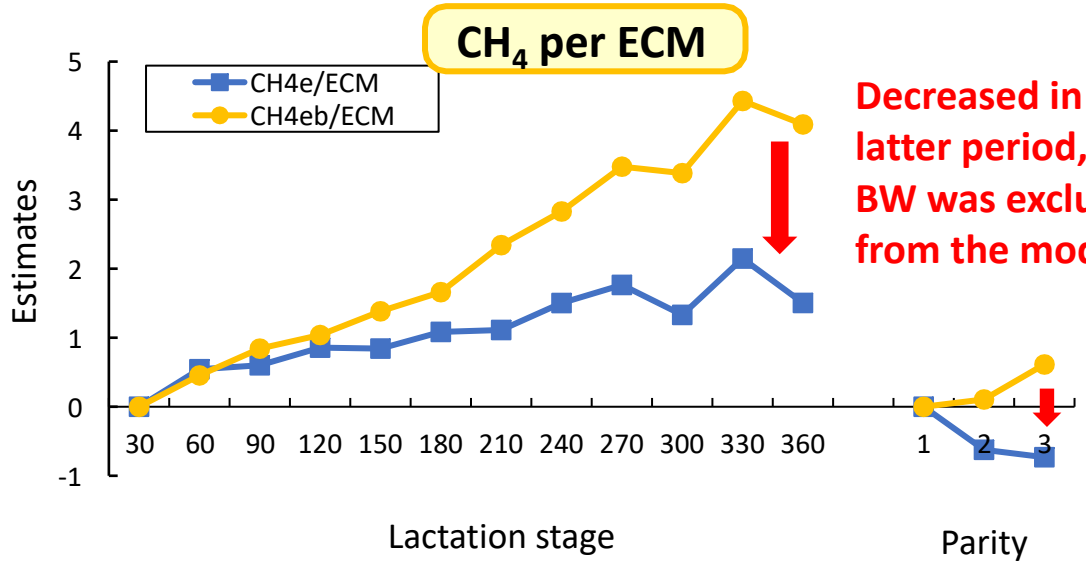
Study 3

Repeatability

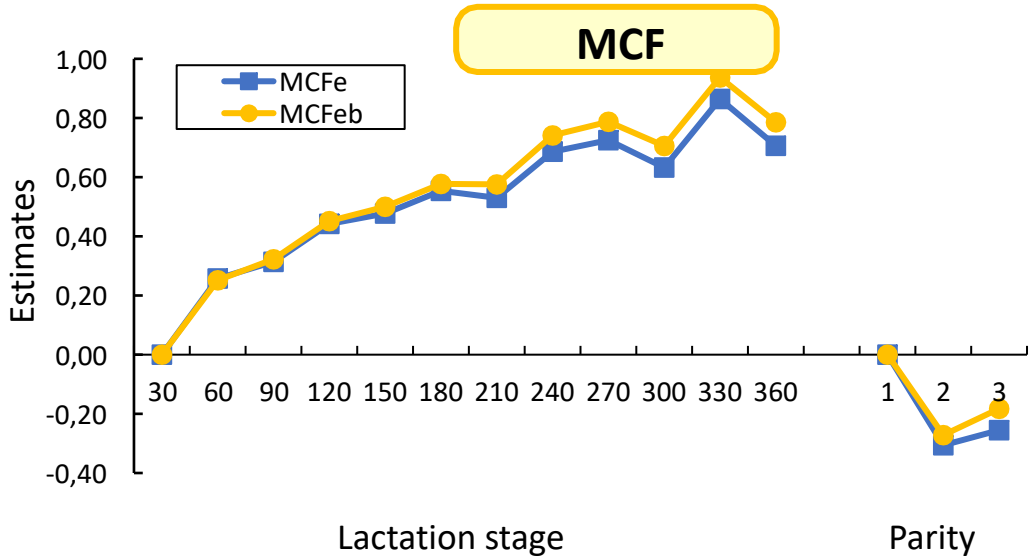
$$R = \frac{\hat{\sigma}_u^2 + \hat{\sigma}_{pe}^2}{\hat{\sigma}_u^2 + \hat{\sigma}_{pe}^2 + \hat{\sigma}_e^2}$$

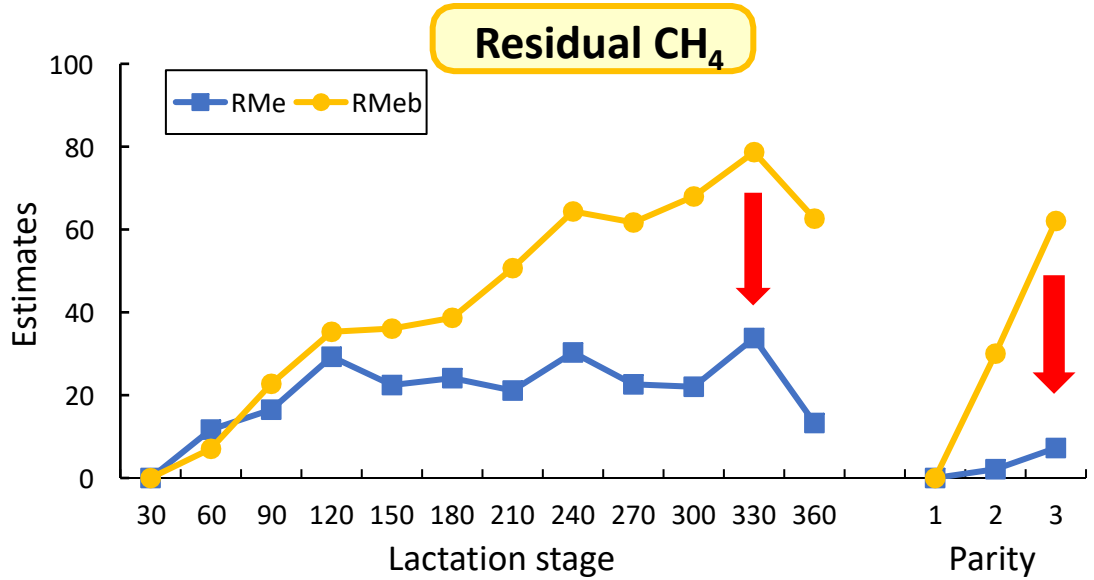
Results: Study 1: Impact of BW on predicting methane-related traits





Decreased in the latter period, when BW was excluded from the model

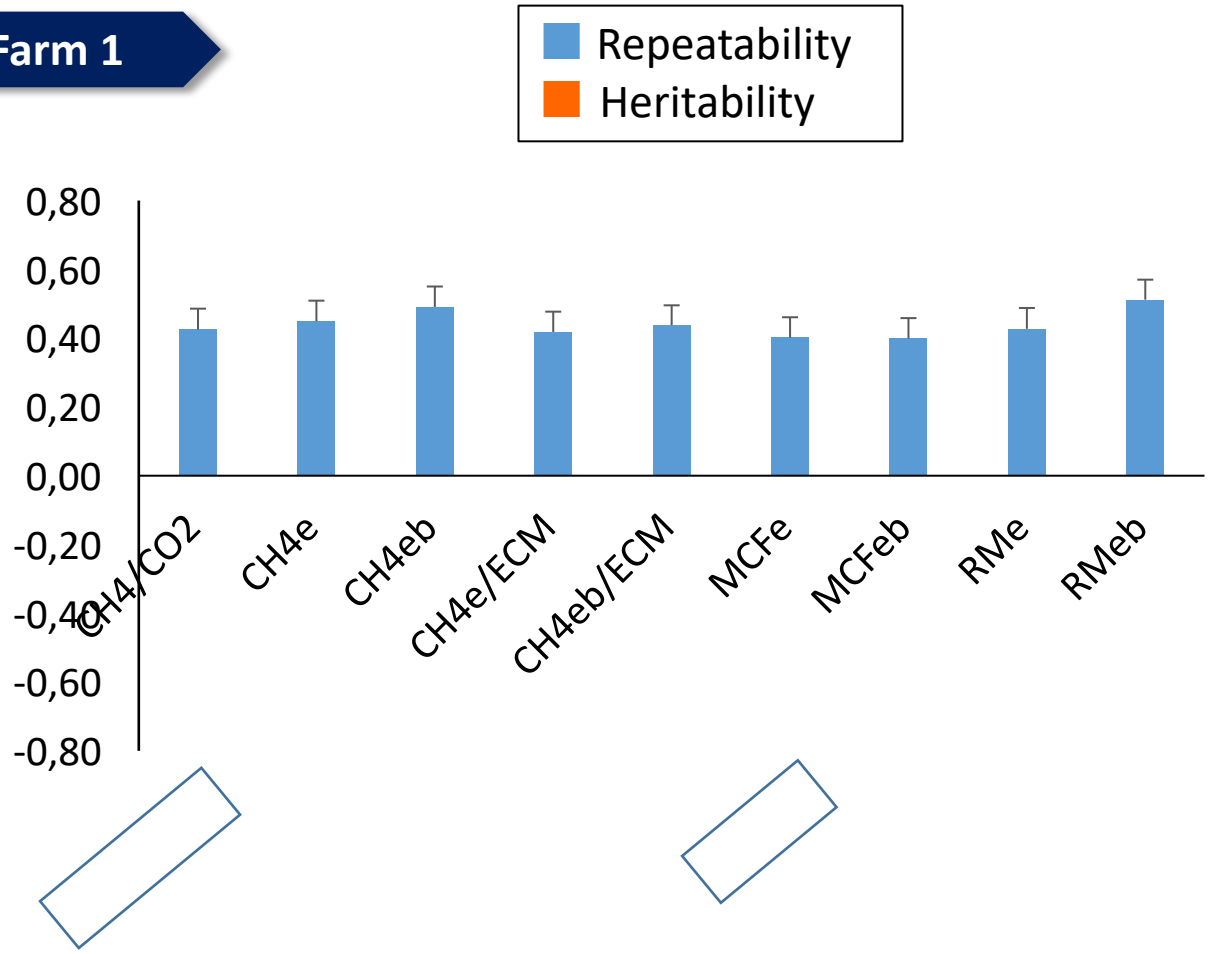




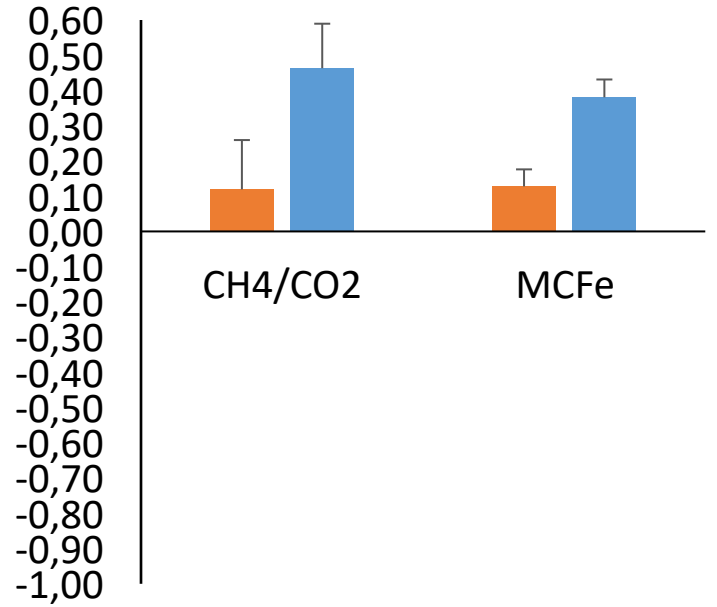
MCF can be reliably evaluated during the lactation stage and parity without BW

Results: Study 2, Study 3: Heritability and repeatability estimates

Farm 1



Farm 2

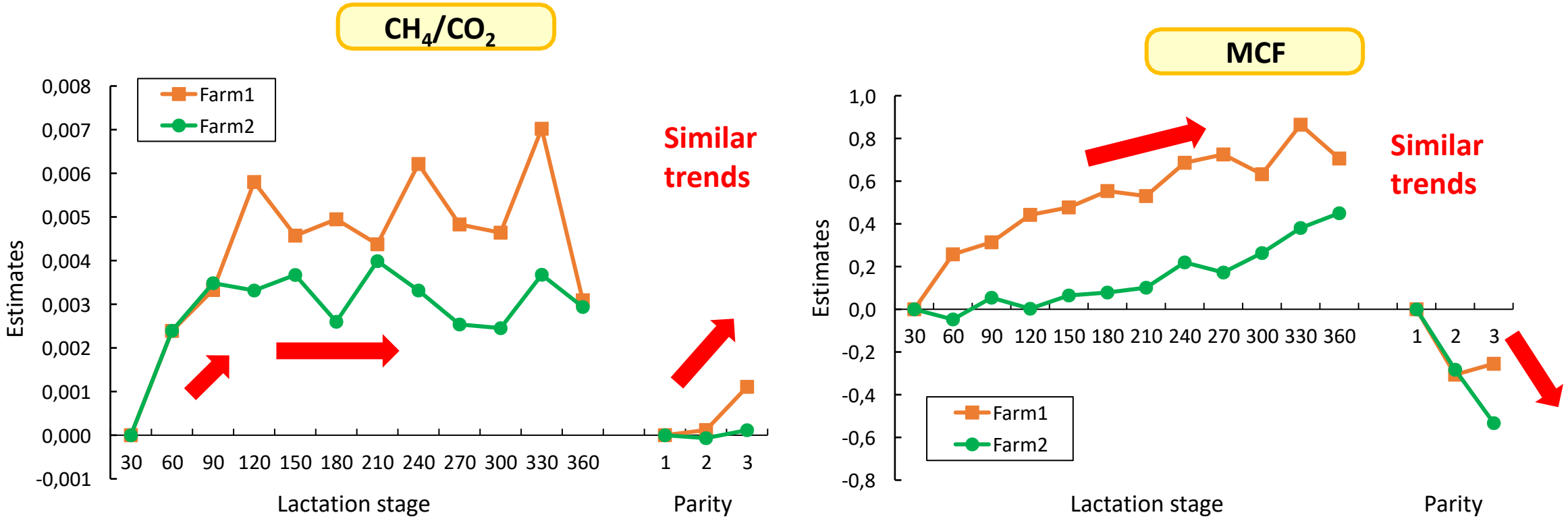


Study2: Low heritability estimates for CH_4/CO_2 (0.12) and MCF (0.13) in Farm 2.

Study3: Moderate repeatability estimates for CH_4/CO_2 and MCF in both farms (0.38 – 0.46).

Low heritability and moderate repeatability for CH_4/CO_2 and methane-related traits

Results: Study 3: Comparison of environmental effects between both farms



Study3: Similar trends of CH_4/CO_2 and MCF were observed in both the farms as the lactation stage and parity increased.

Environmental effects for CH_4/CO_2 and MCF could be evaluated consistently on both farms

Conclusions

This study investigated whether CH_4/CO_2 and methane-related traits obtained from the sniffer method can be used as indicators of genetic selection to reduce CH_4 emission from Holstein cows.

Study 1 Impact of BW on predicting methane-related traits in Farm 1.

Estimates of only MCF using the model with and without BW showed a similar trend during the lactation stage and parity.

Study 2 Heritability for CH_4/CO_2 and MCF in Farm 2.

Low heritabilities for CH_4/CO_2 (0.12) and MCF (0.13) were estimated.

Study 3 Comparison of repeatability and environmental effects for CH_4/CO_2 and MCF between both farms.

- Moderate repeatabilities for CH_4/CO_2 and MCF (0.38 – 0.46) were estimated in both farms.
- Similar trends were observed in both the farms as the lactation stage and parity increased.

The sniffer method can be practically applied and repeatability estimates can be utilized in the selection of cows with low CH_4 emission.

Acknowledgements

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Thank you for your attention!!