Comparison of different residual carbon dioxide formulations as a means to select feed efficient dairy cows

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- Feed costs is the main cost of production.
- Higher feed efficiency (FE) ----> profit and environment.
- Feed intake is expensive to record.
- Possibility to record gaseous traits.

- Higher heat production than expected = lower FE = higher CO_2 (Huhtanen et al., 2021)
- A similar criterion like RFI using CO_2 could be developed.

$$RCO_2 = \text{actual } CO_2 - \text{expected } CO_2$$

- The common method of calculating residual metrics is regression.
- Implausiblible partial regression coefficients.
- An alternative is energy requirement coeff. from nutrition studies.

Objectives

- To develop different RCO_2 and RFI formulations.
- To estimate the correlations between RCO_2 and RFI with efficiency traits.
- To compare two divergent groups of animals for residual formulations in terms of feed efficiency.

Data

- No. of animals = **83** primiparous RDC kept in freestall
- CO_2 measurements made from Oct. 2021- May 2023
- **Two** GreenFeed units
- Total number of Obs.: **51977** (3.41 rec/anim/d)
- CO_2 edition criterion: μ ± **2.5 SD**

Summary statistics

Trait	Unit	n	Mean	SD
Carbon dioxide production	g/d	13136	12240.5	1466.63
Dry matter intake	kg/d	16060	19.7	2.52
Energy-corrected milk	kg/d	16517	30.7	4.31
Metabolic body weight	$kg^{0.75}$	16517	120.4	9.33
Body weight loss	kg/d	16517	0.11	0.325
Body weight gain	kg/d	16517	0.27	0.254

Calculation of phenotypes and analysis

Scenario 1: Multiple linear regression

$\mathrm{RFI_{MLR}}$ / $\mathrm{RCO_{2MLR}}$ = DMI – [$\hat{\mu}$ + $\hat{\gamma}_1$ × $\mathrm{ECM_i}$ + $\hat{\gamma}_2$× $\mathrm{MBW_i}$ – $\hat{\gamma}_3$× $\mathrm{BWL_i}$ + $\hat{\gamma}_4$× $\mathrm{BWG_i}$]

$\mathbf{RFI_{MLR}}$ = DMI – $\underbrace{\boxed{[2.014 + \mathbf{0.309} \times \mathrm{ECM} + \mathbf{0.067} \times \mathrm{MBW} \mathbf{-\ 3.004} \times \mathrm{BWL} + \mathbf{1.9} \times \mathrm{BWG}]}}_{\text{Expected DMI}}$

$\mathbf{RCO_{2MLR}}$ = CO_2 – $\underbrace{\boxed{[2825.0 + \mathbf{106.1} \times \mathrm{ECM} + \mathbf{47.6} \times \mathrm{MBW} \mathbf{-\ 970.6} \times \mathrm{BWL} + \mathbf{1769.1} \times \mathrm{BWG}]}}_{\text{Expected } CO_2}$

Calculation of phenotypes and analysis

Scenario 2: Finnish energy requirement tables (Luke, 2022)

$\mathbf{RFI_{FIN}}$ = DMI – $\boxed{[\mathbf{0.477} \times \text{ECM} + \mathbf{0.0477} \times \text{MBW} \mathbf{- 2.588} \times \text{BWL} + \mathbf{3.142} \times \text{BWG}]}$

$\boxed{\mathbf{5.15}, \mathbf{0.515}, \mathbf{-28} \text{ and } \mathbf{34}}$ were divided by the energy density of the diet.

$\mathbf{RCO_{2FIN}}$ = CO_2 – $\boxed{[\mathbf{295.4} \times \text{ECM} + \mathbf{29.5} \times \text{MBW} \mathbf{- 452.9} \times \text{BWL} + \mathbf{882.4} \times \text{BWG}]}$

$\boxed{\varnothing = \gamma \, . \, (1 - k_l) \, . \, \tau}$ e.g., 295.4 = 5.15 × (1 – **0.61**) × 147.06 gr CO_2/MJ heat production

(Huhtanen et al., 2021)

Conversion efficiency of ME to
NEL in Finnish requirement tables

Calculation of phenotypes and analysis

Scenario 3: Nutrient requirement of dairy cattle (NRC, 2021)

$\mathbf{RFI_{NRC}}$ = DMI – [**0.440** × ECM + **0.0586** × MBW **–** **3.292** × BWL + **3.292** × BWG]

$\boxed{\textbf{4.765}, \textbf{0.634}, \textbf{-35.62} \text{ and } \textbf{35.62}}$ were divided by the energy density of the diet.

$\mathbf{RCO_{2NRC}}$ = CO_2 – [**238.3** × ECM + **31.7** × MBW **–** **426.4** × BWL + **1361.9** × BWG]

$\underline{\varnothing = \gamma \;.\; (1 - k_l) \;.\; \tau}$ e.g., 238.3 = 4.765 × (1 – **0.66**) × 147.06 gr CO_2/MJ heat production

Conversion eff. of ME to
NEL in NRC 2021

Efficiency traits

Energy conversion efficiency (**ECE**) = ECM / MEI

Carbon dioxide intensity (**CO_2I**) = CO_2 / ECM

Methane intensity (**CH_4I**) = CH_4 / ECM

Trait	Unit	n	Mean	SD
ECE	kg/MJ ME	16060	0.145	0.023
CO_2I	g/kg	13136	405.5	77.18
CH_4I	g/kg	13136	14.3	3.11

The best half (low) and worst half (high) of the animals in terms of RFI and RCO_2 were compared (only animals with data in ≥ 100 DIM).

Correlations between DMI, energy sinks, efficiency measures

Trait	DMI	ECM	MBW	BWL	BWG	ECE	CO_2I	CH_4I
CO_2	0.58	0.17	0.43	-0.25	0.40	-0.31	0.50	0.55
DMI		0.36	0.31	-0.32	0.25	-0.47	-0.06	0.13
ECM			-0.02[b]	0.27	-0.33	0.63	-0.72	-0.59
MBW				0.00[ns]	0.37	-0.21	0.30	0.27
BWL					-0.38	0.55	-0.29	-0.32
BWG						-0.51	0.51	0.46
ECE							-0.71	-0.65
CO_2I								0.88

without superscript = $p < 0.01$; [b] = $p < 0.05$; [ns] = non-significant

Correlations with production & efficiency traits

Trait	RCO_{2MLR}	RCO_{2FIN}	RCO_{2NRC}	RFI_{MLR}	RFI_{FIN}	RFI_{NRC}
CO_2	0.80	0.66	0.73	0.28	0.19	0.15
DMI	0.29	0.18	0.24	0.75	0.59	0.57
ECM	0.00^{ns}	-0.59	-0.47	0.00^{ns}	-0.32	-0.21
ECE	-0.23	-0.70	-0.64	-0.59	-0.76	-0.64
CO_2I	0.51	0.90	0.84	0.20	0.40	0.30
CH_4I	0.55	0.86	0.83	0.22	0.39	0.29

without superscript = $p < 0.01$; ^{ns} = non-significant

Comparison between low and high Residual formulations

	RCO_{2MLR}		RCO_{2FIN}		RCO_{2NRC}	
Trait	low	high	low	high	low	high
CO_2	11732	12868	11841	12758	11702	12898
ECE	0.149	0.139	0.152	0.136	0.151	0.137
CO_2I	381	433	371	443	373	442
CH_4I	13.35	15.30	12.93	15.72	13.07	15.58

	RFI_{MLR}		RFI_{FIN}		RFI_{NRC}	
Trait	low	high	low	high	low	high
CO_2	12038	12562	12042	12558	12187	12413
ECE	0.147	0.141	0.150	0.138	0.149	0.139
CO_2I	398	416	384	430	390	425
CH_4I	13.98	14.67	13.41	15.24	13.75	14.91

Main findings

- Selection based on RCO_2 formulations would improvement energy conversion efficiency.
- Residual formulations calculated using energy requirement tables are better able to distinguiush more efficient animals.
- RCO_2 has the potential to simultaneously improve feed efficiency and reduce emissions.

Thank You

Any Question?

Luke
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