Measuring individual carbon dioxide emissions as a proxy for feed efficiency on dairy farms – preliminary results

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Abstract

The costs and practical challenges of measuring individual feed efficiency on dairy farms have hampered its use both in farm management and genetic selection. The concept of residual carbon dioxide (RCO_2) is similar to the index of residual feed intake (RFI), and used as a proxy, it could potentially enable ranking cows based on feed efficiency. In this study, we aimed to assess the relationship between RCO_2 and RFI in mid-lactation (115 to 175 days in milk), using data of 313 cow-per-treatment observations from five experiments with individual feed intake records. Carbon dioxide production was measured by GreenFeed units. Residual CO_2 (kg/day) and RFI (kg of dry matter/day) were estimated using a mixed model approach. Three cow groups (high/mid/low) of equal sizes were created both for RCO_2 and RFI. Cows in the high-RCO_2 group produced 1.92 kg/day (95% CI: 1.78 – 2.06, $P < 0.0001$) more carbon dioxide than their low-RCO_2 herd mates. At the same time, high-RCO_2 cows had 1.31 kg/day (95% CI: 0.95 – 1.67) higher RFI compared to their low-RCO_2 counterparts ($P<0.0001$). The overall classification accuracy based on RCO_2, using RFI as a reference, was 48.2%, however, inefficient (i.e. high RFI) cows could be identified with 59.0% accuracy. In conclusion, relevant differences were found between RCO_2 groups in terms of feed efficiency. Therefore, routinely collecting individual carbon dioxide emissions seems to be a promising tool to record feed efficiency on a large scale.

Keywords: dairy cattle, feed efficiency, residual feed intake, carbon dioxide, GreenFeed.

Introduction

Dairy production has to meet the increasing demand for milk and dairy products of the growing world population. Improved feed efficiency of dairy cows has large potential to reduce the environmental impact of this growth in multiple ways. First of all, land requirements of feed production can be decreased by 6.7% per cow via reducing feed intake by one standard deviation, at the same level of energy-corrected milk yield (Bell *et al.*, 2012). Moreover, traditional selection for improved feed efficiency can decrease methane emissions per kg of fat- and protein corrected milk by 26% over a selection period of 10 years (de Haas *et al.*, 2011). More feed efficient cows also produce less manure, thereby reducing the amount of methane and nitrous oxide released into the atmosphere (Connor, 2015). Farmers also benefit from improved feed efficiency through

reduced feed costs, which represent more than 50% of the total cost of milk production (European Commission, 2020). As a moderately heritable trait, feed efficiency could be improved by selective breeding, although, the costs and practical limitations of recording dry matter intake (DMI) limit selection (Seymour *et al.*, 2019).

The concept of residual carbon dioxide (RCO_2) is similar to the index of residual feed intake (RFI), and used as a proxy alone or in combination with other easily available parameters, it could potentially enable ranking cows based on feed efficiency (Huhtanen *et al.*, 2021). The concept of RCO_2 was originally developed using data from respiration chambers, but using sensors with highly repeatable carbon dioxide measurements (e.g. GreenFeed), the approach could be used on the farms, as well. In this study, we aimed to assess the relationship of RCO_2 and RFI in mid-lactation on a dairy farm.

Materials and methods

Data

The data of 313 cow-per-treatment observations from five experiments, carried out at Dairy Campus of Wageningen University and Research (Leeuwarden, The Netherlands), were used in the analyses. Dry matter intake (kg/day), energy-corrected milk (kg/day), daily average body weight (kg), and carbon dioxide production (kg/day) were collected. Carbon dioxide production was measured by GreenFeed (C-Lock, Inc., Rapid City, SD) units. Dry matter intake from GreenFeed bait was not taken into account. Records between 115 and 175 days in milk were retained for the analyses, to minimize the possible effects of changes in energy balance, and because RFI measured in this period is highly correlated with the average RFI over the whole lactation (Martin *et al.*, 2021).

Statistical analysis

Residual CO_2 and RFI were obtained from mixed-effects models, accounting for energy-corrected milk and metabolic body weight (MBW, i.e. body weight$^{0.75}$) as fixed effects, and treatment and experiment as random effects. Cows were classified into three equal-sized groups (high/mid/low, n = 104 – 105 each) based on RCO_2 and RFI. The resulting groups were compared using linear models, followed by Tukey's post hoc tests for pairwise comparisons.

Results and discussion

The descriptive statistics of the parameters are shown in Table 1. The level of dry matter intake, energy-corrected milk production, and the body weight of cows were comparable to those of Huhtanen *et al.* (2021).

Table 1. Descriptive statistics of the analysed parameters.

Parameter	Mean	SD
Dry matter intake (kg/day)	20.5	3.5
Carbon dioxide production (kg/day)	13.7	1.3
Energy-corrected milk (kg/day)	31.7	5.3
Metabolic body weight (kg)	130.8	10.0

Significant differences in RCO_2 were observed between RCO_2 groups (Table 2). The low-RCO_2 group produced on average 1.92 kg/day less carbon dioxide than the high-RCO_2 group, at the same level of energy-corrected milk yield and metabolic body weight ($P < 0.0001$). Feed efficiency, expressed in RFI, differed significantly between RCO_2 groups. The low-RCO_2 group consumed 1.31 kg less feed per day than the high-RCO_2 group, at the same energy-corrected milk production and metabolic body weight ($P < 0.0001$). Our results support the findings of Huhtanen *et al.* (2021), who found similar differences between low- and high-RCO_2 groups both in terms of RCO_2 and RFI.

Residual CO_2 and RFI groups are cross-tabulated in Table 3. Overall, 48.2% of the cows were correctly classified based on RCO_2, using RFI as reference, however, inefficient (i.e. high-RFI) cows could be identified with 59.0% accuracy. Inefficient cows were rarely misclassified as being efficient (16.2%), and vice versa (14.4%). This supports the potential of residual carbon dioxide to be used as a proxy for feed efficiency on dairy farms.

On the other hand, care should be taken when evaluating RCO_2, because energy balance influences RCO_2. For example, cows in negative energy balance mobilize body fat reserves to produce milk fat, which process does not generate carbon dioxide, consequently, these cows can be erroneously considered efficient. Therefore, carbon dioxide measurements should be performed in mid-lactation, when the probability of such misclassification is low (Huhtanen *et al.*, 2021). Alternatively, changes in body condition or milk composition can be followed to obtain information on energy balance (Friggens *et al.*, 2007; Thorup *et al.*, 2018).

Table 2. Differences in residual carbon dioxide production (RCO_2) and residual feed intake (RFI) between RCO_2 groups.

	RCO_2			RFI		
RCO_2 group	Difference (kg/day)	95% CI	P-value	Difference (kg/day)	95% CI	P-value
Low vs. high	-1.92	-2.06 – -1.78	<0.0001	-1.31	-1.67 – -0.95	<0.0001
Mid vs. high	-1.02	-1.16 – -0.88	<0.0001	-0.89	-1.25 – -0.53	<0.0001
Low vs. mid	-0.90	-1.04 – -0.76	<0.0001	-0.42	-0.78 – -0.06	0.0168

Table 3. Number (% in parentheses) of cows by residual carbon dioxide (RCO_2) group, using residual feed intake (RFI) groups as reference.

	RCO_2 group		
RFI group	High (n = 105)	Mid (n = 104)	Low (n = 104)
High (n = 105)	62 (59.0)	26 (24.8)	17 (16.2)
Mid (n = 104)	28 (26.9)	39 (37.5)	37 (35.6)
Low (n = 104)	15 (14.4)	39 (37.5)	50 (48.1)

Conclusion

We confirmed the utility of residual carbon dioxide as a proxy for feed efficiency on dairy farms. For future use in practice, carbon dioxide measurements should either be performed in mid-lactation, or preferably, energy balance of the animals should be estimated in parallel. Individual carbon dioxide measurements offer potential to distinguish efficient from inefficient cows on dairy farms, without the need to measure individual dry matter intake.

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