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Biological implications of longevity in dairy cows: 2. Changes in methane emissions and efficiency with age

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ABSTRACT

Previous studies indicated that absolute CH_4 emissions and CH_4 yield might increase and that milk production efficiency might decrease with age in cattle. Both would make strategies to increase longevity in dairy cattle less attractive. These aspects were experimentally determined in Brown Swiss cattle distributed continuously across a large age range. Thirty lactating dairy cows (876–3,648 d of age) received diets consisting of hay, corn silage, and grass pellets supplemented with 0 or 5 kg of concentrate per day. Twelve heifers (199–778 d of age) received hay only. Cows and heifers were members of herds subjected to the 2 different feeding regimens (with or without concentrate) for the past 10 yr. Methane emissions were measured individually for 2 d in open-circuit respiration chambers, followed by quantifying individual feed intake and milk yield over 8 d. Additional data on digestibility, rumination time, and passage time of feed of all experimental animals were available. Regression analyses were applied to evaluate effects of age and feeding regimen. Body weight, milk yield, and the hay proportion of forage dry matter intake were considered as covariates. Methane emissions per unit of intake, body weight, and milk yield were significantly related to age. Their development in the cows with age was characterized by an increase to maximum at around 2,000 d of age, followed by a decline. This response was not accompanied by corresponding age-related changes in intake, chewing activity, digesta passage time, and digestibility of organic matter, which would have explained shifts in CH_4. However, fiber digestibility showed a similar change with age as methane emissions, resulting in quite stable methane emissions per unit of digestible fiber. As expected, methane emissions intensity per unit of milk produced was greater by 8% without concentrate than with concentrate, but no difference was noted in the response to age when the animals were subjected to different feeding regimens. The efficiency of milk production was only marginally influenced by age and diet, and no different response was observed for age in the 2 dietary regimens. In conclusion, life cycle analyses of milk production systems focusing on longevity should consider changing methane yields with age in addition to the variation in environmental costs for replacements of culled cows.
Key words: greenhouse gas, lactation number, residual feed intake, forage-based diet, feed efficiency

INTRODUCTION

The contribution of methane emissions from ruminants to global greenhouse gas (**GHG**) budgets is substantial (e.g., FAOSTAT, 2014). The current search for efficient mitigation measures focuses on nutritional strategies (e.g., Beauchemin et al., 2008; Hristov et al., 2013a,b) and on animal breeding measures (e.g., Hristov et al. 2013b; Pinares-Patiño et al., 2013). Research activities mostly aim at reducing CH_4 emissions in relation to actual milk yield (CH_4 emission intensity) and less so on strategies affecting entire dairy production systems. Milk production by dairy cows has undergone a remarkable increase, which is often sustained with increasing amounts of concentrate. This helps to reduce enteric CH_4 emission intensity further (discussed in Beauchemin et al., 2008), even when considering the concomitantly increased manure-derived CH_4 amounts (Hindrichsen et al., 2006). However, the concentrate production results in substantial GHG emissions (Thomassen et al., 2008). This counteracts its mitigating effect in enteric emissions (O'Brien et al., 2012). Furthermore, resource use for concentrate production directly competes with the production of human food (Cassidy et al., 2013).

Almost in parallel with the increase in milk yield, there has been a distinct decrease in the length of the productive life of dairy cows, with cows reaching only

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2.5 to 3.3 parities before being culled (e.g., Hare et al., 2006). It is well known that milk yield increases in the first few lactations before it reaches a plateau between lactation 5 to 8, after which it starts to decrease (Lubritz et al., 1989; Horn et al., 2012). Thus, a large part of the highly productive lifetime is systematically lost. This could be avoided with increased longevity, where there is also an environmental benefit given by the postponed replacement associated with proportionately lower numbers and, thus, emissions from replacement heifers that have to be reared (Bell et al., 2015). Promoting longevity would therefore dilute emissions from replacement. It is, however, still unresolved whether a longevity strategy is actually environmentally sound in terms of GHG emissions. The advantages mentioned could be counteracted by an increasing enteric CH_4 emission with age, an aspect which has not yet been considered in life cycle analyses. Although no systematic study of such age effects exists, some controversial evidence exists. Ramírez-Restrepo et al. (2015) found no difference between <1-yr-old heifers and >6-yr-old cows in CH_4 yield per kilogram of DMI. By contrast, the evaluation by Zeitz et al. (2012) across several experiments indicated an almost linear increase in CH_4 yield per kilogram of DMI when opposing weaned, fattened calves to adult cows fed diets with similar concentrate proportions. Studies in sheep (Knight et al., 2008a) and red deer (Swainson et al., 2007) also reported greater CH_4 yields per kilogram of DMI in mature animals compared with young animals. To the contrary, Knight et al. (2008b) found a greater CH_4 yield per kilogram of DMI in 12- to 16-wk-old calves compared with 2 adult cows fed the same low-quality feed. None of these studies compared adult animals of different ages.

A high feed conversion and milk production efficiency is the key for economically viable production systems and, given that this can be accomplished with the same feeds, is important also from a world nutrition point of view (Connor, 2015). Cows with higher daily milk yield need relatively less feed (nutrients) for maintenance, and thus are particularly efficient in transforming nutrients into milk in the short term. But even at the same milk yield and BW, animal-to-animal variation in feed intake exists. Various methods of defining efficiency in dairy cows have been introduced (Coleman et al., 2010; Berry and Crowley, 2013; Connor, 2015). They range from ratio traits such as gross feed conversion efficiency (SCM or ECM per unit of feed intake) and milk production per unit of BW, to profitability-focused measures such as income over feed costs, and to residual feed intake (**RFI**) or residual solids production. The RFI is calculated as the difference between actual feed (or energy) intake of an animal and its predicted feed (energy) requirements (Hegarty et al., 2007). Numerous physiological processes have been related to feed-efficient animals, but the biological basis is not yet fully understood (Herd and Arthur, 2009).

Differences in feed intake were also found to explain a considerable share of the phenotypic and genotypic variance found in CH_4 emission of sheep (Pinares-Patiño et al., 2013). Additionally, ruminal CH_4 represents a loss of energy for the animal. Therefore, low-CH_4 cows likely need less feed per kilogram of milk and would be potentially more feed-efficient. Consistent with this, Nkrumah et al. (2006) and Hegarty et al. (2007) found a low CH_4 production in low-RFI beef cattle. Therefore, improving feed efficiency is a promising indirect approach for minimizing CH_4 emission intensity and seems to be also directly related to CH_4 emissions (Basarab et al., 2013). Evidence also exists that divergence in feed efficiency is retained from the calf stage to the lactating stage (Macdonald et al., 2014). However, information on age-related changes in feed efficiency in literature is scarce. Some of the processes affecting feed efficiency, such as feeding behavior (Dado and Allen, 1994; Maekawa et al., 2002) and fiber digestibility (Graham, 1980), might be influenced by senescence, but the extent to which such developments add up to efficiency changes with age is unclear.

The objective of the current study was to determine CH_4 emissions and efficiency of dairy cows continuously across a large age range. With this approach, it was investigated whether (1) an increase in CH_4 production with age in dairy cattle occurs and (2) whether this happens at a concomitant decrease in feed efficiency. It was further studied whether the age-dependent responses depend on diet type. Therefore, the age effects on CH_4 emission were tested with cows fed 2 different diets, either with or without concentrate supplementation. Such feeding strategies could also part of high-performance versus longevity strategies. As enteric CH_4 is linked to digestion characteristics (Okine et al., 1989; Pinares-Patiño et al., 2007; Goopy et al., 2014), the findings were related to additional data on intake and digestion available from the experimental animals (described in detail in Grandl et al., 2016).

MATERIALS AND METHODS

Animals and Feeding

The experiment was approved by the veterinary office of the Swiss canton of Zurich (149/2013). The experiment was carried out from October 2013 to February 2014. More details on the animals and the experimental procedures are given in Grandl et al. (2016).

The experimental animals were selected from 2 Brown Swiss herds kept at the Agricultural Education