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Effects of replacement of late-harvested grass silage and barley with early-harvested silage on milk production and methane emissions

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ABSTRACT

This study evaluated the effects of gradual replacement of a mixture of late-cut grass silage (LS) and barley with early-cut grass silage (ES) on milk production, CH_4 emissions, and N utilization in Swedish Red cows. Two grass silages were prepared from the same primary growth of timothy grass sward but harvested 2 wk apart [11.0 and 9.7 MJ of metabolizable energy/kg of dry matter (DM)]. Four diets, fed as a total mixed ration, were formulated to meet the metabolizable energy and protein requirements of 35 kg of energy-corrected milk (ECM) by gradually replacing a mixture of LS and barley with ES (0, 33, 67, and 100% of the forage component of the diet), whereas the proportion of barley decreased from 47.2 to 26.6% of diet DM. Expeller canola meal was used as a protein supplement. Sixteen Swedish Red cows were used in 4 replicated 4 × 4 Latin squares. Cows were offered diets ad libitum and milked twice daily. Each period of 28 d comprised 14 d of diet adaptation followed by 14 d of data collection. Intake and milk yield were recorded daily, and milk samples were collected on d 19 to 21 and d 26 to 28 of each period. Diet digestibility was determined by grab sampling using indigestible neutral detergent fiber as an internal marker. Gas emissions were measured using the GreenFeed system (C-Lock Inc., Rapid City, SD). Dry matter intake (DMI) linearly decreased from 22.6 to 19.3 kg/d as the proportion of ES increased in the diet. The ECM yield did not differ among treatments, but milk protein yield decreased with increasing proportion of ES in the diet. Because of reduced DMI with increasing ES, feed efficiency (ECM/DMI) improved with an increased proportion of ES in the diet. Nitrogen efficiency (milk N/N intake) did not change despite a linear increase in milk urea N concentration from 9.7 (LS alone) to 11.9 mg/dL (ES alone) with graded replacement of LS and barley by ES in the diet. Lower DMI responses in ES diets were partly compensated for by increased organic matter digestibility (656 g/kg of DM for LS alone; 715 g/kg of DM for ES alone) related to improved forage digestibility at early harvesting. Total CH_4 emissions and CH_4 intensity (CH_4/ECM) were not influenced by diet, but CH_4 yield (CH_4/DMI) increased linearly from 19.5 to 23.0 g/kg of DMI with greater inclusion of ES in the diet. In conclusion, replacing LS and barley with ES improved the conversion of feed to milk without increasing CH_4 emissions or compromising N efficiency.
Key words: concentrate, feed efficiency, grass silage, methane

INTRODUCTION

Compared with other livestock species, ruminants have the unique ability to transform nonedible feedstuffs (e.g., forages) into highly valuable products for human consumption. However, cattle production has been targeted during recent decades for its contribution to greenhouse gas emissions. In the rumen, enteric CH_4 is produced during microbial fermentation of dietary carbohydrates and, quantitatively less importantly, from protein. Volatile fatty acids, CO_2, H_2, and microbial cells are the end products of fermentation (e.g., Van Soest, 1994). Methanogenesis is an important biochemical pathway because it is the main H_2 sink in rumen conditions (Czerkawski, 1986), but it also represents an energetic loss for the cow that ranges, depending on intake and diet composition, from 2 to 12% of gross energy (**GE**) intake (Johnson and Johnson, 1995). Therefore, potential improvements in reducing enteric CH_4 emissions might improve the feed efficiency of the animals.

Dry matter intake and diet composition are the key factors affecting CH_4 emissions (Hristov et al., 2013; Ramin and Huhtanen, 2013). Increased concentrate feeding promotes milk production and is considered one strategy for reducing CH_4 intensity. Low CH_4 emissions have been observed for feedlot-type diets containing

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more than 90% of concentrate (Johnson and Johnson, 1995). However, within common ranges used in dairy cow diets, the effect of concentrate proportion on CH_4 emissions was relatively small (Ferris et al., 1999). In a meta-analysis conducted by Ramin and Huhtanen (2013), differences between dietary carbohydrates (NDF vs. NFC) in their effects on CH_4 yield were marginal for diets containing ≤75% concentrates on a DM basis. The model of Sauvant and Giger-Reverdin (2009) predicts maximum CH_4 yield at 35% concentrate on a DM basis and moderate decreases of between 35 and 60% of concentrate. High levels of concentrate supplementation can increase the incidence of acidosis and laminitis (Nocek, 1997) and decrease cell wall digestibility, as discussed by Nousiainen et al. (2009).

Grass silage is usually the main component of dairy cow diets in Nordic countries. Maturity at harvest is the major factor influencing the nutritive value of grass silage because of its effect on digestibility. Digestibility is the most important forage factor influencing silage DMI (Huhtanen et al., 2007) and, consequently, nutrient supply. In a literature review by Rinne (2000), the average DMI and milk yield responses reported were 0.16 and 0.32 kg/d per 10 g/kg of DM increase in silage digestible OM (**DOM**) concentration. Although CH_4 yield generally increases with improved diet digestibility (Blaxter and Clapperton, 1965; Ramin and Huhtanen, 2013), it usually decreases when expressed per unit of digestible energy (e.g., Beever et al., 1988).

Improving forage quality can allow concentrate supplementation to be reduced without compromising milk production. Huhtanen et al. (2013) compiled results of 4 feeding experiments investigating the effects of digestibility of grass silage and level of concentrate supplementation on milk production and found, on average, that 0.81 kg more concentrate DM was required to compensate for 10 g/kg lower DOM concentration in silage DM. These results suggest that it is possible to maintain the same level of milk production by improving forage quality while reducing concentrate input. However, to our knowledge, no data on the effects of this strategy on CH_4 emissions and N efficiency in dairy production have been reported. The main aim of this study was to investigate whether milk production can be maintained without increasing CH_4 intensity (g of CH_4/kg of ECM) by improving dietary forage quality while simultaneously decreasing the use of concentrate. In the present paper, forage quality refers to OM digestibility.

MATERIALS AND METHODS

All animals were registered and cared for according to guidelines approved by the Swedish University of Agricultural Sciences (Umeå, Sweden) Animal Care and Use Committee and the National Animal Research Authority (Stockholm, Sweden). The experiment was carried out in accordance with the laws and regulations controlling experiments performed with live animals in Sweden.

Experimental Design, Animals, and Management

A production trial was conducted at Röbäcksdalen experimental farm of the Swedish University of Agricultural Sciences (63°45′ N, 20°17′ E). Sixteen Swedish Red dairy cows (12 multiparous and 4 primiparous; mean BW = 635 ± 76 kg; 79 ± 14.4 DIM, producing 34 ± 6.9 kg of milk/d at the start of the experiment) were used in a replicated 4 × 4 Latin square design trial. The dietary treatments in the study involved gradually replacing late-cut silage (**LS**) and rolled barley with 3 incremental levels of early-cut silage (**ES**).

The experimental periods each lasted for 28 d and were divided into 14 d of adaptation and 14 d of data recording and sampling. The cows were assigned to blocks according to parity and milk yield and were randomly allocated to 1 of the 4 treatments within block (square). The cows were housed in an insulated loose-housing barn equipped with an automatic feed intake recording system and were fed a TMR ad libitum with free access to water. The feed components were mixed using a TMR mixer (Nolan A/S, Viborg, Denmark) and then delivered by an automatic feeding wagon to the feed troughs 4 times per day at 0600, 1100, 1500, and 1900 h. The cows were milked twice per day at 0600 and 1500 h.

Feeds and Diet Formulation

Two grass silages of different predicted in vivo digestibility (DOM: 685 and 607 g/kg of DM) were harvested 2 wk apart (June 10 and 24, 2013) using a disc mower conditioner (GMT 3605 FlexP, JF-Stoll A/S, Sønderborg, Denmark) and a precision chop forage wagon (ES 5000 MetaQ Protec, JF-Stoll A/S). Silages were harvested from the primary growth of a third-year ley dominated by timothy grass (*Phleum pratense*), with some red clover (*Trifolium pratense*). The fields were fertilized with 70 kg of N/ha in the spring.

The crops were wilted to a DM concentration of approximately 300 g/kg and ensiled in bunker silos using a commercial acid-based additive (propionic and formic acids; ProMyrTM XR 630, Perstorp, Sweden) provided at a rate of 3.5 L/t. The experimental diets were formulated using the Lypsikki ration formulation system (Huhtanen and Nousiainen, 2014) to meet the ME and MP requirements for production of 35 kg of