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Effects of replacing maize silage with lucerne silage and lucerne silage chop length on rumen function and milk fatty acid composition

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ABSTRACT

The objective of this study was to investigate whether higher lucerne (*Medicago sativa*; alfalfa) silage inclusion rate and longer lucerne chop length improves rumen function through increased provision of physically effective fiber, when included in a maize and lucerne silage-based total mixed ration. Diets were formulated to contain a 50:50 forage:concentrate ratio [dry matter (DM) basis] and be isonitrogenous and contain equal levels of neutral detergent fiber (320 g/kg). The forage portion of the offered diets was composed of maize and lucerne silage DM in proportions (wt/wt) of either 25:75 (high lucerne; HL) or 75:25 (low lucerne; LL). Second-cut lucerne was harvested and conserved as silage at either a long (L) or a short (S) chop length (geometric mean particle lengths of 9.0 and 14.3 mm, respectively). These variables were combined in a 2 × 2 factorial arrangement to give 4 treatments (HLL, HLS, LLL, LLS), which were fed in a 4 × 4 Latin square design study to 4 rumen-cannulated, multiparous, Holstein dairy cows in mid lactation. Effects on DM intake, chewing behavior, rumen volatile fatty acid concentration, rumen pH, rumen and fecal particle size, milk production, and milk fatty acid profile were measured. Longer chop length increased rumination times per kilogram of DM intake (+2.8 min/kg) relative to the S chop length, with HLL diets resulting in the most rumination chews. Rumen concentrations of total volatile fatty acids, acetate, and n-valerate were higher for the HLS diet than the other 3 diets, whereas rumen propionate concentration was lowest for the HLL diet. Physically effective fiber (particles >4 mm) percentage in the rumen mat was increased when L chop length was fed regardless of lucerne inclusion rate. No effect of treatment was observed for milk yield, although milk protein concentration was increased by L for the LL diet (+1.6 g/kg) and decreased by L for the HLL diet (−1.4 g/kg). Milk fat concentrations of total *cis*-18:1 (+3.7 g/100 g of fatty acids) and 18:3 n-3 (+0.2 g/100 g of fatty acids) were greater with HL. In conclusion, longer lucerne silage chop length increased time spent ruminating per kilogram of DM intake, but had no effect on rumen pH in the present study. Increasing dietary lucerne inclusion rate had no effects on rumination activity or rumen pH, but decreased the ratio of n-6:n-3 polyunsaturated fatty acid concentrations in milk fat.

Key words: lucerne, silage, rumination, rumen health, milk fatty acid, effective fiber

INTRODUCTION

The physical form of a TMR can affect rumen function and the efficiency of digestion in lactating dairy cows (Allen, 1997). Lucerne silage is thought to promote rumen health as it contains high NDF and ADF concentrations as well as having a higher natural buffering capacity (based on cation exchange capacity) than silages such as maize or ryegrass (McBurney et al., 1983). Factors that are considered markers of rumen health include pH, VFA profile, time spent ruminating (increasing saliva production), and consistency of the rumen mat (Weidner and Grant, 1994; Plaizier et al., 2008; Zebeli et al., 2012). For optimal rumen health, highly fermentable concentrate feedstuffs must be adequately balanced by forage physically effective fiber (**peNDF**) in TMR.

Physically effective fiber is defined as the NDF present within the long forage particles (Mertens, 1997) and can be increased by lengthening forage particle size. However, relationships between particle size and the rumen environment are complex and different particle sizes can play different roles, such as rumen mat formation and stimulation of rumination, although there are conflicting views within the literature on the relative effectiveness of different particle sizes. For example, Zebeli et al. (2012) suggested that all particles greater than 1.18 mm are effective at stimulating rumination but only particles greater than 8 mm form the structure

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of the rumen mat, whereas Heinrichs (2013) suggested that only particles greater than 4 mm should be considered physically effective. Furthermore, an oversupply of long particles has been shown, in some instances, to reduce DMI and milk yield, possibly through excessive rumen fill (Kononoff and Heinrichs, 2003) and reduced surface area for bacterial attachment and thus digestibility (Zebeli et al., 2008). Therefore, the optimum dietary inclusion rate (**IR**) of individual forages may vary depending on their chop lengths (**CL**). To this end, the main objective of this study was to evaluate the effect of 2 IR of lucerne silage within a maize and lucerne silage-based TMR with 2 different lucerne CL on parameters associated with rumen health and function. A secondary objective was to examine whether any changes in diet composition and rumen fermentation were associated with changes in milk yield and composition.

Table 1. Ingredients used to create experimental TMR

	Diet[1]	
Ingredient (g/kg of DM)	LL	HL
Lucerne silage	125	375
Maize silage	375	125
Concentrate blend		
Cracked wheat	80	80
Maize meal	54	97
Unmolassed sugar beet feed	40	40
Soy hulls	82	108
Soybean meal	100	65
Rapeseed meal	100	65
Molasses	10	10
Dicalcium phosphate	5	5
Salt	5	5
Dairy mineral	10	10
Megalac[2]	15	15

[1]LL = low lucerne diet; HL = high lucerne diet.

[2]Megalac rumen-protected fat supplement (Volac International Ltd., Royston, UK).

MATERIALS AND METHODS

Forage Harvesting and Clamp Sampling

The present study formed part of a larger trial reported previously (Thomson et al., 2017) utilizing the same dietary treatments and a larger cohort of cows. In brief, the lucerne silage used was a second cut crop, harvested in the calendar year before the present study at an estimated 10% bloom, windrowed, and wilted for 48 h to produce a high DM concentration (576 g/kg) silage. Alternate swaths originating from the same field area were used to create 2 silages with differing CL, long (**L**) and short (**S**), by altering the knife arrangement of a precision chop forage harvester (Claas Jaguar, Claas Group, Harsewinkel, Germany) from a theoretical CL of 14 mm (shortest setting) to 19 mm (longest setting), which produced silages of 9.0 and 14.3 mm geometric mean particle length, respectively, assessed using a Penn State Particle Separator (**PSPS**; Heinrichs, 2013). The L and S chopped material was ensiled separately in identical adjacent clamps. Maize silage for the study was taken from a crop of mixed varieties harvested in the year before the present study and ensiled in a concrete-walled clamp with no additive. The geometric mean particle length for the maize silage was determined to be 10 mm.

Diets

A TMR with 50:50 ratio of forage:concentrate (DM basis) was fed. The forage was composed of maize and lucerne silage at IR (DM basis) of either 25:75 (high lucerne; **HL**) or 75:25 (low lucerne; **LL**), respectively. The 2 IR (LL or HL) and the 2 CL (L or S) were combined in a 2 × 2 factorial arrangement to give 4 treatments (**HLL**, **HLS**, **LLL**, **LLS**). Diets were formulated (Thomas, 2004) to be isonitrogenous (170 g of CP/kg of DM) and contain similar levels of NDF (320 g/kg of DM) through variation in the IR of soy hulls and rapeseed meal, based on preliminary analysis of core silage samples and reference values for other components. Maize meal was included at higher rates in the HL diet to offset the reduction in maize silage starch inclusion (Table 1); however, starch concentration was still greater in LL diets than HL diets (Table 2) and predicted ME concentration was lower in HL than LL diets (11.5 and 12.0 MJ/kg of DM, respectively).

Animals

Four multiparous Holstein-Friesian dairy cows in mid lactation (161 DIM, SEM ±23.1), producing 39.7 L/d milk yield (SEM ±6.2 L), and in 6th parity (SEM ± 0.3) on average at the start of the study were used. Cows weighed 741 kg (SEM ±13.9) at the start of the study and gained 25 kg (SEM ±34.6) on average over the study duration. Cows were fitted in a previous lactation with rumen cannula (Bar Diamond, Parma, ID). Animals were randomly assigned to 1 of 4 initial treatments according to a 4 × 4 Latin square design balanced for carryover effects with 21-d periods. All regulated animal procedures used were licensed and monitored by the UK Government Home Office under the Animal (Scientific Procedures) Act 1986. Animals were housed in a cubicle yard and individually fed once daily for ad libitum intake through Insentec RIC feeders (Insentec B.V., Marknesse, the Netherlands) during wk 1 and 2 of each period. Cubicles were bedded with wood