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Effects of intraruminal urea-nitrogen infusions on feed intake, nitrogen utilization, and milk yield in dairy cows

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ABSTRACT

The objective of this study was to determine the effects of supplementation of protein deficient diet with increasing amounts of urea-N on feed intake, milk yield, rumen fermentation, and nutrient digestibility in dairy cows. The hypothesis was that low rumen ammonia-N concentrations provide suboptimal conditions for rumen microbes and these conditions can be alleviated by urea-N that increases rumen ammonia-N concentrations. To evaluate this hypothesis, the diet was formulated slightly deficient with respect to rumen-degradable protein. To supplement the diet with rumen degradable N, 5 levels of urea-N (0, 17, 33, 49, and 66 g/d) were continuously infused into the rumen of 5 dairy cows according to a 5 × 5 Latin square. Increasing levels of urea-N infusion increased N intake and N excretion in urine and feces in a linear manner and tended to increase milk and milk protein yields. Feed intake and fiber digestibility were not affected by urea-N infusion levels. Rumen ammonia-N concentrations remained low (3.5 mg/100 mL) and did not respond to urea-N infusions levels between 0 to 49 g/d, whereas the highest level of urea-N (66 g/d) increased rumen ammonia-N concentration to 5.1 mg/100 mL (quadratic effect). These observations suggested that rumen microbes efficiently captured ammonia-N from rumen fluid until sufficient intracellular ammonia-N concentrations were attained, after which ammonia-N concentrations started to increase in extracellular rumen fluid. In contrast, milk urea-N concentrations increased in a curvilinear manner (cubic effect) from 4.4 to around 6 mg/100 mL for the medium levels of urea-N and then to 7.9 mg/100 mL for the highest level of urea-N infusion. The current results indicated that 18% of supplementary N intake was secreted in milk and 53% in urine. In spite of low rumen ammonia-N concentrations observed for the basal diet, it was estimated that only 43% of supplementary N was captured by rumen microbes. Estimated true digestibility for supplementary N (93%) provided further evidence that urea-N stimulated microbial N synthesis. The current results indicate that rumen ammonia-N concentration was an insensitive indicator of N deficiency at low levels of diet CP, whereas milk urea-N was responsive to diet CP concentrations at all urea-N infusion levels.
Key words: urea, dairy cow, nitrogen, rumen

INTRODUCTION

The main principle in formulation of diets for dairy cows has been to provide a ration that allows individuals to satisfy their nutritional requirements. In an attempt to account for the N requirements of the rumen microbes and protein requirements of the cow, a distinction between RDP and RUP has been made in the current feed evaluation systems. However, the success of assigning dietary protein to these 2 fractions has been meager (Schwab et al., 2005). Arguably, dairy cows do not have absolute requirements for the amount of MP because they can adapt to different levels of nutrition by adjusting their feed intake and milk yield as required to maintain a balance between nutrient supply and body requirements (Vérité and Delaby, 2000; Huhtanen et al., 2011b). The optimum amount of CP in the diet depends on definition because the optimum for milk yield is often very different from the optimum for N use efficiency (Huhtanen et al., 2011a). Supplementation of dairy cow diets with protein feeds has often resulted in positive production responses in terms of milk and milk protein yield (Vérité and Delaby, 2000; Ipharraguerre and Clark, 2005; Huhtanen et al., 2011a). In spite of positive milk yield responses to increases in CP intake, the N use efficiency (milk N/N intake) has consistently decreased (Castillo et al., 2001; Nursoy et al., 2018). The main reason for such decreases is that a large proportion of feed protein is degraded in the rumen and only a small proportion enters the omasal

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canal as undegradable feed protein (Broderick et al., 2010). Furthermore, increasing the MP to energy ratio above recommendations resulted in linear increases in urine N excretion but only minor increases in milk yield (Vérité and Delaby, 2000). Attempts to increase the proportion of RUP in protein feeds have often been successful in enhancing ruminal outflow of nonammonia N, but the effects on milk CP yield have been minor and sometimes even negative (Ipharraguerre and Clark, 2005). Feeding a diet that provides RDP in excess of microbial needs will inevitably decrease the N use efficiency (Broderick, 2003; Huhtanen and Hristov, 2009) but even maintaining the N use efficiency using supplements enriched with RUP seems unrealistic. This has been convincingly demonstrated by studies in which supplementary protein was supplied directly into the abomasum of dairy cows (Choung and Chamberlain, 1993; Guinard et al., 1994). In both studies lowest levels of casein or soya protein isolate infused into the abomasum were efficiently used for milk protein synthesis and either improved or maintained the N use efficiency of the basal diet. However, higher amounts of either casein or soya protein resulted in diminishing utilization for milk protein synthesis (Choung and Chamberlain, 1993; Guinard et al., 1994). In practice such utilization rates of supplementary protein, as achieved using abomasal casein infusions, cannot be attained because of inevitable degradation losses in the rumen, lower intestinal CP digestibility, and less ideal AA composition of RUP supplements. Arguably, the most efficient means of improving the N use efficiency in milk production is to formulate a diet that provides sufficient RDP for rumen microbes but avoids excess supply that is metabolized to ammonia-N, absorbed from the digestive tract, and lost in urine (Huhtanen and Hristov, 2009). A previous study in lactating dairy cows given pulse doses of ^{15}N labeled ammonia-N and grass silage soluble N indicated that 53 and 62%, respectively, of rumen bacterial N was derived from rumen ammonia-N pool (Ahvenjärvi et al., 2018). These observations suggest that rumen ammonia-N pool plays an important role in rumen N dynamics and NPN sources could be used to complement deficiencies in RDP supply.

The objective of the current study was to assess the critical diet CP and rumen ammonia-N concentrations, below which the microbial N synthesis and fiber digestibility are decreased relative to the optimal conditions. The hypothesis underlying the current study was that feed intake, nutrient digestibility, and milk yield of lactating dairy cows are compromised when offered a diet formulated slightly deficient in terms of RDP. The hypothesis further assumed that suboptimal rumen conditions could be improved by urea-N infusions into the rumen that increase rumen ammonia-N concentrations.

MATERIALS AND METHODS

Animals, Diet, and Experimental Design

The current experiment was conducted in compliance with the Finnish Act on the Use of Animals for Experimental Purposes and experimental procedures were approved by the National Animal Experiment Board. The effects of intraruminal urea-N infusions were investigated using 5 lactating dairy cows that received a basal diet formulated marginally deficient of RDP. Grass silage was provided as forage because it is the most widely cultivated forage crop in Northern Europe. In addition, our previous study (Ahvenjärvi et al., 2018) indicated that a pulse dose of ammonia-N introduced into the rumen of dairy cows fed grass silage-based diet was efficiently used for microbial N synthesis. Experimental animals were multiparous Finnish Ayrshire dairy cows equipped with 10 cm i.d. rumen cannulas (Bar Diamond Inc., Parma, ID). The cows were on average 77 DIM (SD 12.3) at the beginning of the experiment and weighed 620 kg (SD 35.6). The basal diet was offered 4 times daily at 0600, 0900, 1800, and 2000 h according to appetite allowing at least 5% for the daily refusals. Silage was prepared from a primary growth of a mixture of timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*) grass species. Grass was cut and conditioned using a mower-conditioner and allowed to wilt for a few hours before it was harvested using a precision chopper. To restrict the extent of silage fermentation, silage additive [AIV 2 Plus (Formic acid 77%, Ammonium formate 5.5%) Taminco Finland Oy, Oulu, Finland] was applied onto grass at harvest at a rate of 5 L/t. Grass was ensiled in bunker silos until mixed with concentrates to prepare TMR that contained (per kg of DM) 511 g of grass silage, 156 g of wheat, 152 g of oats, 147 g of molassed sugar beet pulp, 20 g of solvent-extracted rapeseed meal, and 15 g of mineral and vitamin premix (Rehumelica Oy, Vaasa, Finland).

The experimental treatments consisted of 5 levels of urea-N (0, 17, 33, 49, and 66 g/d of N; Sigma-Aldrich Chemie GmbH, Steinheim, Germany) dissolved in 6 L of water and infused into the rumen through a rumen cannula using a peristaltic pump (Watson-Marlow 502 S, Falmouth, UK). Urea-N was administered by means of water infusion to avoid palatability problems often encountered with urea-N-containing diets and to ensure constant daily doses. Treatments were randomly allocated to each cow according to a 5 × 5 Latin square