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High-sugar alfalfa for dairy cows

Robert Berthiaume [A], *Andre F. Brito* [B], *Gaëtan F. Tremblay* [C], *Gilles Bélanger* [C], *Carole Lafrenière* [D], *Annick Bertrand* [C], *Yves Castonguay* [C], *Réal Michaud* [C] *and Guy Allard* [E]

[A] Valacta, Sainte-Anne-de-Bellevue, QC, Canada
[B] University of New Hampshire, Durham, NH, USA
[C] Agriculture and Agri-Food Canada, Québec, QC, Canada
[D] Agriculture and Agri-Food Canada, Kapuskasing, ON, Canada
[E] Université Laval, Québec, QC, Canada
Contact email: rberthiaume@valacta.com

Abstract. Alfalfa proteins are extensively degraded during wilting, silage fermentation, and in the rumen. To efficiently use alfalfa non protein N, rumen microbes need a readily available energy source such as nonstructural carbohydrates (NSC); otherwise, surplus N in the form of rumen ammonia is converted into urea and excreted in the environment. Increasing the NSC concentration of alfalfa was thus the focus of our research program. Our objectives were to assess the impact of high NSC alfalfa on digestibility and microbial protein synthesis measured in vitro, and on ingestion, rumen metabolism, N use efficiency, and dairy cow performance. Increasing NSC concentration of alfalfa significantly enhanced in vitro dry matter (DM) digestibility and decreased NH3-N concentration in rumen fluid. An increase of 23 g/kg in alfalfa NSC concentration can improve forage DM intake (+5 %) and energy corrected milk production (+8 %). Feeding high-NSC alfalfa led to a higher rumen pH, suggesting that sugars do not cause rumen acidosis, and to a lower milk urea N (MUN) indicating an improvement in N utilization. Increasing NSC concentration of alfalfa is a low-cost tool to improve its utilisation in dairy rations and potentially mitigate the environmental footprint of milk production.

Keywords: N use, nonstructural carbohydrates, milk, baleage.

Introduction

Alfalfa is widely cultivated in North America. However, between 50 and 80% of alfalfa crude protein (CP) is degraded to non-protein N (NPN) in the silo, leading to excessive ammonia formation in the rumen. An increase in alfalfa NSC concentration that reduces proteolysis in the silo and balances the supplies of fermentable energy and rumen degradable protein (RDP) should enhance ammonia capture by ruminal microbes and improve N utilization in dairy cows. The concentration of NSC varies diurnally in forages because of the plants' potential to accumulate carbohydrates during the photoperiod (Morin *et al.* 2011; 2012). The PM cutting of alfalfa and other forage species (PM vs. AM) has been shown to increase their NSC concentration. Therefore, we hypothesized that feeding high NSC alfalfa would improve N utilization, dry matter intake (DMI), and milk yield of dairy cows. The general objective of the studies reported herein was to increase the energy content of alfalfa and the resulting dairy cow performance. Specific objectives were to evaluate the impact of forages rich in energy on rumen metabolism, DMI, N use efficiency, and performance of dairy cows.

Methods

In this paper, we present an overview of our research findings on the impact of increasing forage NSC concentration on dairy cow performance. The research was conducted in eastern Canada [growing degree days (0°C basis), 2300 to 2700; annual precipitation, 900 mm]. The NSC concentration was determined by the sum of glucose, fructose, starch, fructan (grasses), and pinitol (legumes) concentrations. *In vitro* studies were conducted with dual flow fermenters similar to those described by Hoover *et al.* (1976) to determine *in vitro* dry matter digestibility, N metabolism, VFA concentrate-ions and microbial efficiency. To confirm our *in vitro* data we used 16 lactating (8 rumen cannulated) dairy cows (Brito *et al.* 2008; 2009a). Cows were fed forage based diets to investigate the effects of alfalfa daytime cutting management on ruminal metabolism, nutrient digestibility, nitrogen balance, and milk yield.

Results and Discussion

In vitro studies

The studies reported (Table 1) were based on previous field trials showing that cutting in the afternoon (PM *vs.* AM, Berthiaume *et al.* 2006) and selecting genotypes that contained more sugars (NSC contrasted alfalfa, Berthiaume *et al.* 2010) increased the NSC concentration and decreased the CP and NDF concentrations in alfalfa and other forages.

In general, feeding high-NSC alfalfa increased DM digestibility and reduced both the acetate to propionate

Table 1. Summary of two in vitro trials with high and low NSC alfalfa

	NSC (g/Kg)		DMD[z] (%)		A:P		NH_3-N(mg/dL)	
	High[y]	Low	High	Low	High	Low	High	Low
PM *vs* AM alfalfa	133 a	71 b	nd	nd	2.7 a	3.9 b	58.4 a	63.6 b
NSC contrasted alfalfa	179 a	74 b	74 a	65 b	3.0 a	3.6 b	26.0 a	33.6 b

[z]DMD = *In vitro* rumen Dry matter digestibility ; A:P = Acetate to Propionate ratio. [y]High and Low refer to High- and Low-NSC alfalfa obtained using either genetic variability or time of cutting during the day. Numbers followed by different letters were significantly different (P<0.05).

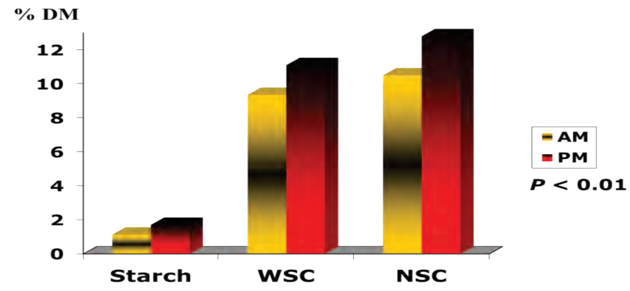

Figure 1. Effects of cutting time on alfalfa baleage NSC concentration

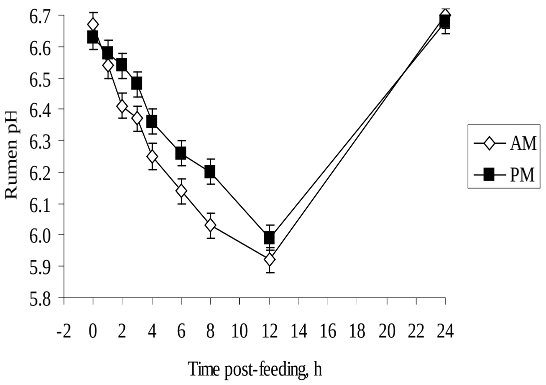

Figure 2. Diurnal variations of rumen pH in dairy cows fed baleage harvested from alfalfa cut at sunup (AM) or sundown (PM)

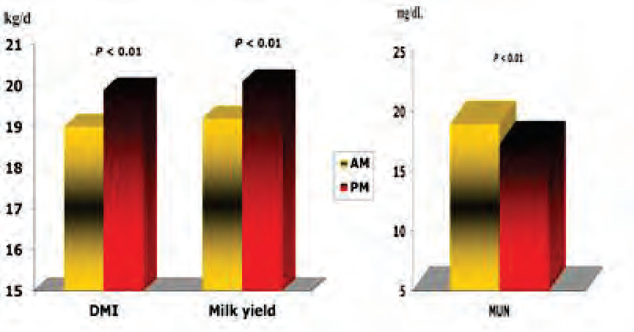

Figure 3. Effects of alfalfa cutting time (AM vs. PM) on dry matter intake (DMI), milk yield and MUN

ratio and the concentration of ammonia in the artificial rumen. These results are evidence that the energy and protein contained in high-NSC alfalfa were used more efficiently by the rumen bacteria.

In vivo *studies*

Compared to AM baleage, PM baleage concentrations of starch, WSC, and NSC were increased by 50, 19, and 22%, respectively (Fig. 1). Rumen pH was sign-ificantly higher comparing PM- *vs.* AM-cut alfalfa at 2, 3, 4, 6, and 8 h post-feeding (Fig. 2) whereas concentrations of rumen ammonia did not differ between forage treatments. This is contrary to in vitro data but it must be emphasized that in the controlled conditions of *in vitro* systems, there is no absorption of ammonia or recycling of urea, which are two important factors influencing the concentration of ammonia in the rumen.

Dry matter intake and milk yield were both greater when feeding PM- rather than AM-cut alfalfa (Fig. 3). Yields of milk components were also significantly higher when cows were fed PM- *vs.* AM-cut alfalfa baleage. Digestible organic matter (OM) intake was 0.8 kg/d higher when feeding PM- rather than AM-cut alfalfa, which corresponds to an increment of 13 MJ of ME intake with the former treatment assuming an energy content of 16 MJ/kg of digestible OM. Considering that cows fed PM-cut alfalfa yielded 1.6 kg/d more energy corrected milk (ECM) than those fed AM-cut alfalfa, the marginal response in ECM to incremental metabolizable energy (ME) intake was 0.12 kg of ECM/MJ of ME.

Milk urea N was lower with feeding PM- vs. AM-cut alfalfa baleage suggesting improvement in N utilization by shifting alfalfa cutting from AM to PM. Increased forage NSC improved the capacity of ruminal microbes to capture ammonia and use it as a N source for growth and yield. Ammonia is often the main N source for microbial protein synthesis and it is essential for the growth of several species of ruminal bacteria. In fact, ruminal bacteria incorporated more ammonia N when cows were fed PM- vs. AM-cut alfalfa (data not shown) further explaining the enhanced ruminal outflow of bacterial non ammonia N with PM-cut alfalfa. Finally, efficiency of N use was greater when cows were fed PM- rather than AM-cut alfalfa baleage. Further studies conducted with early and mid lactation cows fed alfalfa (Brito *et al.* 2009b) or timothy (Brito *et al.* 2010) generally concurred and reported that lactating dairy cows eat more and produce more milk with high NSC forages.

Conclusion

Increasing forage NSC concentrations decreases rumen ammonia and acetate concentrations whereas rumen pro-pionate concentration increases, leading to a more gluco-genic *in vitro* fermentation. Forages with more NSC are more digestible and enhance the synthesis of microbial proteins measured in vitro and in vivo. Dairy cows ingest more DM when fed forages with more NSC leading to a more efficient use of dietary N and to an increment in milk production (5-10%). Increasing NSC concentration in alfalfa does not appear to cause rumen acidosis. More research is needed to determine which of the changes associated with PM cutting or genetic selection (increased NSC and IVDMD, lowered NDF and CP) are the most important from a mechanistic point of view.

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