CHAPTER 42

# Taking Advantage of Diurnal Shifts in the Nutritive Value of Forages

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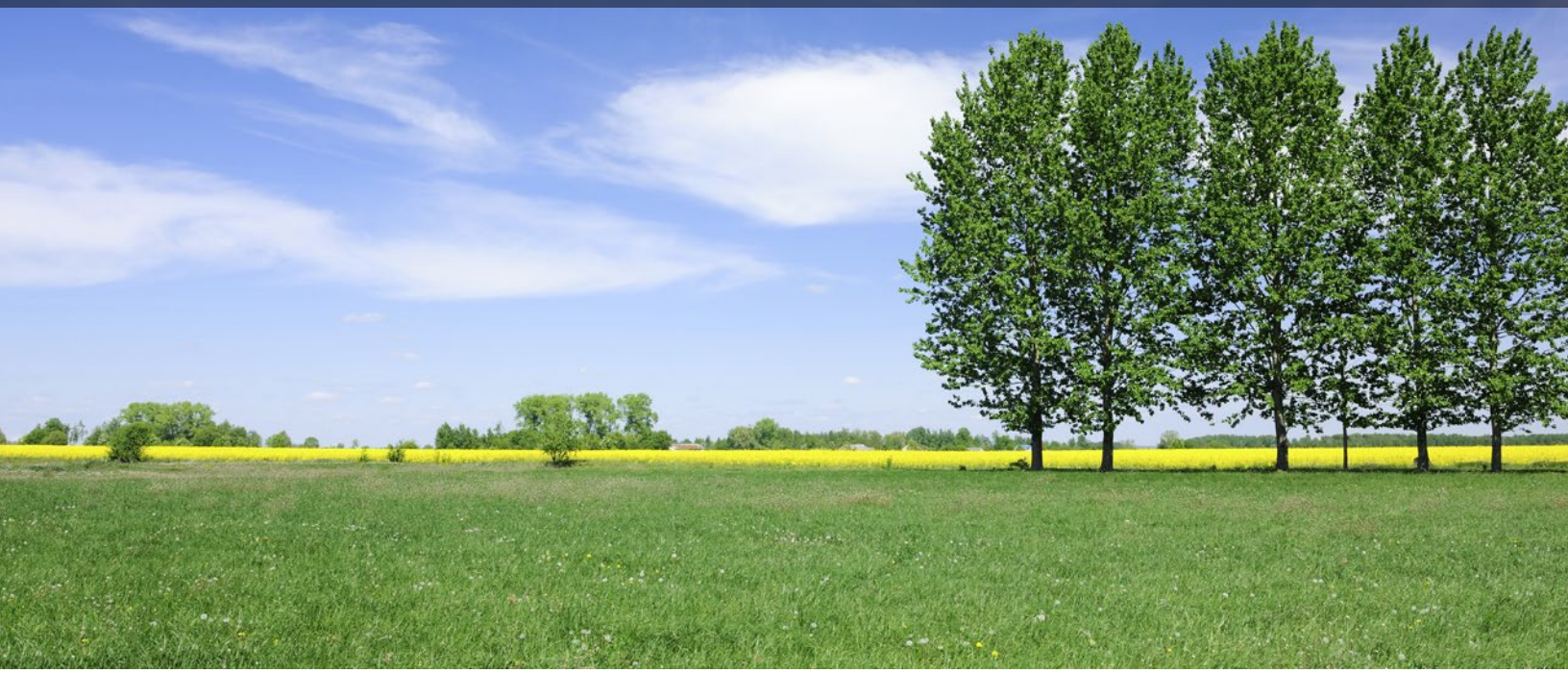

Total non-structural carbohydrates (NSC) provide readily fermentable energy to rumen microbes and their increased concentration in forages improves nitrogen (N) use efficiency in dairy cows. The concentration of non-structural carbohydrates varies diurnally in forages because of the plants' potential to accumulate carbohydrates during the photoperiod. In Canada, alfalfa and timothy are widely cultivated forage species. Unfortunately, between 50 and 80% of the crude protein (CP) in alfalfa silage and timothy silage is degraded to non-protein nitrogen (NPN) in the silo, leading to excessive ammonia formation in the rumen. Thus, an increase in alfalfa and timothy non-structural carbohydrates that reduces proteolysis in the silo and balances the supplies of fermentable energy and rumen degradable protein should enhance ammonia capture by ruminal microbes and improve N utilization in dairy cows. Daytime cutting management (afternoon- vs. morning-cut) has been shown to increase non-structural carbohydrates in forages. Therefore, we hypothesized that feeding high non-structural carbohydrate forage would improve N utilization, dry matter intake, and milk yield in dairy cows. The general objective of the studies reported herein was to increase the energy content of forages with a view to improve dairy cow performance. Specific objectives were to evaluate the impact of a forage rich in energy on rumen metabolism, dry matter intake, N use efficiency and performance of dairy cows.

### Diurnal variations of non-structural carbohydrates and nutritive value in alfalfa and timothy

We studied the diurnal variations of nutritive value attributes in alfalfa and timothy to determine the best time of day for cutting to maximize non-structural carbohydrates. Field-grown alfalfa was cut every 2 h between 0600 and 2000 h on six different days at early flowering stage (spring growth) and summer regrowth at two sites. The non-structural carbohydrates concentration increased during the day in all growth cycles and sites due mostly to an increase in starch concentration (Fig. 1). Concentrations of non-structural carbohydrates peaked between 11–13 h after sunrise.

### Management practices that favour the accumulation of energy in forages

We also wanted to determine how variations of non-structural carbohydrate concentration caused by time of cutting during the day differ among: 1) forage species, 2) alfalfa

genotypes and 3) wide vs. narrow swath, and how these variations were related to other attributes of forage nutritive value. These experiments showed that:

1) Amongst the two legume (alfalfa, red clover) and six grass species (smooth bromegrass, meadow bromegrass, reed canarygrass, tall fescue, timothy, Kentucky bluegrass) tested, red clover and tall fescue had the greatest non-structural carbohydrate concentration (9.42% of dry matter) across time of cutting (morning vs. afternoon) and growth periods (spring vs. summer) whereas reed canarygrass had the lowest concentration (6.55% dry matter). Concentration of non-structural carbohydrates of all species increased with afternoon-cutting although with some variation among forage species. Increased non-structural carbohydrate concentration with afternoon-cutting resulted in significant but small decreases in N, acid detergent fibre (ADF), and neutral detergent fibre (NDF) concentrations and a small increase in *in vitro* true digestibility (IVTD).
2) Both selecting alfalfa genotypes with more non-structural carbohydrates and cutting the forage in the afternoon contributed to higher concentrations in the forage. This effect was greater for time of cutting (+42%) than for genetic selection (+9%). Again, the increase in afternoon-cutting was associated with a decrease in fibre concentrations, and an increase in both *in vitro* true digestibility and digestible neutral detergent fibre.
3) Non-structural carbohydrates were on average 24% greater in afternoon- than in morning-cut alfalfa. More importantly, the concentration of non-structural carbohydrates remained greater in afternoon- compared to morning-cut alfalfa throughout the wilting period, which is obviously longer with afternoon cut forages since there is little drying during the night. Rapid drying, such as in wide swaths benefits non-structural carbohydrates.

We concluded that choosing the proper forage species and cultivars, and cutting in the afternoon while leaving the forage to dry in wide swaths are potential ways to increase the non-structural carbohydrate content in forages.

**What do the rumen bacteria think?**

Efficient microbial protein synthesis in the rumen requires a balanced supply of rumen degradable protein and energy. This energy is largely provided by water soluble carbohydrates from the diet. Therefore, any treatment that increases

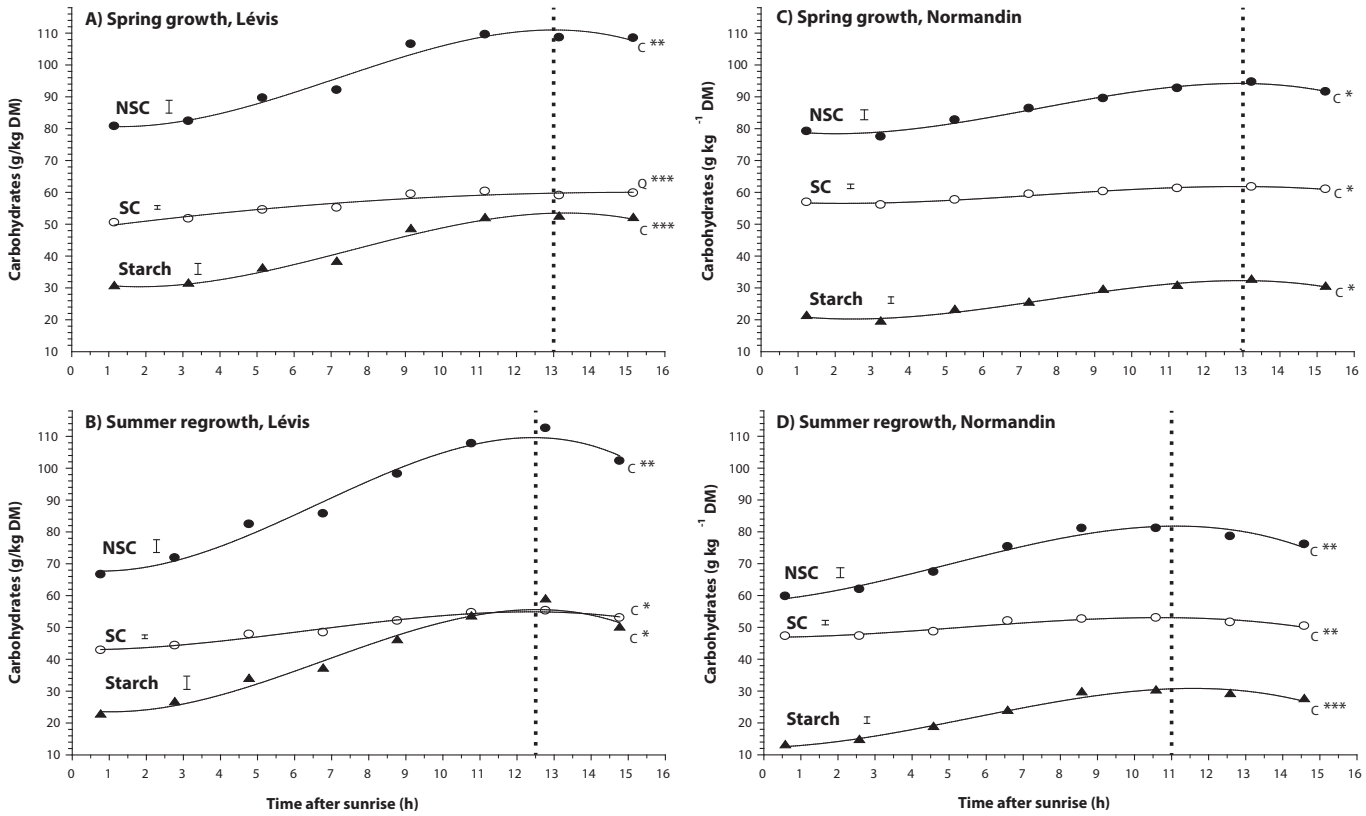


**Figure 1. Diurnal variations in alfalfa concentrations of non-structural carbohydrates (NSC), soluble carbohydrates (SC), and starch in spring and summer growths at Lévis and Normandin, QC (6–day averages). Dotted lines represent time after sunrise when non-structural carbohydrates peaked.**

**Table 1. Summary of three *in vitro* trials with contrasting non-structural carbohydrate (NSC) forage.**

| | NSC (%) | | DMD[a] (%) | | A:P[b] | | $NH_3$-N(mg/dL) | |
|---|---|---|---|---|---|---|---|---|
| | *High* | *Low* | *High* | *Low* | *High* | *Low* | *High* | *Low* |
| **PM vs AM alfalfa** | 13.3 | 7.1 | nd | nd | 2.7 | 3.9 | 58.4 | 63.6 |
| **NSC contrasted alfalfa** | 17.9 | 7.4 | 74 | 65 | 3.0 | 3.6 | 26.0 | 33.6 |
| **NSC contrasted timothy** | 13.7 | 9.6 | 79 | 81 | 2.9 | 3.1 | 15.3 | 49.4 |

[a]DMD = ***In vitro*** rumen dry matter digestibility; [b]A:P = acetate: propionate ratio.

water soluble carbohydrates in forages without increasing rumen degradable protein is beneficial. Table 1 summarizes the results of three different *in vitro* studies.

The studies show that high non-structural carbohydrate increased digestibility of forages and reduced both the acetate: propionate ratio and the concentration of ammonia in the rumen. This is evidence that forages with high non-structural carbohydrates were used more efficiently by the rumen bacteria.

### What do the cows think?

To confirm our laboratory results, we fed 16 late lactation dairy cows an all-forage diet to investigate the effects of cutting time of alfalfa on ruminal metabolism, nutrient digestibility, N balance, and milk yield. Afternoon-cut baleage had higher concentrations of starch (50%), water soluble carbohydrates (19%), and non-structural carbohydrates (22%) than morning-cut baleage (Fig. 2).

Rumen pH from 2–8 h post-feeding was significantly higher for afternoon- than morning-cut alfalfa (Fig. 3) whereas rumen ammonia did not differ between forage treatments. This is contrary to *in vitro* conditions where there is no absorption of ammonia and/or recycling of urea, which are two important factors influencing the concentration of ammonia in the rumen.

We found that dry matter intake and yield of milk and of milk components were greater when feeding afternoon-cut alfalfa (Fig. 4). Intake of digestible organic matter was 0.8 kg/d (1.76 lb/d) higher when feeding afternoon-cut alfalfa, which corresponds to an increment of 13 MJ of ME intake with the afternoon harvest assuming an energy content of 16 MJ/kg of digestible organic matter. Considering that cows fed afternoon-cut alfalfa yielded 1.6 kg/d (3.5 lb/d) more energy corrected milk, there was 0.12 kg additional energy corrected milk per MJ of metabolizable energy.

Milk urea N was lower with feeding afternoon-cut alfalfa baleage suggesting improvement in N utilization. Increased forage non-structural carbohydrates improved the capacity of ruminal microbes to capture ammonia and use it as a N source for growth and yield. Ammonia

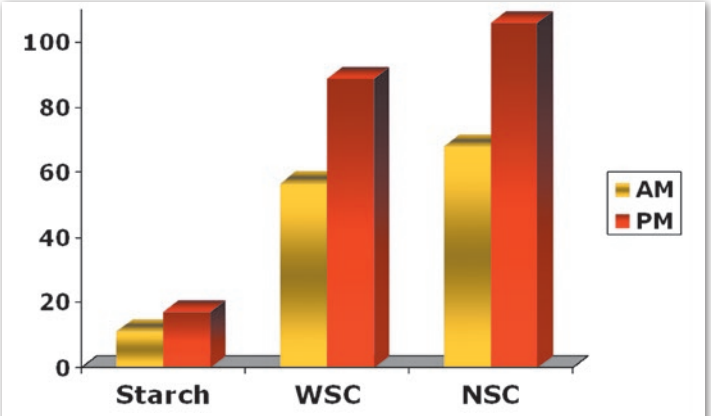


**Figure 2. Effect of cutting time on alfalfa baleage NSC concentration (g/kg DM).**

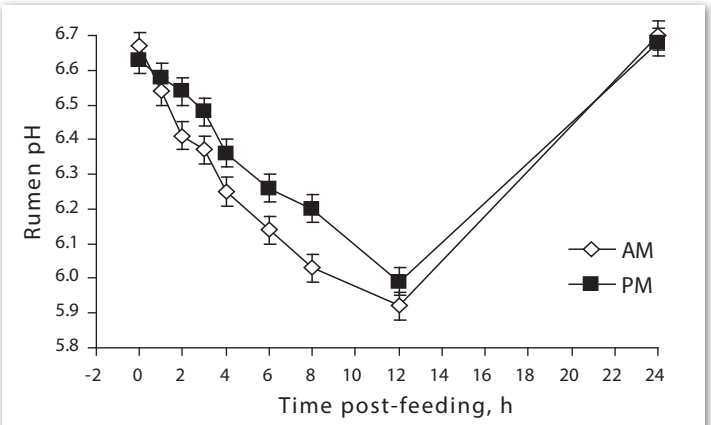


**Figure 3. Diurnal variation of rumen pH in dairy cows fed baleages harvested from alfalfa cut at sundown (PM) or sunup (AM).**

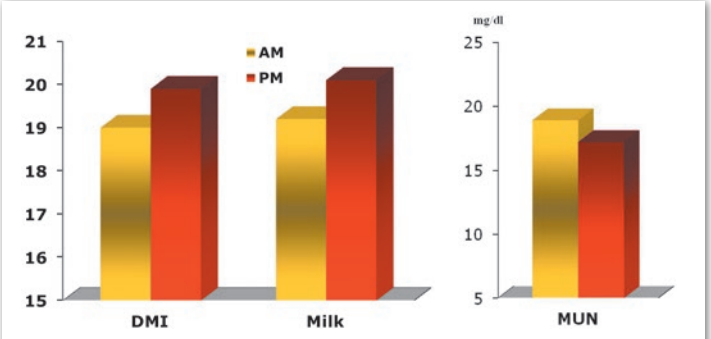


**Figure 4. Effect of cutting time on DMI, milk production and milk urea nitrogen (MUN).**

**Table 2. Summary of four in vivo trials with high- and low-NSC forage.**

| | NSC (%) | | DMI[a] (kg/d) | | Milk (kg/d) | | MUN[b] (mg/dL) | |
|---|---|---|---|---|---|---|---|---|
| | *High* | *Low* | *High* | *Low* | *High* | *Low* | *High* | *Low* |
| **Brito et al. 2009** | 4.2 | 3.0 | 21.5 | 22.0 | 27.5 | 28.6 | 10.7 | 11.6 |
| **Brito et al. 2010** | 7.7 | 6.0 | 19.0 | 18.2 | 22.6 | 21.8 | 19.6 | 20.0 |
| **Miller et al. 2001** | 16.5 | 12.6 | 15.1 | 14.2 | 15.3 | 12.6 | 16.0 | 22.0 |
| **Moorby et al. 2006** | 24.3 | 16.1 | 18.8 | 16.6 | 32.7 | 30.4 | 21.0 | 24.0 |

[a]DMI = Dry matter intake; [b]MUN = milk urea N.

is often the main N source for microbial protein synthesis and it is even essential for the growth of several species of ruminal bacteria. In fact, ruminal bacteria incorporated more ammonia N when cows were fed afternoon-cut alfalfa (data not shown) further explaining the enhanced ruminal outflow of bacterial non-ammonia N. Finally, efficiency of N use was greater when cows were fed afternoon-cut alfalfa baleage. Other studies conducted with early and mid lactation cows fed alfalfa (Brito et al. 2009), timothy (Brito et al. 2010) or perennial ryegrass (Miller et al. 2001; Moorby et al. 2006) confirm these results (Table 2).

**Our results demonstrate that:**

1) 
- The diurnal increase of non-structural carbohydrates in alfalfa and timothy varied with harvest season and location, varying from 1.6–4.2% DM, but always peaking at 11–13 h after sunrise. Non-structural carbohydrates increased with afternoon-cutting for all species tested. These increases were accompanied by decreases in N, fibre (ADF and NDF) and by increases in *in vitro* DM digestibility.
- Red clover and tall fescue forages had the greatest (9.4% DM) whereas reed canarygrass forage had the lowest concentrations of non-structural carbohydrates (6.5% DM).
- The concentration of non-structural carbohydrates in alfalfa can be improved from 11.5–12.5% DM (9%) after one cycle of genetic selection.
- Concentration of non-structural carbohydrates remained 14% greater in afternoon than morning-cut alfalfa throughout the wilting period, especially when forage was wilted in wide swaths and conditions favoured fast wilting.

2) 
- Increasing forage non-structural carbohydrates decreases rumen ammonia and increases acetate: propionate ratio, leading to a more glucogenic fermentation (*in vitro* studies).
- Forages with more non-structural carbohydrates are more digestible and promote synthesis of microbial proteins (*in vitro* studies).
- Dairy cows ingest more DM when fed forages with more non-structural carbohydrates leading to both a more efficient use of dietary N and to 5–10% more milk production.
- With increasing costs of fuel and concentrates, even small changes in plant composition will have significant impacts on sustainability of milk production.

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**References available online at www.farmwest.com**

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