Improving forage nonstructural carbohydrates through management and breeding

Gilles Bélanger [A], Gaëtan F Tremblay [A], Annick Bertrand [A], Yves Castonguay [A], Robert Berthiaume [B], Réal Michaud [A], Sophie Pelletier [A], Chantale Morin [AC], Carole Lafrenière [D] and Guy Allard [C]

[A] Agriculture and Agri-Food Canada, Québec, QC, Canada
[B] Valacta, Sainte-Anne-de-Bellevue, QC, Canada
[C] Université Laval, Québec, QC, Canada
[D] Agriculture and Agri-Food Canada, Kapuskasing, ON, Canada.
Contact email: gilles.belanger@agr.gc.ca

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Introduction

Nonstructural carbohydrates (NSC) are an important source of readily fermentable energy available to rumen microbes. Limited concentrations of readily available energy in forages combined with fast and intensive protein degradation contribute to poor N use efficiency by dairy cows and other ruminants. Increasing NSC in forages has been shown to improve intake, milk yield, and N use efficiency (Brito *et al.* 2009). We assessed several strategies to increase forage NSC accumulation, including PM-cutting, species selection and genetic improvement.

Methods

In this paper, we present an overview of our research findings on increasing NSC concentration in forages. Field experiments were conducted in eastern Canada [growing degree days (5 °C basis), 1350 to 1700; annual precipitation, 900 mm] to determine the effects of PM *vs.*AM cutting (Morin *et al.* 2011, 2012a), wilting of PM- *vs.* AM-cut forages (Morin *et al.* 2012b), forage species widely used in eastern Canada (Pelletier *et al.* 2010), and genetic selection on forage NSC concentration and other nutritive value attributes. In all experiments, collected forage samples were rapidly heated in a microwave oven for 1 min to stop enzymatic activity, dried at 55°C, ground at 1 mm, and scanned using near infrared reflectance spectroscopy (NIRS). Calibration and validation sets of samples were analyzed for soluble carbohydrates (sucrose, glucose, fructose, fructans, and pinitol) by high-performance liquid chromatography and for starch by colorimetry. The NSC concentration was determined by the sum of soluble carbohydrate and starch concentrations and then predicted by NIRS.

Results and Discussion

PM vs. AM cutting

Plant NSC concentration increases during the day when carbohydrate synthesis through photosynthesis exceeds utilization. This diurnal increase in NSC concentration has been shown to be as large as 60 g/kg DM and comes mostly from an increase in starch concentration in alfalfa (*Medicago sativa* L.; Morin *et al.* 2011) and sucrose concentration in timothy (*Phleum pratense* L.; Morin *et al.* 2012a). Greatest NSC concentrations in timothy and alfalfa were reached between 11 and 13 h after sunrise in both spring and summer regrowth. This diurnal increase has been observed in most forage species although the extent of the increase varied with species (Pelletier *et al.* 2010). When the increase in NSC concentration with PM-cutting was greater than 20 g/kg DM, it was usually accompanied by a decrease in N, acid detergent fiber (ADF), and neutral detergent fiber (NDF) concentrations and by an increase in *in vitro* digestibility of DM.

Plant cells stay alive after cutting and continue to use NSC for respiration until they die. During the first day of wilting, alfalfa NSC concentration decreased at a rate ranging from 0.2 to 3.5 g/kg DM/h depending on growth cycles (Morin *et al.* 2012b) and this rate of decrease in NSC concentration was not affected by the time of cutting (PM vs. AM). Consequently, PM-cut alfalfa still had a greater NSC concentration at the end of the wilting period (Fig. 1). We have shown that alfalfa NSC losses during the night following the late PM-cutting are low and that they are more than compensated by early morning photosynthesis the next day (Morin *et al.* 2012b). Photosynthesis of cut alfalfa continued for up to 3 h in the morning until it dried to around 350 g DM/kg FM. Wilting alfalfa in wide swaths reduced wilting time by up to 9 h, resulting in greater NSC concentration. When wilting conditions provide fast drying and two consecutive sunny days are forecasted, producers could combine cutting in late PM and in wide swaths to produce, in less than 24 h, wilted alfalfa forage with a greater NSC concentration.

Species

Little information exists on species differences for NSC concentration. Species differed in NSC concentration with tall fescue [*Schedonorus phoenix* (Scop.) Holub] having the greatest concentration among six grass species (65 – 94 g/kg DM) and red clover having a greater concentration than alfalfa (94 vs. 71 g/kg DM) (Pelletier *et al.* 2010). Legume or grass species with a high NSC concentration also tended to have lower concentrations of ADF and NDF, resulting in a greater *in vitro* digestibility of DM.

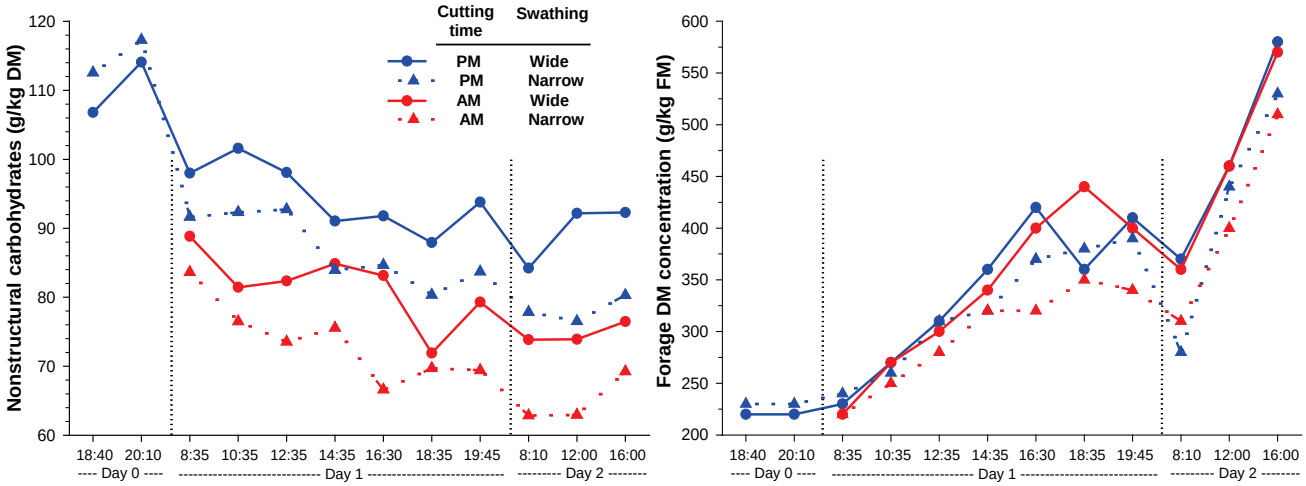

Figure 1. Changes in forage nonstructural carbohydrate and DM concentrations during field wilting of an alfalfa summer regrowth cut at the end of a sunny day (PM) or the following morning (AM) with narrow or wide swaths. Adapted from Morin *et al.* (2012b).

Alfalfa populations with improved NSC concentration

Forage NSC concentration can be improved by genetic selection but the potential for improvement for most forage species is not known. We investigated the possibility of increasing the NSC concentration of alfalfa via genetic selection. Two populations were obtained by inter-crossing 10 genotypes selected for high (NSC+) or low (NSC-) NSC concentrations from 500 genotypes of a well-adapted cultivar (AC Caribou) to eastern Canada; the populations were compared in a field experiment. Improving alfalfa NSC concentration by 5-10% was shown to be possible using genetic selection.

Conclusion

Species selection, genetic selection, late PM cutting, and wide swathing are strategies that increase forage nonstructural carbohydrate concentration by 10 to 40 g/kg DM with a potential positive impact on ruminant performance.

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