FORAGE MACERATION ON A SELF-PROPELLED MOWER: EFFECT OF WINDROW DEPOSITION AND INVERSION

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ABSTRACT
Forage maceration is an intensive conditioning technique applied at mowing with high speed rolls. Maceration has been observed to enhance the field wilting rate, produce a more efficient silage fermentation and accelerate ruminal degradation. An important technical hurdle has been to scale up maceration for wide mowers without reducing capacity. The paper descibes a three-roll maceration unit that was integrated in a self-propelled 4.2 m wide mower. A capacity of 2.75 ha/h and throughputs up to 14 t DM (dry matter)/h or 64 t WM (wet matter)/h were achieved in alfalfa and timothy. Compared to a commercial mower-conditioner, the macerator increased field drying rates by 25 to 35%. A deposition conveyor was judged unnecessary as it did not reduce losses and did not improve the drying rate. Maceration followed by inversion could save one field drying day out of three traditionally needed for haymaking.

KEYWORDS
Drying, wilting, conditioning, mowing, maceration, windrow, handling, forage

INTRODUCTION
The concept of forage maceration and mat making was proposed in the mid 1970's and further developed in the 1980's, notably in Wisconsin (Koegel et al., 1992). These researchers and others (Savoie et al., 1993; May, 1994) applied maceration on field working prototypes. There have been attempts to develop commercial machines (Deutz-Fahr, 1993) but the complexity of maceration and mat forming devices have hindered its application on high capacity machines.

Maceration has several advantages compared to conventional mowing-conditioning: more rapid field wilting, more efficient lactic fermentation for silage and improved ruminal degradability of forage (Koegel et al., 1992; Petit et al., 1994). The objective of the reported research was to design and assess a simplified maceration unit on a large capacity mower.

METHODS
The basic self-propelled (SP) mower was composed of a commercial 70-kW tractor and a 4.2 m wide cutterbar header (MacDon Industries, Winnipeg, Manitoba; tractor model 9000 and header model 920). A three-roll macerator was designed, fabricated and added to the SP mower (Figure 1). Progressively increasing roll speeds, rough grooved surfaces and a tight clearance (1 mm) between rolls ensured a pulling and shredding effect on the crop. A deflector with fins was adjusted to modify windrow width between 1.2 m and 2.1 m. A deposition belt could be installed or removed quickly to compare delicately deposited windrows and non-deposited, ejected windrows. The control mower-conditioner was a 3.0 m wide disk mower with intermeshing finger conditioning (Kuhn, Saverne, France; model FC 300).

Three mowing-conditioning-conveying treatments (macerator with conveyor, macerator without conveyor, control) were applied in either alfalfa or timothy. Windrows were either wide or narrow, with a planned ratio of windrow width over mowing width of 0.5 or 0.4, respectively. Half the windrows were turned over manually with a pitchfork 8 h after mowing to simulate mechanical inversion. All windrows were baled after 30 to 34 h of field wilting. Treatments were duplicated on each of four mowing dates or blocks (June 20, 26, 28 and July 12, 1995). During each block, there were therefore 48 experimental units (EU), each corresponding to a 70 m long strip of forage mowed and conditioned (3 treatments), wide or narrow, inverted or not, in alfalfa or timothy and duplicated (3 x 2 x 2 x 2 x 2). Forage from each EU was placed in a meshed tray 1.8 m by 0.9 m and weighed regularly to estimate water evaporation and moisture content. A drying coefficient k (units of h^{-1}) was calculated from the exponential decay equation $k = (1/t) \ln (M_o/M)$, where t is the drying time interval (h), M_o is the initial moisture content on a dry basis (g water/g dry matter) and M is the final moisture content (g/g).

RESULTS AND DISCUSSION
Weather conditions were generally favorable during the four wilting periods (June 20-21, 26-27, 28-29 and July 12-13) with an average pan water evaporation of 5.9 mm/d. Crop purity averaged 81% in alfalfa and 80% in timothy. Initial moisture content was similar in timothy and grass and decreased with maturity (83.3%, 79.2%, 78.9% and 72.4%, on a wet basis, for blocks 1, 2, 3 and 4, respectively). Yields were similar for both crops and increased with maturity (3.7, 4.7, 4.9 and 5.2 t DM/ha, respectively). Operating speeds averaged 6.9 km/h for the macerator and 7.9 km/h for the control.

Effective mowing width averaged 4.04 m with the mower-macerator and 2.79 m with the control mower-conditioner. The field capacity of the mower-macerator averaged 2.75 ha/h, with throughputs as high as 14 t DM/h or 64 t WM/h. Wide and narrow windrows with the mower-macerator averaged 1.95 m and 1.68 m, respectively. They were 1.43 m and 1.10 m, respectively, with the control mower-conditioner.

Drying coefficients of macerated forage were not significantly different with or without the deposition conveyor, and in wide or narrow windrows. However narrow control windrows dried 25% more slowly than wide control windrows or macerated windrows on the first day of wilting (0.080 h^{-1} vs 0.107 h^{-1}). Over a two-day (33 h) drying period, windrow inversion significantly increased drying rate of wide macerated windrows (0.087 h^{-1} vs 0.075 h^{-1}) but had no effect on control windrows (0.063 h^{-1} vs 0.065 h^{-1}). A combination of maceration, wide windrows and inversion dried 35% faster than control, wide and inverted windrows. Maceration could produce dry hay (final moisture < 20%, wet basis) within 30-34 h after mowing, i.e. by late afternoon of the second day. The control wide windrows would require 50-54 h, i.e. mid-afternoon of the third day. Dry matter loss in macerated alfalfa averaged 4.5% without inversion and 7.1% with inversion. The control non-macerated alfalfa had 7.9% loss either with or without inversion.

In conclusion, macerating rolls were successfully implemented on a self-propelled high capacity mower. They effectively increased the drying rate by 20 to 30% compared to a control mower-conditioner, without causing more loss. Macerated windrows benefited from inversion. Maceration can potentially save half a day of field wilting for silage making and a full day for hay making under good weather conditions.

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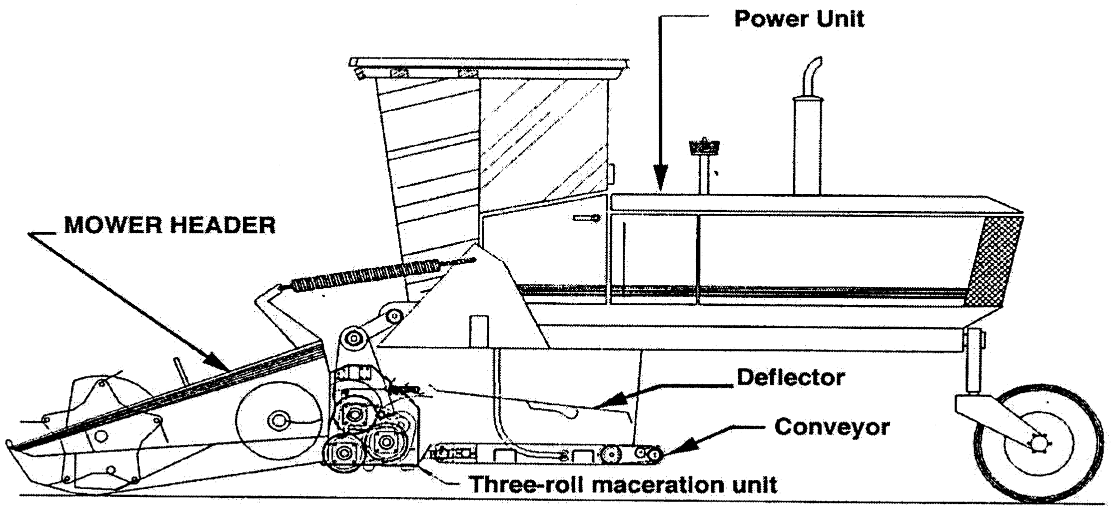

Figure 1
Schematic view of the self-propelled mower with a 3-roll maceration unit and a deposition conveyor.

Table 1
Drying coefficients estimated over two time periods in first day of drying and over two days in 1995 at the Normandin Experimental Farm, QC.

Treatment	Windrow	Drying coefficient (h^{-1})				
		k_1 (d1)0800-(d1)1300h–	k_2 (d1)0800-(d1)2000h	k_3 (d1)0800-(d2)1700h		
				Inverted	Non-inverted	Mean
Macerated with conveyor	Narrow	0.139a*	0.104a	0.067	0.067	0.067abc
	Large	0.139a	0.111a	0.087	0.072	0.080a
Macerated without conveyor	Narrow	0.135a	0.104a	0.081	0.066	0.074ab
	Large	0.139a	0.116a	0.087	0.077	0.082a
Control	Narrow	0.099b	0.080b	0.054	0.051	0.052c
	Large	0.124ab	0.099ab	0.063	0.065	0.064bc

– This bracket means the period between 0800h on the first day (d1) and 1300h on the first day.
* Means with the same letter in the same column are not significantly different from the SAS LSMEANS function at 1%.