Forage mat making: maceration, pressure and density effects on drying

P. SAVOIE1,2, S. BEAUREGARD3 and C. LAGUE2

Agriculture Canada (Lennoxville); 2Département de génie rural, Faculté des sciences de l’Agriculture et de l’Alimentation, Université Laval, Québec, PQ, Canada G1K 7P4; and 3Ministère de l’Environnement du Québec, Direction du milieu agricole et du contrôle des pesticides, 3900 rue Marly, 5e étage, Ste-Foy, PQ, Canada G1X 4E4. 1Contribution 350. Received 21 December 1990; accepted 12 November 1991.

Savoie, P., Beuaregard, S. and Lague, C. 1992. Forage mat making: maceration, pressure and density effects on drying. Can. Agric. Eng. 34:069-074. Fresh alfalfa was superconditioned by shearing through a series of macerating rolls and by compression into a thin mat of thickness ranging between 5 and 14 mm. The total time for the forage mat to reach 20% moisture in laboratory conditions is dependent on the drying rate. Forage mat pressure is a series of macerating rolls, pressure) or by changing the width of the mat. Results may help design a more efficient field machine.

The alfalfa crop was obtained from large experimental plots at the Deschambault Research Station (Quebec) during the second and third cuttings in 1988. It was superconditioned with two small stationary units: a macerator and a press described below. The treated forage was left to dry in a laboratory wind tunnel simulating field conditions to measure treatment effects on the drying rate.

Experimental design
A first experiment was conducted between July 25 and August 12, during the second growth cycle, to study the effect of mat density, mat pressure, and maceration severity. The alfalfa had a higher in vitro fiber digestibility than normally conditioned alfalfa. Hong et al. (1988) also measured improved digestibility and increased milk production from dairy goats fed superconditioned alfalfa hay.

There are several design criteria that still need to be optimized to build an efficient mower-superconditioner. Koegel et al. (1988) built a successful small scale field prototype. They recommended, however, a reduction in the weight of the machine. Straub et al. (1989) proposed a conveyor type pick up to facilitate harvest of the thin mat.

The objective of the present paper was to investigate the effects of maceration severity, mat compression pressure and mat density on forage drying rate increases. These factors can be modified by changing some machine parameters (number of macerating rolls, pressure) or by changing the width of the mats. Results may help design a more efficient field machine.

INTRODUCTION
Forage superconditioning is achieved at the time of mowing by processing the fresh material through a series of macerating rolls or grinding rolls operated at differential speeds. The mashed forage is then compressed into a thin mat by a continuous belt press. The concept was originally proposed by Krutz et al. (1979) as a means of increasing the drying rate compared to conventional conditioning. Laboratory and field studies reported by various research groups in the United States, Canada and Germany have shown a marked reduction in the drying time required to harvest hay or wilted forage with the mat making technique (Shinners et al. 1987; Schurig and Rödel 1989; Savoie and Beuaregard 1991). Under controlled and constant drying conditions, superconditioned forage dried from 80% to 20% moisture in less than 6 h compared to 24 h with normal conditioning. Such a mechanical treatment has the potential of reducing field hay drying time in Eastern Canada from the current three days to less than a day under good climatic conditions. In addition to reducing field respiration losses and the risk of rained-on hay, superconditioning appears to improve the forage feed value. Sirohi et al. (1988) showed that macerated alfalfa had a higher in vitro fiber digestibility than normally conditioned alfalfa. Hong et al. (1988) also measured improved digestibility and increased milk production from dairy goats fed superconditioned alfalfa hay.
series wind tunnel, mat density was set at four levels (0.35, 0.50, 0.61 and 0.76 kg DM/m²) and mat compression pressure at two levels (140 and 280 kPa). Forage was macerated only once in this experiment. In the parallel tunnel, mat density was set at four levels (0.35, 0.47, 0.60 and 0.72 kg DM/m²) and maceration severity at two levels (one or two passes through the macerator). In this latter experiment, mat compression pressure was set at 210 kPa. Both experiments in the third cutting were conducted simultaneously with forage cut during three consecutive weeks (September 19, 26 and October 3) and tests were repeated twice each week.

Macerator and press

The equipment used to treat the forage has been described in detail in Savoie and Beauregard (1991).

The macerator consisted of seven steel rolls and is illustrated in Fig. 1. Each roll was knurled lengthwise with grooves spaced 2 mm at a depth of 1.5 mm. Six rolls had a 150 mm diameter; the seventh roll, the feeding roll, was 200 mm in diameter. All rolls were 720 mm long. Spacing between the rolls was 0.5 mm. A 3.7 kW motor ran the double V-belts used to transmit power to the macerating rolls.

![Macerator](image1)

Fig. 1. Schematic view of the macerator.

The upper rolls and the lower-rear roll turned at 1250 rpm while the two other lower rolls turned at 1875 rpm and the feeding roll at 1000 rpm. Forage was macerated by the shearing force caused by the tangential speed difference between rolls (9.8 m/s on top and 14.7 m/s on bottom rolls). Forage was hand deposited on a belt conveyor which fed into the macerator.

The press was a double belt press very similar to the one described by Koegel et al. (1988); it is illustrated in Fig. 2. A fine polyester screen-type belt turned around a 600 mm diameter drum while a 6 mm thick rubber belt turned along a roller chain. As macerated forage entered between the two belts, the forage was compressed into a thin mat which dropped out at the bottom. A 5.6 kW motor ran the press at low speed and high torque. The pressure between the drum and the belts could be adjusted pneumatically by an air chamber between 0 and 350 kPa. Forage juice was extracted in the press; it flowed through the perforated polyester belt and through the drum slots back onto the mat. The linear belt and drum speeds for all tests were set at about 0.38 m/s (1.4 km/h) such that the forage had a dwell time of 1.7 s through the 120° arc of contact.

![Press](image2)

Fig. 2. Schematic view of the belt press (Koegel et al. 1988).

Wind tunnels

Two wind tunnels were used to simulate field drying conditions. The parallel wind tunnel was used during the first and third experiments. It was designed to contain eight wire-mesh (25 mm x 25 mm mesh) trays (350 mm wide by 450 mm long) placed in two lines of four trays. Air was blown across the two lines in four parallel airflow patterns. Air speed was controlled at 0.7 m/s and radiation from infrared lamps averaged 250 W/m². Average air temperature was 31°C and relative humidity 41%. Calibration tests with eight small evaporation pans indicated that these environmental conditions produced an average water evaporation rate of 0.44 mm/h (three replicates per tray position).

The other wind tunnel, called the series tunnel, was used during the second experiment. It was built and described by Thibault et al. (1991). Eight wire-mesh trays (25 mm x 25 mm mesh), 300 mm wide by 550 mm long, were placed one next to the other widthwise along the tunnel. The series wind tunnel was set at a radiation intensity of 350 W/m², air speed of 1.2 m/s, air temperature of 26.0°C and air relative humidity of 50%. Equivalent average pan water evaporation rate was 0.50 mm/h.

Experimental procedure

Forage was mowed in the morning of day 1 of each week with a disk mower and rubber conditioner rolls (Vicon, KM281). Forage was stored in sealed polyethylene bags and kept at 2°C until the experiment started. The moisture content of forage was determined by oven drying at 60°C for 72 h (ASAE 1991). On the first day, a quick estimate was obtained within 30 minutes with an evaporative forage moisture tester (Koster Crop Tester, Strongsville, OH). At the beginning and at the end (22 h later) of each drying experiment, one sample was taken from each drying tray to determine moisture content by the ASAE (1991) standard method. Dry matter in each tray was estimated as the average of initial and final dry matter masses, based on initial and final moisture contents, and wet matter masses.

The first replication started on day 2 and the second replication started on day 3 of each week. Fresh forage was taken out of the polyethylene bags and processed through the macerator.
A known quantity of macerated forage was deposited on the upper belt of the press and pressed. The quantity corresponded to the equivalent mat density required for the specific test (mass of dry matter per unit area). The compressed forage mat was covered with polyethylene until the eight treatment combinations were prepared and placed simultaneously in the drying chamber of the wind tunnel.

In the series wind tunnel, mass of the forage was measured automatically every 15 minutes. In the parallel wind tunnel, mass of the forage was measured manually every hour during the first eight hours, once after eleven hours and finally after 22 h of drying. In the parallel wind tunnel, trays were rotated after each hourly weighing so that each tray spent equal time in each of the eight tray positions.

Drying model

The main variable that was used to compare treatments was the drying coefficient. It is obtained from the falling rate drying model (Pattey et al. 1988).

\[
\frac{M - Me}{Mo - Me} = \exp(-kt)
\]

where:

- \(M\) = moisture content, dry basis (d.b.),
- \(Me\) = equilibrium moisture content (d.b.),
- \(Mo\) = initial moisture content (d.b.),
- \(k\) = drying coefficient (h\(^{-1}\)), and
- \(t\) = drying time (h).

For each forage sample, an average drying coefficient was obtained based on all observations in the interval where moisture content was above 0.25 kg/kg, d.b. (generally less than 22 h). The equilibrium moisture content was set constant for the eight trays in each wind tunnel. It varied between 0.04 and 0.08 kg/kg, moisture contents at which the mass of the fastest drying forage trays remained constant.

Another measure of drying was also used: the time for a sample to reach 20% moisture content on a wet basis (w.b.) (0.25 kg/kg, d.b.). This time, called T20, was compared between treatments.

### RESULTS AND DISCUSSION

The crop used in the experiments contained 84% and 85% alfalfa during second and third cuttings respectively. Other forage material was predominantly grass. During second cutting, alfalfa was at full bloom stage for the three mowing dates. During third cutting, alfalfa remained at the bud stage for the three mowing dates. The average initial moisture contents of the forage mats were 4.11, 3.64 and 4.45 kg/kg, d.b. (80.4, 78.5 and 81.7%, w.b.) for second cutting (July 25, August 1 and 8). They were 4.49, 3.40 and 4.40 kg/kg, d.b. (81.8, 77.3 and 81.5%, w.b.) during third cutting (September 19 and 26, October 3).

In general, compression of the macerated forage into a mat slightly reduced moisture content by absolute amounts varying between 0.2 and 1.4 kg water/kg DM, or between 1.5 and 5 units of % on a wet basis. More water was extracted when the forage had higher initial moisture levels. Another study provides greater details on the amounts of juice extracted during the process (Savoie and Beauregard 1990).

Mat thickness was measured during the third cutting (96 mats). It averaged 9.0 mm, ranging between 5.0 and 14.0 mm. The specific mass of mats increased with compression pressure; it was 50 kg DM/m\(^3\) at 140 kPa and 69 kg DM/m\(^3\) at 280 kPa. More severe maceration also resulted in mats of higher specific mass (70 kg DM/m\(^3\) for double maceration versus 55 kg DM/m\(^3\) for single maceration).

Drying results for the first experiment are summarized in Table I. Mat density and compression pressure were statistically significant factors on mat drying (p < 0.01). The thinner mats (0.35 kg DM/m\(^2\)) had a drying coefficient (\(k = 0.453\) h\(^{-1}\)) 56% greater on average than the drying coefficient (\(k = 0.290\) h\(^{-1}\)) of the thicker mats (0.52 kg DM/m\(^2\)). Higher pressure also increased the average drying coefficient by 19%. These results are illustrated in Fig. 3. There were no significant interactions at the 0.05 level.

Maceration severity did not have a significant effect on the drying coefficient (p = 0.75). Since greater severity of maceration increases power requirements (Shinners et al. 1988), a single series of seven macerating rolls is sufficient. Future research should consider the possibility of further simplifica-

<table>
<thead>
<tr>
<th>Mat density (kg DM/m(^2))</th>
<th>Compression pressure (kPa)</th>
<th>Number of macerations</th>
<th>k Mean (h(^{-1}))</th>
<th>S.d. (h(^{-1}))</th>
<th>Initial moisture (kg water/kg DM)</th>
<th>T20 Mean (h)</th>
<th>S.d. (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.35</td>
<td>138</td>
<td>1</td>
<td>0.418</td>
<td>0.073</td>
<td>4.56</td>
<td>7.55</td>
<td>1.42</td>
</tr>
<tr>
<td>0.35</td>
<td>138</td>
<td>2</td>
<td>0.400</td>
<td>0.025</td>
<td>4.15</td>
<td>7.46</td>
<td>0.40</td>
</tr>
<tr>
<td>0.35</td>
<td>276</td>
<td>1</td>
<td>0.507</td>
<td>0.071</td>
<td>4.29</td>
<td>6.04</td>
<td>0.87</td>
</tr>
<tr>
<td>0.35</td>
<td>276</td>
<td>2</td>
<td>0.487</td>
<td>0.059</td>
<td>3.83</td>
<td>6.02</td>
<td>0.70</td>
</tr>
<tr>
<td>0.52</td>
<td>138</td>
<td>1</td>
<td>0.262</td>
<td>0.048</td>
<td>4.56</td>
<td>12.05</td>
<td>1.97</td>
</tr>
<tr>
<td>0.52</td>
<td>138</td>
<td>2</td>
<td>0.277</td>
<td>0.040</td>
<td>4.15</td>
<td>10.92</td>
<td>1.53</td>
</tr>
<tr>
<td>0.52</td>
<td>276</td>
<td>1</td>
<td>0.309</td>
<td>0.051</td>
<td>4.29</td>
<td>9.98</td>
<td>1.72</td>
</tr>
<tr>
<td>0.52</td>
<td>276</td>
<td>2</td>
<td>0.304</td>
<td>0.046</td>
<td>3.83</td>
<td>9.43</td>
<td>1.51</td>
</tr>
</tbody>
</table>

(1) After compression of the mats (average of 12 samples per pressure and maceration severity level).

CANADIAN AGRICULTURAL ENGINEERING Vol. 34, No. 1, JANUARY/FEBRUARY/MARCH 1992 71
The time needed to dry hay to 20% moisture varied between 6 and 12 h. The parallel wind tunnel, in which results from Table I were obtained, had a pan evaporation rate of 0.44 mm/h. During a typical sunny summer day in Eastern Canada, total pan evaporation will be in excess of 5 mm/day, equivalent to 11.4 h in the tunnel. Clearly the low density mats would easily dry within a day. The higher density mats (0.52 kg DM/m²) might require a second day of drying to reach safe baling moisture content.

Drying results during the third cutting are presented in Table II. Mat density and compression pressure both had significant impact on mat drying in the series wind tunnel experiment (p< 0.01). The higher pressure resulted in an 8% increase of the drying coefficient, on average. As mat density increased, the drying coefficient decreased linearly (Fig. 4). A statistical contrast of linear, quadratic and cubic components was done on the drying coefficients as a function of density. With data from the series tunnel, the linear term explained 67.0% of the variation of the sum of squares (p < 0.001), the

![Graph showing the effect of compression pressure and density on the drying coefficient of forage mats.](image)

**Fig. 3.** Effect of compression pressure and density on the drying coefficient of forage mats.

### Table II. Drying coefficients (k) and time to reach 20% moisture content, wet basis (T20) during the third cutting (average of six trials)

<table>
<thead>
<tr>
<th>Mat density (kg DM/m²)</th>
<th>Compression pressure (kPa)</th>
<th>Number of macerations</th>
<th>k</th>
<th>T20&lt;sup&gt;(1)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean (h⁻¹)</td>
<td>S.d. (h⁻¹)</td>
</tr>
<tr>
<td><strong>Series tunnel</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.35</td>
<td>138</td>
<td>1</td>
<td>0.490</td>
<td>0.059</td>
</tr>
<tr>
<td>0.35</td>
<td>276</td>
<td>1</td>
<td>0.528</td>
<td>0.034</td>
</tr>
<tr>
<td>0.50</td>
<td>138</td>
<td>1</td>
<td>0.396</td>
<td>0.034</td>
</tr>
<tr>
<td>0.50</td>
<td>276</td>
<td>1</td>
<td>0.424</td>
<td>0.029</td>
</tr>
<tr>
<td>0.61</td>
<td>138</td>
<td>1</td>
<td>0.312</td>
<td>0.029</td>
</tr>
<tr>
<td>0.61</td>
<td>276</td>
<td>1</td>
<td>0.324</td>
<td>0.028</td>
</tr>
<tr>
<td>0.76</td>
<td>138</td>
<td>1</td>
<td>0.231</td>
<td>0.015</td>
</tr>
<tr>
<td>0.76</td>
<td>276</td>
<td>1</td>
<td>0.273</td>
<td>0.026</td>
</tr>
<tr>
<td><strong>Parallel tunnel</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.35</td>
<td>207</td>
<td>1</td>
<td>0.416</td>
<td>0.048</td>
</tr>
<tr>
<td>0.35</td>
<td>207</td>
<td>2</td>
<td>0.435</td>
<td>0.045</td>
</tr>
<tr>
<td>0.47</td>
<td>207</td>
<td>1</td>
<td>0.324</td>
<td>0.064</td>
</tr>
<tr>
<td>0.47</td>
<td>207</td>
<td>2</td>
<td>0.333</td>
<td>0.030</td>
</tr>
<tr>
<td>0.60</td>
<td>207</td>
<td>1</td>
<td>0.231</td>
<td>0.019</td>
</tr>
<tr>
<td>0.60</td>
<td>207</td>
<td>2</td>
<td>0.246</td>
<td>0.017</td>
</tr>
<tr>
<td>0.72</td>
<td>207</td>
<td>1</td>
<td>0.186</td>
<td>0.032</td>
</tr>
<tr>
<td>0.72</td>
<td>207</td>
<td>2</td>
<td>0.202</td>
<td>0.020</td>
</tr>
</tbody>
</table>

<sup>(1)</sup> Calculated with a constant initial moisture content after compression (4.13 kg/kg dry basis; 80.5%, wet basis).
quadratic term explained 0.7% of SS (p = 0.099), the cubic term explained 32.1% of SS (p < 0.001). With data from the parallel tunnel, the linear, quadratic and cubic terms explained 56.4%, 2.1% and 41.5% of SS, respectively. The three terms were significant (p < 0.05), the linear term being most significant. Mats with a density of 0.50 kg DM/m² and less dried to 20% moisture (T20) in less than 8 h in the series tunnel (evaporation rate of 0.50 mm/h). These results concur with those of the first experiment (Table I).

![Graph showing the effect of mat density on forage mat drying coefficient for different wind tunnels](image)

Fig. 4. Effect of mat density on forage mat drying coefficient for different wind tunnels (S = series; P = parallel), number of macerations (1 or 2) and mat compression pressures (138 or 276 kPa).

In the parallel wind tunnel experiment, mat density and number of macerations were both significant factors on mat drying (p < 0.01 and p = 0.05 respectively). Mat density had a linear negative effect on the drying coefficient (Fig. 4). A second maceration increased the drying coefficient by 5% on average over a single maceration. Although the increase is statistically significant, it is probably not large enough to justify the complexity of 14 macerating rolls on a field machine compared with 7 rolls.

Regression equations were developed to estimate the drying coefficients as a function of mat density, compression pressure and maceration severity. An equation was developed from the data observed in each wind tunnel (n = 48 in the series tunnel; n = 96 in the parallel tunnel). The following empirical equation resulted from the series wind tunnel:

\[
k = 0.4987 - 0.0646 \text{DENS} + 0.0437 \ln(\text{PRES}) + 0.0854 \text{MACER}
\]

\[(R^2 = 0.79, p<0.01, \text{standard error} = 0.066 \text{ h}^{-1})\]

where:
- \text{DENS} = \text{forage mat density (kg DM/m²)}
- \text{PRES} = \text{compression pressure (kPa)}
- \text{MACER} = \text{number of macerations, 1 or 2.}

The data from the parallel wind tunnel yielded the following prediction equation:

\[
k = 0.7342 - 0.0593 \text{DENS} + 0.0018 \text{PRES} - 0.0425 \text{MCM} + 0.0168 \text{MATUR}
\]

\[(R^2 = 0.79, p<0.01, \text{standard error} = 0.050 \text{ h}^{-1})\]

where:
- \text{MCM} = \text{initial forage moisture content (kg/kg, d.b.)}
- \text{MATUR} = \text{alfalfa maturity, 0 = bud stage; 1 = full bloom stage.}

On the basis of a daily pan evaporation of 5 mm, the equivalent drying time was 10.0 h in the series tunnel and 11.4 h in the parallel tunnel. These times and Eqs. 2 and 3 were used to estimate the maximum mat density that would dry to 20% moisture in a day. Table III shows results for various combinations of variables.

### Table III. Maximum mat density (kg DM/m²) to harvest 20% moisture content hay (wet basis) in a day, assuming a daily pan evaporation of 5 mm

<table>
<thead>
<tr>
<th>Alfalfa maturity</th>
<th>Compression pressure (kPa)</th>
<th>Number of macerations</th>
<th>Initial moisture content (%)</th>
<th>77</th>
<th>80</th>
<th>83</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Series tunnel</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bud stage</td>
<td>138</td>
<td>1</td>
<td>0.67</td>
<td>0.65</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td></td>
<td>276</td>
<td>1</td>
<td>0.72</td>
<td>0.70</td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td>Full bloom</td>
<td>138</td>
<td>2</td>
<td>0.80</td>
<td>0.78</td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>276</td>
<td>2</td>
<td>0.85</td>
<td>0.83</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td><strong>Parallel tunnel</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bud stage</td>
<td>138</td>
<td>1</td>
<td>0.63</td>
<td>0.69</td>
<td>0.57</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>276</td>
<td>1</td>
<td>0.69</td>
<td>0.63</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>Full bloom</td>
<td>138</td>
<td>1</td>
<td>0.66</td>
<td>0.60</td>
<td>0.50</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>276</td>
<td>1</td>
<td>0.72</td>
<td>0.66</td>
<td>0.56</td>
<td></td>
</tr>
</tbody>
</table>

A mat of density below 0.5 kg DM/m² will easily dry within a day. Mats of higher densities might also dry in a day but will require higher compression pressure or more severe maceration. However, these two controllable factors allow increasing mat density by only 5 to 15%. From a machine design point of view, it is important to spread the mowed forage as wide as possible to make a thin mat. For example, if forage yield is 4 t DM/ha (0.4 kg DM/m²), the ratio of mat width to mowed width should ideally not be smaller than 0.8. This would result in a mat density of 0.5 kg DM/m². If the mat width is reduced further, the actual density will be too high to allow drying hay within a day.

Table III also shows that more mature alfalfa is easier to dry in a mat. Full bloom (mature) alfalfa tends to be initially drier than bud stage (immature) alfalfa. In addition, a greater density mat of mature alfalfa will dry as fast as a lower density mat of immature alfalfa. To get dry hay in a day, the mat density of immature alfalfa should be below 0.45 - 0.50 kg DM/m² while the mat density of mature alfalfa may be as high as 0.70 kg DM/m².

In practice, maceration severity and compression pressure...
should be kept to a minimum to simplify machine components, reduce power requirements and allow good throughput. Mats should be made as wide as possible while avoiding machinery running over the mats. Field management of superconditioning will be important to match crop yield with mat widths. This will insure that most mats will dry in a day and not risk weather damage in subsequent days.

CONCLUSIONS

1. Maceration and compression of fresh alfalfa forage into a thin mat allowed the production of dry hay at 20% moisture content within 6 to 12 h under controlled weather conditions similar to a good drying day (5 mm daily water evaporation).

2. Maceration through 7 shearing rolls resulted in drying rates within 5% of rates for maceration through 14 rolls. Compression pressure of 280 kPa increased drying rate by only 19% compared to a low pressure of 140 kPa. Minimal maceration severity and compression pressure are adequate.

3. Forage density was the single most important factor affecting drying efficiency of the mats. In young alfalfa at the bud stage, the mat density should not be greater than 0.45 kg DM/m² for hay to dry within a day. Mature alfalfa at the full bloom stage dried more easily; a mat with density of 0.70 kg DM/m² could dry within a day.

ACKNOWLEDGEMENTS

The authors thank R. G. Koegel of the USDA Dairy Forage Center and K. J. Shinners of the University of Wisconsin at Madison for providing the stationary macerator and press and for their useful advice. The authors acknowledge the technical help of A. Abbar and M. Binet for data collection. This project was supported by a research contract funded by the joint Canada-Québec agreement for agricultural development.

REFERENCES


