Intensive Forage Conditioning

Intensive Conditioning of Forages to Increase Value

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Introduction

Forage conditioning has been a long standing practice to improve feed quality primarily through decreased drying time. Recently intensive forage conditioning has been introduced as a possible alternative. Intensive or severe conditioning of forage crops greatly reduces the field-drying time required to reach moisture levels suitable for harvesting as hay or as silage. In addition, severely conditioned alfalfa has been shown to increase alfalfa digestibility by 10% or more. Because extreme conditioning creates many small plant fragments which tend to be lost when the forage is placed on the stubble to dry, it has been found advantageous to press the forage into a thin, continuous, cohesive strip called "forage mats." Extreme conditioning is sometimes called "maceration." Prototype machines which (1) mow, (2) macerate, (3) form "mats" and (4) place them on the stubble have been built by research and development groups. Intensive forage conditioning refers to a degree of mechanical conditioning more severe than that achieved by conventional mower-conditioners.

Intensive conditioning yields at least two advantages: (1) an accelerated rate of drying; up to three times as fast as conventionally conditioned forage under good drying conditions, and (2) improved forage utilization; in particular increased energy derived from the forage fiber (~10% increase).

Content

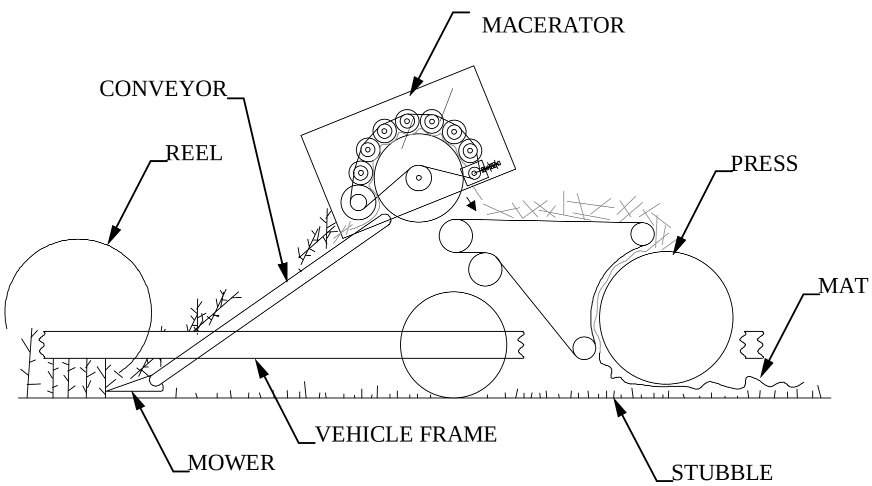

Figure 1. Schematic of the original Wisconsin prototype mat machine.

"Because stems are generally split into many slender ribbons or fibers, and the leaf and stem materials are homogenized, they tend to dry at a common rate."

Equipment and Process

Forage mats are made by a machine which substitutes for the conventional mower-conditioner. This machine carries out four functions: (1) mows, (2) macerates (severely conditions), (3) rolls the forage into thin, continuous, cohesive mats, and (4) places the mats onto the stubble for drying (Fig. 1).

In order to achieve near-optimum drying rates, the mats should be dense and not much thicker than 3/8 inch. For heavy crops, such as first cutting alfalfa, this results in the mats being spread over about 70% of the cut area. For lighter subsequent cuttings, mats would cover 50% or less of the cut area.

A comparison of field-drying of alfalfa mats with that of conventionally conditioned material under very good drying conditions indicated that the mat reached the target moisture content of 20% in less than five hours (Fig. 2, Shinners et al. 1987). In the case of silage-making , a suitable moisture content was reached in about two hours. In either case, the mat process allows alfalfa to be mowed and harvested during the same daylight period. As drying conditions become less favorable, the differences in drying rates between the mats and conventional material become less dramatic, and under extremely bad conditions there may be little difference.

Because stems are generally split into many slender ribbons or fibers, and the leaf and stem materials are homogenized, they tend to dry at a common rate. This largely eliminates the problem of leaves over-drying and shattering while waiting for stems to dry adequately. Small plant fragments are generally "pasted" within the mat structure by the drying plant juice. Therefore, with proper equipment, harvesting losses can be kept to a very modest level.

Severe conditioning or maceration has been accomplished successfully by two different mechanisms to date. The first system (Fig. 3) consists of passing the forage between multiple pairs of rollers with roughened or serrated surfaces with the opposing surfaces traveling at unequal speeds. Alternately, the higher-speed set of rolls can be replaced by a single large diameter drum (Fig. 1). The shearing action of the opposing roller surfaces results in much longitudinal shearing of the plant stems and has a general fiberizing effect. The second conditioning system (Fig. 4) which has been successfully used is called a crushing-impact macerator. It consists of three rolls of approximately equal diameters. The first two are paired and are held together by hydraulic cylinders. When the forage passes between them, stems are crushed flat creating multiple longitudinal cracks. As the forage emerges from between the crushing rolls, it is impacted by longitudinal projections on the rapidly rotating third roll. The impacting of the previously crushed stems tends to open the longitudinal cracks with a fiberizing action. Both processes

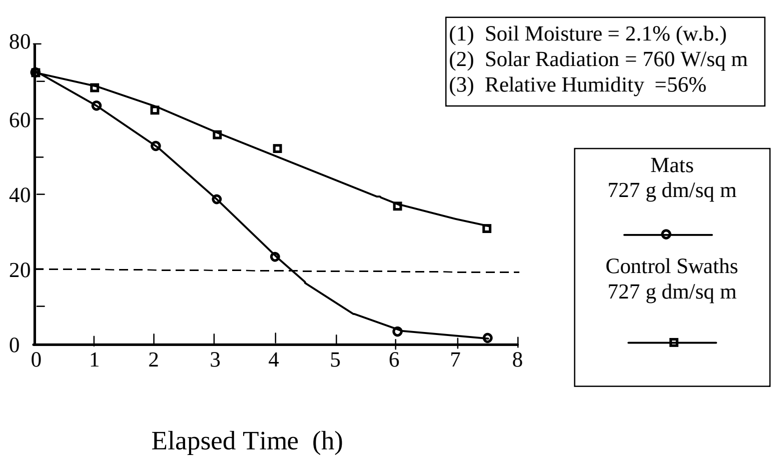

Figure 2. A comparison of drying rates for mat-processed and conventionally conditioned alfalfa.

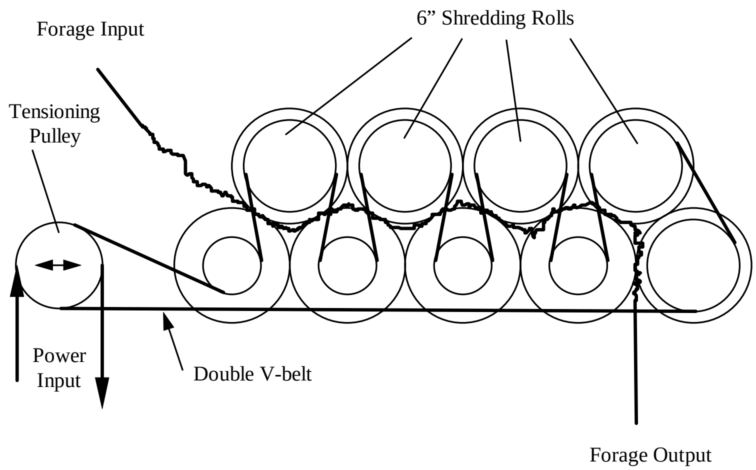

Figure 3. Schematic of roughened - roll macerator.

result in the stems being opened up into many small ribbons or slivers and the leaves being either severely crushed or bruised. The severe conditioning greatly increases the exposed surface area of the plant, ruptures the cells, and makes the plant moisture very available for evaporation.

Mats have been formed and pressed in a variety of ways generally involving drums, rollers, and carrier belts (Fig. 5). The mat press, regardless of its configuration, should fulfill several requirements: (1) its surface speed must match ground speed to allow mats to be laid intact onto the stubble, (2) mats should be supported as close to the stubble as possible, since their wet strength is not great, (3) the mats should be held under pressure for as long as practical to improve their consolidation and strength, and (4) the pressing rolls or surfaces should provide grooves or depressions to allow the plant juice a location for momentary "escape" while the fibrous material is being forced together. As soon as pressure is released from the mat, any free juice is instantly reabsorbed. There is a common misconception that the forage mat process removes juice from the plant material much like the wringer rolls on a washing machine. This is not the case; all plant juice remains with the mat. Fast drying is the result of the juice being more directly exposed to the evaporative process.

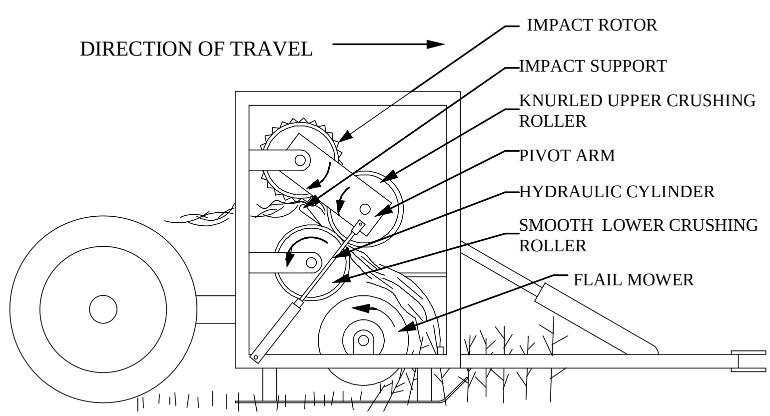

Figure 4. Schematic of crushing-impact macerator with flail mower.

Since mat thickness is an important factor in determining drying rate, it is necessary that mat thickness be kept reasonably uniform to eliminate damp spots, especially when drying for hay. This requires that the press be fed as uniformly as possible from the macerator. If the forage is being ensiled, then mat uniformity is of less importance as long as the final average moisture content is suitable.

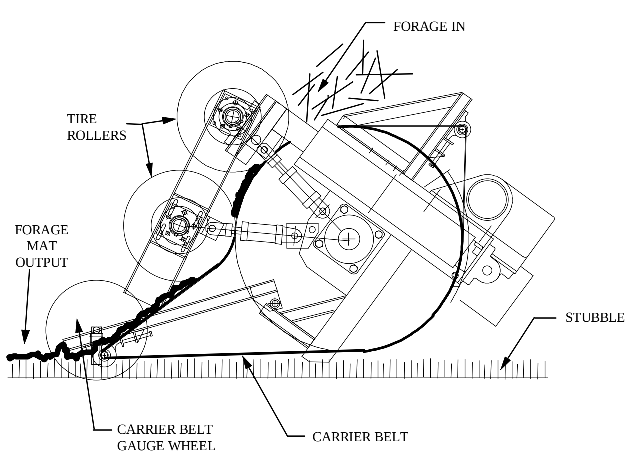

Figure 5. Press for forming macerated forage mats.

Conditioning Level and Digestibility

Intensive conditioning of forage has been shown to improve animal utilization, especially the amount of energy derived from the fiber fraction (Koegel et al.

Table 1.
Parameters from alfalfa conditioning level/digestibility study.

Parameter	Levels
Plant maturity (3rd cutting)	1. Late vegative/prebud, 2. Late bud/early flower, 3. Late flower/early seed
Conditioning level	1. Control, 2. Moderate crushing-impact, 3. Severe crushing-impact, 4. Rotary-impact maceration
Time in Rumen (hr)	6, 12, 24, 48

1992). This raises questions as to the appropriate level of conditioning to realize the potential benefits without over-conditioning, since this increases both capital and operating costs needlessly.

Establishing a relationship between degree of conditioning and increase in animal utilization requires: (1) an objective quantitative measurement of the degree of conditioning and (2) studies which relate rate and/or extent of forage disappearance (in vitro, in situ or in vivo) to degree of conditioning. To accomplish these objectives, an experimental study was undertaken with parameters shown in Table 1. Forage samples were prepared and placed in polyester bags to determine in situ disappearance in the rumen.

Conductivity of forage leachate was chosen to measure the level of conditioning. Conductivity was measured as follows: (1) 25 g fresh weight of forage was placed in 300 g of distilled water and shaken at 200 rpm for two minutes in an orbital shaker, (2) the liquid was filtered through two layers of cheesecloth and allowed to equilibrate for one minute, and (3) conductivity was measured at approximately 25°C.

The rationale for the conductivity measurement was that the higher the number of disrupted cells, the greater the concentration of electrolytes in the leachate. In addition to measuring the leachate conductivity of conditioned forage, forage was treated in a Waring blender, and the conductivity of the resulting leachate measured. This was considered the "ultimate" treatment which would give the maximum attainable leachate conductivity and this would be dependent almost entirely on herbage chemistry. Relative conductivity (RC) was then defined as the conductivity ratio (%) of a conditioned forage to that of the same forage treated in the Waring blender.

Conductivity Measurements vs. Digestibility

Conductivity values for three unconditioned alfalfa controls averaged 51 micro-siemens while corresponding values for the most severe treatment (rotary impact maceration), averaged 1067. Average conductivity for the Waring blender treatments was 1380 giving average relative conductivities (RC) of approximately 3.7% for the controls and 77% for the most severe treatment.

Dry matter disappearance from the polyester bags suspended in the rumen of fistulated cows is plotted vs. time in Figures 6 and 7 for the least and most mature alfalfa studied. It can be seen at 6 hr and 12 hr that the % disappearance increases with the severity of the treatment or RC value. By 48 hours the data points for the different treatments tend to converge. The increase in 6 hour DM disappearance of the most severe treatment relative to the untreated control is 28% for the least mature alfalfa tested and 40% for the most mature.

Figure 8 is a plot of 6 hr dry matter disappearance vs. RC for three levels of maturity. Here dry matter disappearance increases with conditioning severity. The largest benefit in dry matter disappearance occurs with the first in-

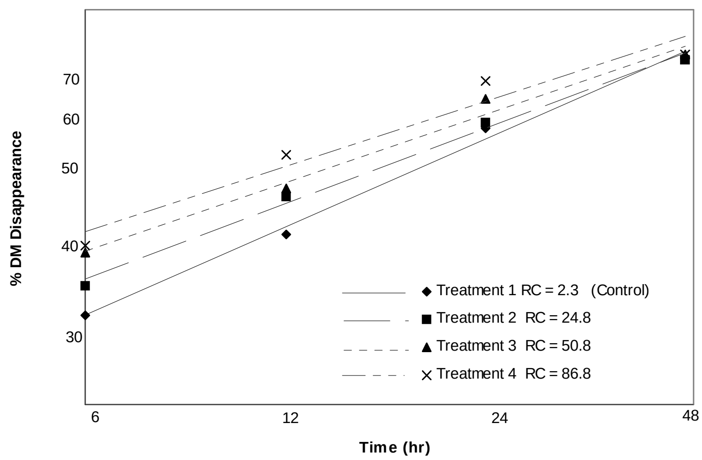

Figure 6. % DM disappearance vs. time. Alfalfa - late vegetative.

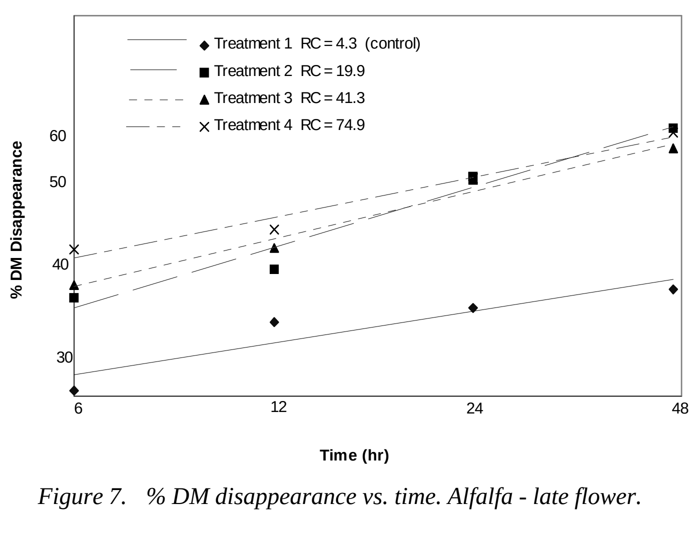

Figure 7. % DM disappearance vs. time. Alfalfa - late flower.

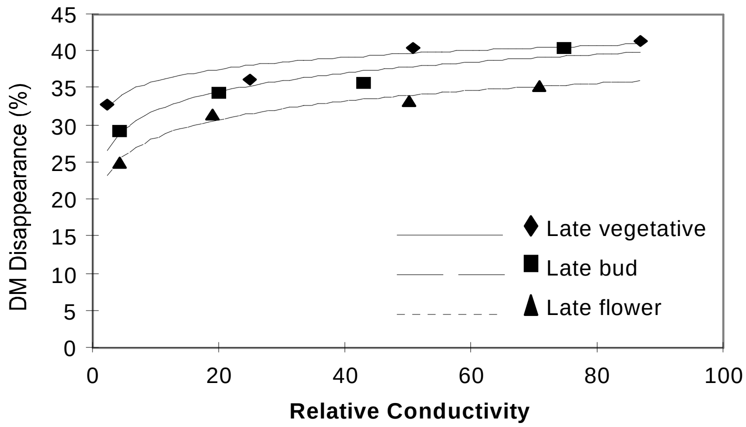

Figure 8. % DM disappearance vs. relative conductivity (6 hr).

Table 2.
Digestibility trials with alfalfa hay on sheep.

	Control	Mat	% Difference
Trial 1. Eight wethers for 12 weeks			
Dry matter intake, kg/d	1.15^b	1.22^a	6.1
Apparent NDF digestibility, %	43.0^d	48.5^c	12.8
Trial 2. Four wethers for 4 weeks			
Dry matter intake, kg/d	1.22	1.28	4.9
Apparent NDF digestibility, %	35.3^d	41.6^c	17.8

^{ab}Means in rows with different superscripts differ ($P < 0.10$)
^{cd}Means in rows with different superscripts differ ($P < 0.05$).

Table 3.
Digestibility trials with lactating goats fed on 60% alfalfa hay and 40% grain (10 goats for 4.5 weeks.)

	Control	Mat	% Difference
Dry matter intake, kg/d	2.44^b	2.58^a	5.7
Milk, 4% fat corrected, kg/d	3.3^b	3.7^a	12.1
Protein, kg/d	0.103^b	0.108^a	4.9

^{ab}Means in rows with different superscripts differ ($P < 0.10$)

Table 4.
Digestibility trials with alfalfa silage fed ad libitum, to sheep.

	Control	Mat	% Difference
Trial 1. Eight sheep for 6 weeks (digestion stalls)			
Ave dry matter digestibility, %	59.68	69.18	15.9
Daily dry matter intake % body weight	3.42^a	4.49^b	31.3
Trial 2. Twenty-six sheep for 2 weeks (pen of 13)			
Daily dry matter intake, % body weight	2.65	3.02	14.0
Ave weight gain, kg	2.98^c	3.68^b	23.5
kg gain/kg dry matter	0.149	0.177	18.8

^{ab}Means in rows with different superscripts differ ($P < 0.10$).

crement of conditioning severity. Successive increments of conditioning severity result in ever smaller increases in DM disappearance. While the slopes of the lines fitted to the data become smaller at higher levels of conditioning, there appear to be small increases in disappearance even at the highest level of conditioning ($70.9 \text{ RC} \leq 86.8$) used in this study.

Based on these data, electrical conductivity of forage leachate appears to be a useful and convenient measure of level of mechanical conditioning. In addition to correlating well with the severity of treatment, it also correlated well with the rate of disappearance of forage dry matter from polyester bags placed in the rumen.

Feeding Trials

A number of feeding trials have been conducted over a period of years comparing animal utilization of severely conditioned alfalfa with that of conventionally harvested material. The results have consistently shown that animals are able to utilize the severely conditioned material to a greater extent. The explanation given for this phenomenon is that the more severely conditioned plant material has more exposed surface area and many more damaged sites where the rumen microorganisms can penetrate and colonize. Microphotographs have borne this out showing many more sites with large colonies of microorganisms.

Early feeding trials were carried out with sheep and goats, because of the relatively small amounts of severely conditioned forage available. Table 2 gives the results of two feeding trials with sheep (Koegel et al. 1992) comparing mat-harvested alfalfa hay with conventionally harvested material. Dry matter intake was increased by 6.1% and 4.9 % and NDF digestibility was increased by 12.8% and 17.8%. A trial with lactating goats comparing the same materials (Table 3) showed the following increases for mat-harvested material: dry matter intake, 5.7%, milk production 12.1%, and protein production 5.3%. Table 4 shows the results of two later sheep feeding trials comparing mat-harvested and conventional alfalfa si-

Table 5.
Digestibility trial with lactating cows fed 65% alfalfa silage and 35% concentrate (12 cows for 8 weeks).

	Control	Mat	% Difference
Milk production, kg/d	24.5	24.2	n.s.d.
Fat, %	3.7	3.5	n.s.d.
Body weight increase, kg/d	0.08[a]	0.44[b]	450
Dry matter intake, kg/d	19.9	19.6	n.s.d.
Calculated energy from forage, MJ/kg	4.61	5.11	10.8

[ab]Means in rows with different superscripts differ (P < 0.01).

"In addition to showing consistent advantages in the energy derived from mat-harvested forages, feeding trials have also shown indications of increases in the level of bypass protein ..."

lage (Koegel et al. 1992). In the first trial the mat-harvested material showed an improvement in dry matter digestibility of 15.9% and in the second trial it showed an advantage in weight gain per unit feed of 18.8%.

In the first feeding trial done with lactating cows, (Koegel et al. 1992) no milk production advantage was found (Table 5). However, the cattle fed with the mat-harvested alfalfa silage had an increase in body weight more than four times that of the control group. Taking into account milk produced, weight gain, and energy for maintenance, it was calculated that the cattle had derived about 10.8% more energy from the mat-harvested silage than from the conventional silage. Based on this and other results, it was believed that mat-harvested forage could be used to replace some of the grain in dairy rations while maintaining production at or near the genetic potential of the cattle.

A recent feeding trial appears to substantiate this belief (Mertens 1995). In this trial two groups of twelve cattle each were selected for equal production. Prior to the trial both groups were fed a relatively high grain:forage ration typical of production practice. At the beginning of the trial both groups were gradually switched to rations higher in forage and lower in grain. As can be seen in Figure 9, after a brief adjustment period, the cattle receiving mat-silage were able to maintain approximately the level of production they had on the previous higher grain ration and to out-produce the cattle on the conventional silage ration by 7-8%.

In addition to showing consistent advantages in the energy derived from mat-harvested forages, feeding trials have also shown indications of increases in the level of bypass protein (that protein which escapes the rumen undegraded allowing more efficient utilization in the gut) for mat-harvested forages relative to conventional forages. Yang et al (1993) showed an increase of estimated bypass protein of 21% for mat-harvested alfalfa hay relative to conventionally harvested alfalfa hay. Mertens (1993) found a decrease in rumen ammonia for mat-harvested alfalfa hay and silage relative to conventionally harvested material of 23.9% indicating less ruminal protein breakdown for the mat harvested alfalfa. Alternatively, greater ruminal fermentation of forage carbohydrate may have supported more incorporation of ruminal ammonia into rumen microbes.

Harvesting and Storage

As stated earlier, intensively conditioned forages may be stored and fed either as silage or as dry hay. In either case the first step is to pick up the forage from the stubble. In early trials, it appeared that the conventional drum and tine pick-up tended to break up the mats leading to excessive losses. As a result, a belt and tine pick-up was developed which could be used with either a baler or a forage harvester (Fig. 10). This pick-up was similar to those used with combines to pick up swathed grain. Other workers have considered a drum and tine pick-up satisfactory, however. More recently a third type of pick-up has been used for picking up mats. This consists of a rap-

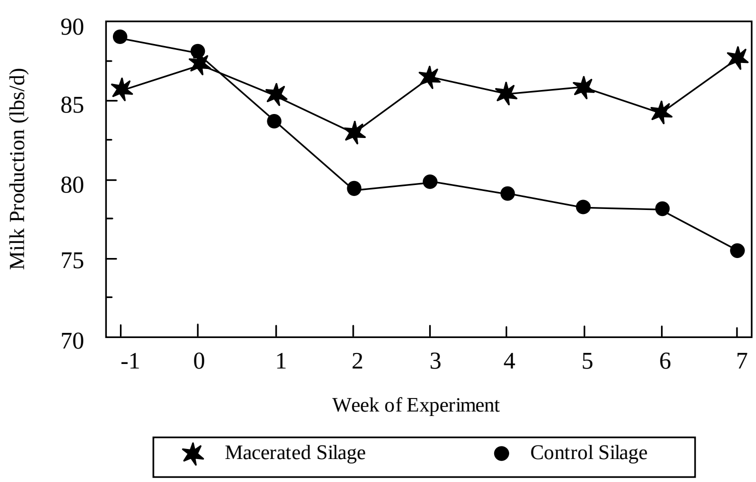

Figure 9. 1995 lactation study comparing macerated and conventionally conditioned alfalfa silage.

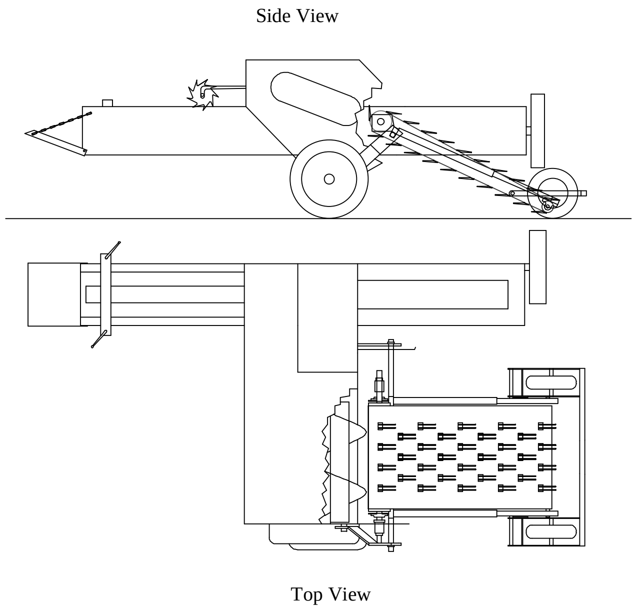

Figure10. Belt-and-tine pick-up for forage mats mounted on conventional small rectangular baler.

idly rotating rotor with plastic paddles enclosed by a suitable housing. In addition to the paddles impacting and throwing pieces of the mats, they create an air stream which appears to entrain small fragments vacuum cleaner fashion. A pick-up unit of this type was made by replacing the rotor of a flail chopper with a plastic paddle rotor. This unit retained the cross auger and blower (which also did minimal chopping), so that it could be used to pick up and convey the mats to a trailed wagon for subsequent ensiling.

Because of the very compliant nature of severely conditioned or macerated alfalfa, it was found that when ensiling good packing was obtained without chopping (Shinners et al. 1988). However, to improve handling characteristics into and out of the silo and in TMR mixers, some minimal chopping might be considered desirable. Muck et al. (1989) found that in ensiled alfalfa, mat-processed material fermented about twice as rapidly as conventionally processed material, reaching final pH in half the time or less.

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The compliant nature of mat-processed alfalfa is also apparent when baling. This has allowed 25%-35% more dry matter to be packed into a bale of a given size. The authors’ experience has been limited to small rectangular bales, however.

If rained on, forage mats retain their integrity. However, leaching loss (loss of soluble carbohydrates) may be 3-5 times that of conventionally conditioned material. The probability of being rained on, however, is minimized by the short dry-down time.

The upper surface of forage mats tend to bleach while drying in sunlight. Because the mats are dense, only a small amount of material in the uppermost layer is affected. After the mats have been broken up in the harvesting process, bleaching is generally not perceptible.

Equipment Development

European manufacturers have taken the lead in development of equipment for intensive conditioning. The Deutz-Fahr Company of Germany has had working prototypes for about five years. These are self-propelled machines having many of the features of the original Wisconsin machine. While farm publications have printed dates for the commercial debut of this machine as early as 1996, this appears doubtful. Two companies, the Greenland Group of the Netherlands and Krone of Germany, have introduced intensive forage conditioning machines to the market. While these machines condition more intensively than conventional machines, they do not condition as intensively as the work reported in the US and they do not form the forage into a cohesive body like a mat. They appear to be adapted to grass and for the production of silage. Since conditioning is less severe than the work reported here, it is not known whether there would be any improvement in digestibility. None has been claimed to date.

Two Canadian research groups are active in the development of equipment for intensive conditioning. They are Agriculture Canada at the University of Laval at Quebec and the Prairie Agricultural Machinery Institute near Winnipeg. The former group has developed several machines including both trailed and self-propelled units and has carried out feeding trials showing improved performance of intensively conditioned forage.

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"... fast dry-down could substantially reduce the respiration losses which continue in the plant material until the moisture content drops below 35%."

Ongoing Research

It is estimated that work on intensive conditioning is ongoing in at least ten different locations around the world. Because the actual level of conditioning varies from place to place and because of the effect these differences are expected to have on both the drying rate and the nutritional value of the forage, it seems imperative that an objective measurement of the intensity of conditioning be available.

Additional, larger scale feeding trials with dairy cattle to determine the extent to which grain can be replaced by severely conditioned forage in rations while maintaining high milk production are planned in Wisconsin during 1996.

Considerations for Forage Producers

Use of intensive conditioning can accelerate forage harvesting. Hay can frequently be baled and removed from the field on the same day it is mowed. This allows the crop to immediately start regrowth. In some areas this could mean an additional cutting per year. In addition, the fast dry-down could substantially reduce the respiration losses which continue in the plant material until the moisture content drops below 35%. The improvement in nutritional value of severely conditioned forage should allow it to command a premium price when this fact has become generally established.

It is clear that the cost of an intensive forage conditioner will be considerably greater than that of a conventional mower-conditioner. Its power requirement will also be greater. Based on the present state of knowledge it appears that both acquisition cost and power requirement may be similar to that of a forage harvester. For the producer making silage there will be some compensation, because the need for chopping will be eliminated or at least minimized. For the producer of bales, there could likewise be some compensation when baling the more compliant material, but this is less clear.

One crucial piece of the puzzle is still missing: mass-produced equipment for intensive conditioning. This will become available when the manufacturers become convinced that they can sell sufficient units to make development and marketing profitable.

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