

Performance of lactating dairy cows fed macerated forage conserved as silage and hay

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¹Department of Animal Science, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2; ²Agriculture and Agri-Food Canada, Brandon, Manitoba, Canada R7A 5Y3. Received 8 December 1998, accepted 2 October 1999.

Suwarno, Wittenberg, K. M., Ingalls, J. R. and McCaughey, W. P. 2000. **Performance of lactating dairy cows fed macerated forage conserved as silage and hay.** *Can. J. Anim. Sci.* **80**: 123–129. The effect of forage maceration at harvest on silage characteristics and its effect on lactation performance of Holstein cows were determined. Either a roller conditioner or a prototype forage macerator manufactured by PAMI were used to cut a 25-ha field of alfalfa (*Medicago sativa*) forage. The harvested forage was wilted and preserved as silage or hay. Maceration of alfalfa forage resulted in a lower crude protein concentration of fresh forage. Silage volatile fatty acid and ethanol concentration and hay and silage nutrient profiles were not affected by harvest methods. Thirty-four Holstein cows (602.9 ± 3.4 kg) in early lactation were used in a 14-wk lactation study. The cows were fed two dietary treatments in the form of a total mixed ration (TMR); one contained roller conditioner-harvested alfalfa silage and hay and the other contained macerator-harvested alfalfa silage and hay. Feed, weighbacks and milk were sampled daily. Daily dry matter intake (21.6 ± 0.5 kg) was not affected by harvest method. Daily milk yield (38.7 ± 0.3 kg) and milk composition were not affected by dietary treatment during the 14-wk lactation trial; however, cows fed the macerated forage as part of a TMR had a 0.23 kg greater daily body weight gain ($P < 0.05$). Dietary energy input and energy output (total energy in milk, maintenance and body weight change) were not affected by dietary treatment; however, energy contained in body weight change was greater ($P < 0.05$) in cows fed a TMR containing the macerated forage.

Key words: Alfalfa, maceration, milk yield, body weight, forage energy

Suwarno, Wittenberg, K. M., Ingalls, J. R. et McCaughey, W. P. 2000. **Performance de vaches laitières en lactation alimentées de fourrage surconditionné conservé en foin et en ensilage.** *Can. J. Anim. Sci.* **80**: 123–129. Nous avons observé les effets du surconditionnement de l'herbe à la récolte sur les caractères de l'ensilage et sur les performances de lactation de vaches Holstein. On employait, soit une conditionneuse à rouleaux ordinaire, soit une surconditionneuse prototype fabriquée par le Prairie Agricultural Machine Institute (PAMI), pour faucher une luzernière (*Medicago sativa*) de 25 ha. Le fourrage était ensuite fané puis conservé en ensilage ou en foin. Le surconditionnement a causé une diminution de la concentration de N total du fourrage frais, mais n'avait pas d'influence sur les concentrations d'acide gras volatils et d'éthanol de l'ensilage, ni sur le profil nutritionnel du foin et de l'ensilage. Trente-quatre vaches Holstein (poids corporel $602,9 \pm 3,4$ kg) en début de lactation étaient utilisées dans une expérience de lactation de 14 semaines. Elles recevaient l'un de deux régimes fourragers sous forme de ration complète, l'un contenant de l'ensilage et du foin de luzerne de conditionnement ordinaire et l'autre de l'ensilage et du foin de luzerne surconditionnée. Aucune différence significative n'était obtenue entre les deux modes de récolte quant à la prise quotidienne de m.s. ($21,6 \pm 0,5$ kg) ni au rendement laitier quotidien ($38,7 \pm 0,3$ kg) et à la composition du lait durant l'épreuve de lactation. Les vaches recevant le fourrage surconditionné démontraient un gain moyen quotidien (GMQ) de 0,23 kg supérieur ($P < 0,05$) à celui des vaches consommant le fourrage conditionné aux rouleaux ordinaires.

Mots clés: Luzerne, surconditionnement, rendement laitier, poids corporel, énergie de provenance fourragère

Alfalfa (*Medicago sativa*) is one of the most important species of forage grown in North America, in part because of consistent high yields of CP and high feeding value for ruminant livestock. Harvest of alfalfa for storage as silage or hay requires that the crop be field wilted to achieve the desired moisture content. Precipitation or high humidity during wilting can reduce forage quality due to extended plant respiration, bacterial growth and leaching. Delaying the harvest until the weather is favourable will result in a decline in forage quality related to maturing of the plant. A better harvest strategy would be to shorten the drying time.

Mechanical and chemical methods have been used to increase drying rate. In the last decade, maceration or longitudinal breaking of the plant stem has received increased attention. Tests under humid conditions in eastern Canada

Abbreviations: ADF, acid detergent fibre, ADIN, acid detergent insoluble nitrogen, BCS, body condition scores, BW, body weight, CP, crude protein, DM, dry matter, DMI, dry matter intake, FCM, fat corrected milk, NDF, neutral detergent fibre, NE_L , net energy lactation, PAMI, Prairie Agricultural Machinery Institute, SE, standard error, TMR, total mixed ration, VFA, volatile fatty acids

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suggest that field wilting time can be cut in half when macerating forage at harvest, reducing risk associated with respiration loss (Savoie et al. 1993) and potentially increasing the soluble carbohydrate fraction of the forage. Increased forage soluble carbohydrate concentration in silage production is related to high levels of lactic acid production and successful fermentation. Muck et al. (1989) identified an increase in the lactic acid bacteria population at early stages of ensiling when forage was harvested with a mower-macerator.

The effect of forage maceration on animal performance is less documented. Koegel et al. (1990) estimated that maceration could increase the energy value of forage by 11% for dairy cows; however, a production trial with late lactation cows showed that the additional energy was directed toward higher body weight gain with no change in milk production for macerated relative to conventional alfalfa forage. In contrast, a trial with dairy goats resulted in a 12% increase in milk production when macerated alfalfa hay was compared with conventional alfalfa hay (Hong et al. 1988). The objective of this study was to evaluate lactating cow production responses when fed early bloom alfalfa forage harvested using either a macerator or a conventional haybine during silage and hay production.

MATERIALS AND METHODS

Forage Treatments

A uniform 25-ha alfalfa field at 0–10% bloom was divided into four sections for both first- and second-cut harvests. Field sections were randomly allocated for harvest using either a macerator prototype manufactured by the Prairie Agriculture Machinery Institute (PAMI), Portage La Prairie, Manitoba (macerated), or a New Holland 116 haybine with a roller conditioner (roller conditioner). Harvests were conducted simultaneously. There were two alfalfa harvests; the 1st cut was conducted on 23 and 24 June and the 2nd cut was conducted on 2, 3 and 4 August 1994. The harvested forage was wilted to reach 45% DM, chopped and loaded into two identical 140-t tower silos: one silo was designated for macerated forage and the other for conventionally harvested forage. A second field containing 2nd-cut alfalfa forage was divided into four blocks: two blocks were assigned to be harvested using a macerator and two using the haybine. This forage was field dried to 85% DM and baled as hay for the production trial.

Four marked burlap bags containing known amounts of harvested forage were placed in each of two levels (levels 1 and 2) of the silo as 1st cut forage was blown into the silo. Similarly, four marked burlap bags were placed at two levels of the silo (levels 3 and 4) at the time silos were filled with 2nd cut forage.

As silos were unloaded during the feeding trial, burlap bags were retrieved, weighed and sub-sampled to determine DM retention, nutrient composition, final pH and VFA concentrations. The subsamples were oven dried (60°C, 48 h) for DM determination and ground with a Wiley Mill fitted with a 1-mm screen for nutrient analysis. Only the intact burlap bags recovered during unloading were used.

Animals and Feeding

Thirty-four animals including 14 primiparous and 20 multiparous Holstein cows were assigned to one of two dietary treatments. One multiparous cow was removed during the first week of the trial due to mastitis, resulting in 33 animals being used for data collection and statistical analysis. Animals were assigned on the basis of number of lactations (first, second and mature), and previous lactation performance. Feeding of the silage and hay treatments started 2 wk prior to calving. Data collection was initiated on the second Saturday after calving and continued for 14 wk.

The silage was fed as part of a TMR, which included a concentrate, a protein supplement, and whole sunflower seeds. Long hay, fed separately at 2 kg head⁻¹ d⁻¹ and the TMR were fed once a day. The TMR was formulated to contain 1.73 Mcal NE_L kg⁻¹ DM, with other nutrient parameters meeting production parameters for a 625-kg cow producing 40 L of milk at 3.60% fat [National Research Council (NRC) 1989]. Actual TMR formulations were revised on a weekly basis, to account for actual silage DM and averaged a 42:58 forage to concentrate ratio, DM basis.

Animal BW and BCS (Edmonson et al. 1989) were determined at the time data collection was initiated and every 4 wk thereafter until animals went off test. Milk yield was monitored daily and milk composition over a 24-h period was assessed on a weekly basis. Feed offered and weighbacks were monitored daily with the amount of feed offered targeted to allow a minimum weighback of 2 kg.

The care and handling of the cows used in this experiment conformed to the guidelines established by the Canadian Council on Animal Care.

Sampling and Nutrient Analysis

Silage and concentrate samples from the production trial were taken on a weekly basis and stored (–20°C). These samples were composited to represent 5-wk intervals during the trial. Composites were dried using a forced air oven (60°C, 48 h).

Silage ethanol, VFA and lactic acid were determined as outlined by Di Corcia and Samperi (1974) using gas chromatography, and silage pH measurement was conducted using an Accumet pH meter (model 810, Fisher Scientific, Nepean, ON).

Hay was core sampled prior to feeding. All analyses for hay DM and nutrient composition were conducted on these core samples. Samples were dried and ground with a Wiley mill, to pass through a 1-mm screen for nutrient analysis. Nutrient analyses included NDF and ADF according to Goering and Van Soest (1970) and ADIN and CP using Kjeldahl N according to Association of Official American Chemists (AOAC 1990 method no. 984.13). Calcium, P, K and Mg were determined after dry ashing forage samples at 550°C for 12 h, followed with determination using a flame atomic absorption spectroscopy (AA/E spectrophotometric model 551: Instruments Laboratory Inc., Willmington, MA). Soluble carbohydrate was determined according to Slominski et al. (1993).

Milk fat, protein and solid-non-fat concentrations were determined by infrared spectroscopy using an infrared

Table 1. Pre-ensiling and post-ensiling forage quality, and silage characteristics for roller-conditioner vs. macerator harvested alfalfa forage placed into tower silos

	Roller conditioner	Macerated	SE
<i>Nutrient content</i>			
Pre-ensiling			
No. of bags	16	16	
DM (%)	46.4	46.0	1.8
CP (g kg ⁻¹)	197 ^a	191 ^b	2.0
ADF (g kg ⁻¹)	326	346	3.1
NDF (g kg ⁻¹)	416	411	3.1
Post-ensiling			
No. of bags	9	7	
DM (%)	45.7	40.3	2.7
CP (g kg ⁻¹)	216	201	4.0
ADF (g kg ⁻¹)	357	383	15.1
NDF (g kg ⁻¹)	444	477	13.0
DM retention ^z (%)	87.0	90.6	2.5
CP retention ^z (%)	91.6	98.7	3.9
<i>Silage characteristics</i>			
pH	5.00	4.76	0.18
Lactic acid (mg g ⁻¹ DM)	42.83	58.59	20.64
Acetic acid (mg g ⁻¹ DM)	12.42	31.04	4.74
Propionic acid (mg g ⁻¹ DM)	0.96	1.16	1.04
Butyric acid (mg g ⁻¹ DM)	3.73	1.86	4.10
Ethanol (mg g ⁻¹ DM)	1.10	2.49	1.26

^z Percent DM retention = (weight out/weight in) × 100.

a, b Lsmeans in rows with different letters are different ($P < 0.05$).

analyser (Milk-O-Scan 203B type 17920 A-SN, Foss Electric, Hillerod, Denmark).

Diet energy density and energy status of cows were estimated using the methods of NRC (1989) and Tyrell and Reid (1965).

Statistical Analysis

Data collected from burlap bags placed into the silos was analysed as a split-split-plot design. The main plot was harvest treatment (Roller-conditioner and Macerated), the sub-plot was harvest period (1st cut and 2nd cut) the sub-sub-plot was level in the silo (levels 1, 2, 3 and 4) with burlap bags as the experimental units. The nutrient composition of the diets was analysed using a general linear model (GLM) procedures (SAS Institute, Inc. 1986). All other data were analysed as a split-plot design, with harvest treatment and parity as the main plot (2 × 2 factorial) using cow within harvest by parity as the error term, and week of lactation as the sub-plot, using GLM procedures of the SAS Institute, Inc. (1986). The Bonferoni difference technique was used to compare least square means when treatment differences were observed. Levels of significance were determined at $P < 0.05$ and trends at $P < 0.10$ unless indicated otherwise.

RESULTS AND DISCUSSION

Time required to achieve a DM concentration of 45% was reduced dramatically with maceration. Due to good drying conditions during first cut, ensiling of macerated forage was initiated within 3.5 h post-cutting vs. 22 h post-cutting for forage cut with a mower conditioner. A long field-wilting period was required for the second cut due to cool tempera-

tures and humid conditions, the wilting time required being 20.5 and 50 h for the two harvest treatments, respectively. Second-cut forage harvested with the mower macerator was baled for hay at 51 h post-cutting whereas that cut with a mower conditioner was baled following 82 h of wilting. Maceration did reduce wilting time of cut forage under good and poor drying conditions in this study.

Silage Trial

Crude protein concentration of the macerated forage was lower than forage harvested with the roller-conditioner at the time of ensiling. No differences due to harvest method were observed for the fibre constituents in fresh forage (Table 1). Cutting height for the macerator prototype and haybine were similar. Greater leaf shedding due to maceration as compared with the roller-conditioner during cutting might be responsible for the lower CP content in macerated forage.

Post-storage nutrient profiles and nutrient retention data retrieved from burlap bags were similar between macerated and conventionally harvested ensiled alfalfa forage (Table 2). The actual differences in CP content observed pre-ensiling was still evident post-ensiling; however, a reduced number of observations due to removal of data from damaged burlap bags may have affected the ability to detect significant differences. Dry matter and CP retention was high for macerated silage, indicating minimum losses related to respiration or effluent loss; the retention values for the conventionally harvested forages were not significantly different.

Final pH, VFA and ethanol levels of ensiled forage retrieved from burlap bags were similar for macerated vs. roller-conditioner harvested forage (Table 1). The profile of the fermentation products of these silages indicate that a good fermentation occurred in both silos. The pH of both silages was higher than optimum; however, this may be related to the high buffering capacity of alfalfa forage.

Lactation Study

Alfalfa was harvested in a relatively optimum stage of growth. The nutrient profile of silages retrieved from the silos and hay used in the feeding trial were similar for the two harvest procedures used despite differences observed in wilting time (Table 2). Benefits due to a reduced wilting time may have been lost for second-cut forage, which was not subjected to precipitation, but dried slowly due to cool, humid conditions. This would not have been the case for first-cut silage. Forage quality in this trial was typical for an early bloom legume under good harvesting and storage conditions. Experimental diets were formulated to be isocaloric on the basis of estimated forage NE_L (NRC 1989) with an actual forage-to-concentrate ratio of 42:58, DM basis (Table 3). The actual dietary nutrient profile was lower in calculated energy density (1.63–1.67 Mcal kg⁻¹ DM) relative to the desired formulation (1.73 Mcal kg⁻¹ DM); however, diets were isocaloric.

Dry matter intake was 21.6 ± 0.5 kg without any differences between treatments (Table 4). Similar results were found by Hong et al. (1988) when lactating goats were fed a

Table 2. Post-storage nutrient composition of alfalfa silage and hay harvested using either a roller-conditioner or a macerator and fed to lactating dairy cows

	Silage ^z		SE	Hay ^y		SE
	Roller-conditioner	Macerated		Roller-conditioner	Macerated	
DM (%)	49.54	48.16	1.60	86.8	87.0	–
Composition (DM basis)						
CP (g kg ⁻¹)	196.1	199.1	3.7	195.1	193.6	14.4
ADIN (mg g ⁻¹ total N)	74.8	85.1	1.5	48.2	42.9	1.2
NDF (g kg ⁻¹)	458.1	461.4	16.5	407.5	400.4	12.7
ADF (g kg ⁻¹)	376.0	371.0	6.8	305.8	296.3	9.4
Soluble carbohydrate (mg g ⁻¹)	33.8	32.6	5.6	84.2	90.2	4.4
NE _L (Mcal kg ⁻¹) ^x	1.23	1.25	–	1.41	1.43	–
P (g kg ⁻¹)	3.20	3.14	0.08	2.10	2.20	0.34
Ca (g kg ⁻¹)	20.3	18.7	0.2	17.0	17.12	1.46
K (g kg ⁻¹) ^w	26.0	26.0	–	21.0	21.0	–
Mg (g kg ⁻¹) ^w	2.60	2.80	–	2.90	2.80	–

^zBased on composite samples of silage fed during the lactation trial.

^yBased on composite of core samples taken from bales fed during the lactation trial.

^xCalculated according to NRC (1989).

^wSamples composited prior to analysis.

TMR ration of macerated vs. conventionally harvested alfalfa hay that was chopped and mixed with concentrate, and by Chiquette et al. (1994) using steers fed macerated vs. conventionally harvested timothy hay that was chopped prior to feeding. Sheep fed chopped macerated alfalfa forage (Hong et al. 1988; Petit et al. 1994) tended ($P < 0.10$) to eat more feed relative to their counterparts fed conventionally harvested forage. Alfalfa hays used by Hong et al. (1988) and Petit et al. (1994) were similar in NDF (41.6–48.6%) and ADF (33.0–38.7%) content relative to the current trial. The fact that lactating cows also were consuming a high proportion of concentrate in the current trial may have negated potential differences due to maceration. Differences in the forage types also may have influenced results. Hong et al. (1988) and Petit et al. (1994) used hay, whereas the current trial used mostly silage. Dry matter intake was lower ($P < 0.01$) for primiparous cows relative to multiparous cows. This was as expected, because rumen capacity as well as potential milk production of multiparous cows is greater relative to those of primiparous cows.

Milk and 4% FCM production were high in this study, but not affected by forage harvest method (Table 5). Lactating goats fed a TMR containing a 60:40 ratio, DM basis, of chopped, macerated alfalfa hay and concentrate (Hong et al. 1988) tended to yield higher 4% FCM, and lactating cows fed macerated alfalfa silage in a TMR [Mertens and Hintz (1990) in Koegel et al. (1992)] had similar milk yields relative to cows fed conventionally harvested forage in the lactation ration. Milk constituent levels were not affected by harvest method of the forage fed to lactating cows (Table 5).

Although DMI and 4% FCM were similar between treatments, animals fed the TMR with macerated forage gained more weight than those fed the TMR with conventionally harvested forage (Table 4), resulting in a higher final weight. This fact suggests that the TMR containing macerated forage was more efficiently used for BW gain relative

Table 3. Formulation and nutrient composition of diets fed to lactating cows

	Roller-conditioner	Macerated
<i>Diet ingredients (g kg⁻¹ DM)</i>		
Alfalfa silage	343.6	325.7
16% concentrate ^z	514.4	530.5
Protein supplement ^y	40.7	41.3
Whole sunflower seeds	22.0	22.3
Alfalfa hay, long	79.3	80.2
Forage:concentrate ratio, DM basis	42:58	41:59
<i>Nutrient composition, DM basis</i>		
CP (g kg ⁻¹)	192.0	191.0
NDF (g kg ⁻¹)	303.0	307.0
ADF (g kg ⁻¹)	202.0	203.0
NE _L (Mcal kg ⁻¹) ^x	1.63	1.67
Ca (g kg ⁻¹)	14.3	14.0
P (g kg ⁻¹)	5.8	5.7
K (g kg ⁻¹)	15.4	15.6
Mg (g kg ⁻¹)	2.6	2.6

^zConcentrate mix consisted of (as fed basis) 52.9% steam-rolled barley and 10.0% steam-rolled corn, 11.0% wheat shorts, 9.0% canola meal, 3.5% distilled grains, 2.6% soybean meal, 2.0% meat meal, 1.0% blood meal, 2.0% wheat, 0.8% Co-I salt, 0.7% dynamate (Pitman Moore Inc., Oakville, ON, Canada; contained guaranteed analysis of 22% S, 18% K, and 11% Mg), 0.6% limestone, 0.8% dicalcium phosphate, 1.0% micropremix, 2.0% talc, and 0.2% mold inhibitor.

^yProtein supplement consisted of (as fed basis) 42.0% distilled dried grains, 7.0% fish meal, 22.8% canola meal, 20.0% soybean meal, 3.0% beet molasses, 0.3% niacin, and 5.0% sodium bicarbonate.

^xCalculated NE_L (NRC 1989).

to that of the control diet. Koegel et al. (1992) cited the findings of Mertens and Hintz (1990), that growing sheep gained more weight when they were fed macerated alfalfa silage ($P < 0.06$) relative to control. Overall, BCS tended ($P < 0.07$) to be higher for cows fed the macerated diet (Table 4). Multiparous cows fed macerated diets had higher

Table 4. Post-partum intake, BW, and BCS of lactating dairy cows fed alfalfa silage and hay harvested using a macerator vs. a roller-conditioner as parts of TMR

	Harvest method (Trt)		SE	Significance ^z		
	Roller-conditioner	Macerated		Parity	Trt × parity	Trt × time
No.	16	17				
DMI kg d ⁻¹	21.7	21.4	0.5	0.01	NS	NS
%BW	3.46	3.45	0.11	NS	NS	NS
<i>Body weight</i>						
Final (kg)	619.6 ^b	641.5 ^a	10.7	0.01	NS	NS
Change (kg d ⁻¹)	0.17 ^b	0.40 ^a	0.07	0.05	NS	NS
<i>BCS^y</i>						
Mean (unit)	2.80	2.94	0.05	NS	0.04	NS
Change (unit d ⁻¹)	-0.02	-0.001	0.006	0.07	NS	NS

^zProbability associated with an effect.

^yBody condition scores were estimated based on score 1–5, 1 is thinnest or severe under conditioning and 5 is fattest or severe over conditioning (Edmonson et al. 1989).

a, b LSmeans in rows with different letters are different ($P < 0.05$). NS, not significant.

Table 5. Milk yield and composition when Holstein cows were fed a total mixed ration containing alfalfa forage harvested with a roller-conditioner or a macerator

	Harvest method (Trt)		SE	Significance ^z		
	Roller-conditioner	Macerated		Parity	Trt × parity	Trt × time
<i>Yield (kg d⁻¹)</i>						
Milk	38.8	38.5	0.3	0.01	NS	NS
4% FCM ^y	31.8	31.8	0.1	0.01	NS	NS
Butterfat	1.08	1.09	0.06	0.01	NS	NS
Protein	1.17	1.19	0.03	0.01	NS	NS
Solids non-fat	3.34	3.38	0.09	0.01	NS	NS
<i>Composition (g 100 g⁻¹)</i>						
Butterfat	2.78	2.84	0.14	NS	NS	NS
Protein	3.04	3.09	0.04	0.01	NS	NS
Solids non-fat	8.62	8.76	0.07	0.05	NS	NS

^zProbability associated with an effect.

^y4% FCM, fat corrected milk (NRC 1989). Calculated with an equation: 4% FCM = (0.4) (kg of milk) + (15) (kg of milk fat).

($P < 0.05$) BCS for the last 10 wk of the lactation trial than cows fed the control diets (Fig. 1). Both multiparous groups of cows dropped their BCSs during the first 4 wk of the lactation trial; however, the cows fed a TMR containing the roller-conditioner harvested alfalfa forage showed a greater decrease in BCS during that period relative to cows fed a TMR containing macerated alfalfa forage. The body weight of cows during that period decreased 38.4 kg as compared to a 6.3 kg decrease in BW over the same period of time for cows fed a TMR containing the macerated alfalfa forage. The decrease in both BW and BCS in multiparous cows during the initial weeks of lactation is related to a greater energy output in the form of milk relative to energy consumed. The energy shortage is supplied by body fat mobilization. This situation did not happen in heifers because their milk production was not great enough to cause a negative energy balance. At the end of the trial (week 14 post-partum), cows

receiving a TMR containing the macerated forage almost recovered their BCS (3.1) while in the same period, cows fed a TMR containing the roller conditioner harvested forage were still well below their initial BCS. The better BCS in the cows fed a TMR containing the macerated forage at week 14 post-partum coupled with similar production levels suggests that forage maceration has benefits to early lactation animals.

Animals consumed a similar amount of energy (35.4 and 35.3 Mcal d⁻¹, respectively, Table 6) from both dietary treatments over the course of the 14-wk lactation trial. Similar production of milk and milk constituents by both groups of animals resulted in no differences in milk energy output between the two dietary treatments. Energy for maintenance was not significantly affected by treatment. However, animals fed the TMR containing macerated forage gained more weight as indicated by a greater energy

Table 6. Post-partum energy status of Holstein cows as influenced by harvest method of alfalfa

	Harvest method (Trt)		SE	Parity	Significance ^z	
	Roller-conditioner	Macerated			Trt × parity	Trt × time
Energy input ^z						
Total (Mcal NE _L d ⁻¹)	35.37	35.31	0.72	0.01	NS	NS
Energy output (Mcal NE _L d ⁻¹)						
Milk ^y	24.43	24.49	0.76	0.01	NS	NS
Maintenance ^x	9.76	9.90	0.13	0.01	NS	0.06
BW change ^x	0.93 ^b	2.08 ^a	0.36	0.002	NS	NS
Total	35.13	36.48	0.84	0.01	NS	NS
Dietary energy density (Mcal NE _L kg ⁻¹ DM)						
Estimated ^z	1.63	1.65	—	—	—	—
Calculated ^w	1.66	1.74	0.04	NS	NS	NS

^zEstimated from NRC (1989) values; based on composition of diets, energy values of each feedstuff and daily intake.

^yCalculated from daily protein yield (P, g kg⁻¹) and butterfat yield (BF, g kg⁻¹) of milk (Tyrell and Reid 1965); Energy in milk (MJ kg⁻¹) = 0.0376(BF) + 0.0209(P) + 0.948. Joule is converted to calorie in this table.

^xEnergy for maintenance and BW change were calculated based on BW and daily BW change respectively (NRC 1989, table 6.3; energy for maintenance = (BW^{0.75}) × 0.08, and energy for BW change was either -4.92 Mcal kg⁻¹ BW loss or +5.12 Mcal kg⁻¹ BW gain.

^wCalculated from total energy output and DMI; Energy density = total energy output/DMI.

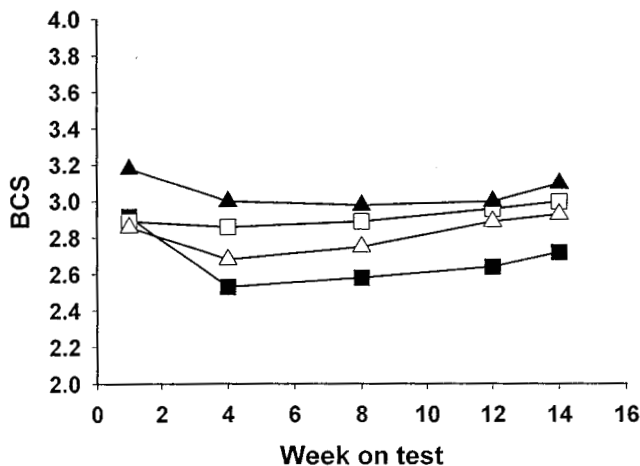


Fig. 1. Body condition scores of multiparous and primiparous cows in response to experimental diets during a 14-wk lactation trial (■, roller conditioner-multiparous; ▲, macerated-multiparous; □, roller conditioner-primiparous; △, macerated-primiparous). Pooled SE = 0.07.

output for BW change. Calculated total energy outputs (sum of energy in milk, maintenance and BW change) were not significantly affected by harvest methods. Higher conversion of feed energy to body mass for the lactation ration containing macerated forage relative to control maybe partly be due to a greater NDF digestibility (Hong et al. 1988), greater soluble fraction or increased degradability (Chiquette et al. 1994) in the macerated forage.

CONCLUSIONS

Maceration of early-bloom alfalfa at the time of harvest did not result in a change in silage nutrient composition at the time of feeding. Feeding macerated silage and hay to lactat-

ing cows did not affect DMI, milk production or milk composition; however maceration did result in higher body weight gain in the initial 14 wk of lactation.

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Association of Official Analytical Chemists 1990. Official methods of analysis. 15th ed. AOAC, Arlington, VA.

Chiquette, J., Savoie, P. and Lirette, A. 1994. Effects of maceration at mowing on digestibility and ruminal fermentation of timothy hay in steers. *Can. J. Anim. Sci.* **74**: 235–242.

Di Corcia, A. and Samperi, R. 1974. Determination of trace amounts of C₂-C₅ acids in aqueous solutions by gas chromatography. *Anal. Chem.* **46**: 140–143.

Edmonson, A. J., Lean, I. J., Weaver, L. D., Farver, T. and Webster, G. 1989. A body condition scoring chart for Holstein dairy cows. *J. Dairy Sci.* **72**: 68–78.

Goering, H. K. and Van Soest, P. J. 1970. Forage fibre analyses (apparatus, reagents, procedures, and some applications), *Agric. Handbook 379*, ARS-USDA, Washington, DC.

Hong, B. J., Broderick G. A., Koegel, R. G., Shinnors, K. J. and Straub, R. J. 1988. Effect of shredding alfalfa on cellulolytic activity, digestibility, rate of passage, and milk production. *J. Dairy Sci.* **71**: 1546–1555.

Koegel, R. G., Straub, R. J., Shinnors, K. J., Broderick, G. A. and Mertens, D. R. 1990. Mechanical and thermal treatments of forage crops for improving properties. International Conference "Ag. Eng. 90", Berlin, Germany. October 1990.

Koegel, R. G., Straub, R. J., Shinnors, K. J., Broderick, G. A. and Mertens, D. R. 1992. An overview of physical treatment of lucerne performed at Madison, Wisconsin, for improving properties. *J. Agric. Eng. Res.* **52**: 183–191.

Muck, R. E., Koegel, R. G., Shinnors, K. J. and Straub, R. J. 1989. Ensilability of mat-processed alfalfa. Pages 2055–2061 in

Proceedings of the 11th Commission Internationale du Genie Rural (CIGR). Dublin, Ireland.

National research Council. 1989. Nutrient requirements of dairy cattle. 6th rev. ed. National Research Council, National Academy Press, Washington, DC.

Petit, H. V., Savoie, P., Tremblay, D., Dos Santos, G. T. and Butler, G. 1994. Intake, digestibility, and ruminal degradability of shredded hay. *J. Dairy Sci.* **77**: 3043–3050.

Savoie, P., Chabot, R. and Tremblay, D. 1993. Loss and drying characteristics of forage mats after rainfall. *Trans. ASAE* **36**: 1533–1539.

Slominski, B. A., Guenter, W. and Campbell, L. D. 1993. New approach to water-soluble carbohydrate determination as a tool for evaluation of plant cell wall degrading enzymes. *J. Agric. Food Chem.* **41**: 2304–2308.

SAS Institute, Inc. 1986. SAS user's guide: Statistics. SAS Institute, Inc, Cary, NC.

Tyrell, H. F. and Reid, J. T. 1965. Prediction of the energy value of cow's milk. *J. Dairy Sci.* **48**: 1215–1223.

