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Performance of Growing Lambs Fed Two Levels of Concentrate with Conventional or Macerated Timothy Hay^{1,2}

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ABSTRACT: Thirty-two Outaouais male lambs were used in a 2 × 2 factorial design to compare growth and carcass characteristics of lambs fed conventional and macerated hay at two levels of concentrate. Timothy hay was harvested with either a prototype mower-macerator or a conventional mower-conditioner. Hays offered for ad libitum intake were fed with isonitrogenous supplements containing either 400 g of commercial concentrate or a mixture of 100 g of commercial concentrate and 158 g of canola meal. Lambs were fed from an initial weight of 22 kg to a slaughter weight of 43 kg. Feeding the highest level of concentrate tended to decrease hay intake but in-

creased DMI and ADG. Feeding macerated hay had no effect on DMI, digestibility, ADG, and gain:feed. There was an interaction ($P < .08$) between type of conditioning and feeding level of concentrate for carcass weight, dressing percentage, and muscular conformation of hind leg roast. In general, the highest values were obtained for lambs fed the higher level of concentrate. Efficiency of ME utilization for gain was similar among treatments. These data suggest that the benefits of macerated timothy hay and higher amounts of concentrate on carcass quality are additive.

Key Words: Sheep, Concentrates, Carcasses, Forage

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Introduction

Maceration of alfalfa increases the rate of drying relative to conventionally conditioned forage (Shinners et al., 1988) and improves forage quality. Milk production of goats increased by 12% when they consumed macerated rather than conventional alfalfa hay (Hong et al., 1988a). Moreover, maceration increased intake and digestibility of alfalfa and timothy hays by mature sheep as a result of greater ruminal degradability of DM and ADF (Petit et al., 1994).

Protein supplementation increased the ADG of growing lambs fed high-quality, forage-based diets without any effect on forage DMI and carcass fat (Chestnutt, 1992; Petit and Castonguay, 1994). A small amount of fish meal was as effective as a large amount of grain in promoting weight gain of growing lambs fed high-quality silage (Petit and Castonguay, 1994). This demonstrates that grain level in the diet can be decreased by feeding low amounts of protein supplement, although no comparison has been reported for hay-based diets and canola meal as the protein source. The two objectives of this experiment were to determine whether maceration would increase the digestibility of timothy hay and the need to supplement with concentrate, and to compare growth and carcass quality of lambs fed macerated or conventional timothy hay.

Materials and Methods

Animals and Housing. The experiment was conducted at the Sheep Research Farm of Agriculture and Agri-Food Canada at La Pocatière, QC, during the summer of 1995. Thirty-two Outaouais intact male lambs, averaging $22.0 \pm .3$ (SE) kg and $69.4 \pm .3$ d of

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age, were randomly assigned to a completely randomized design. Two methods of forage conditioning and two levels of concentrate supplementation were evaluated in a 2×2 factorial arrangement. Lambs were kept indoors in individual pens (1.2 m²). Wood shavings were used for bedding. Lambs were weighed every 2 wk. Feed was withheld overnight before weighing at the beginning of the experiment and the morning before lambs were sent to the slaughterhouse. The lambs were fed to a final live weight of approximately 43 kg. Cold carcass data obtained included carcass weight, dressing percentage, total tissue depth (TTD), carcass lean yield, and conformation. Total tissue depth was measured with a steel ruler on the left carcass side, between the 12th and 13th ribs and 11 cm from the carcass midline. Grade reading (GR) was obtained by the equation $GR = [6.38 + (.88 \times TTD)]$ (Anonymous, 1992). Carcass lean yield was estimated from warm carcass weight (WCW) and GR by the regression equation: carcass lean yield (%) = $[65.80 - (.074 \times WCW)] - (.432 \times GR)$ (Anonymous, 1992). Muscular development was coded as 1 = extremely deficient, 2 = deficient, 3 = moderate, 4 = good, and 5 = excellent (Anonymous, 1992). No problems with feet, legs, stiffness, or health of the lambs were noticed. Animals were cared for according to the guidelines of the Canadian Council on Animal Care.

Diets and Feeding. The two forage conditioning methods consisted of timothy harvested with either a prototype mower-macerator (MM) or a conventional commercial disk mower (CO) 2.8 m wide and equipped with a rubber roll conditioner (model 5209; New Idea, Coldwater, OH). The prototype mower-macerator included a 2.8-m disk mower (model 5209 modified; New Idea), three serrated rolls of 2.1 m width and .20 m diameter to macerate the crop, and a conveyor composed of plastic slats for deposition of the macerated windrow onto the stubble (Asselin et al., 1994). Timothy was mowed on June 22, 1994, at early head stage from the primary growth of a pure sward at the Normandin Research Farm. Alternate rows of the grass were harvested with each machine. Forages were partially cured in the field, turned with a windrow inverter (model 166; New Holland Corp., New Holland, PA), baled with a rectangular-bale baler (model 326; New Holland), and forced-air-dried in an enclosed barn. Macerated hay was turned once and field-cured for 44 h. Conventional hay was turned twice and field-cured for 47 h. Both hays were barn-dried to reach 88% DM.

Hays were fed daily with two levels of concentrate: 400 g of commercial concentrate (HC) or a mixture of 100 g of commercial concentrate and 158 g of canola meal (LC). Both concentrates were designed to result in similar CP intake, which averaged 10.4 g/d. Lambs were fed once daily for ad libitum intake with 5 to 10% orts. Orts consisted only of hay because the supple-

ments were fed before the forage and consumed readily by the lambs. Samples of feed were taken weekly and frozen for chemical analyses. The commercial concentrate contained, on a DM basis, 39.4% oats, 30.0% barley, 13% canola meal, 8.5% soybean meal, 6% molasses, and 3.1% minerals (Ca, 4.2%; P, 2.9%; Na, 2.0%; salt, 5.0%; Mg, 1.0%; Fe, 300 mg/kg; Mn, 500 mg/kg; Zn, 900 mg/kg; I, 4.0 mg/kg; Co, 1.0 mg/kg; F, 250 mg/kg; vitamin A, 100,000 IU/kg; vitamin D₃, 10,000 IU/kg; vitamin E, 200 UI/kg). Salt and a mineral-vitamin mix (Ca, 16.0%; P, 10.0%; Na, 12.0%; salt, 30.0%; Mg, 1.0%; Fe, 5,900 mg/kg; Cu, 6.0 mg/kg; Mn, 1,950 mg/kg; Zn, 5,500 mg/kg; I, 80.0 mg/kg; Co, 20.0 mg/kg; F, < 630.0 mg/kg; > 565,000 IU of vitamin A/kg; > 102,500 IU of vitamin D₃/kg; and > 800 IU of vitamin E/kg) were available free-choice.

Total collection of feces was carried out on wk 5. The lambs were fitted with a canvas bag to collect feces. Samples of feed and orts were taken daily during the feces collection and pooled on a 7-d basis for further analyses, with one pooled sample of feed and orts analyzed for each treatment diet and each lamb, respectively. Daily output of feces was determined, and all feces were frozen daily and accumulated for the 7-d period. Thereafter, a subsample was collected and used for laboratory analyses.

Chemical Analysis

Dry matter of feed ingredients, orts, and feces was determined by oven drying at 105°C. Feces were dried at 55°C for 96 h before analyses. Feed ingredients, orts, and feces were ground to pass a 1-mm screen in a Wiley mill before analyses of fiber and energy. Total N was measured in fresh feed ingredients and orts and in dry feces; samples were mineralized using a mixture of sulfuric and selenious acids as described by Isaac and Johnson (1976). Total N was measured on an autoanalyzer LCHAT (Lachat Instruments, Milwaukee, WI) using the LCHAT method 13-107-06-2-D (Lachat Instruments, 1992) which is a method that uses salicylate, hypochlorite, and sodium nitroprusside. Determination of NDF and ADF was done with the nonsequential procedure of Goering and Van Soest (1970) using sodium sulfite and α -amylase during NDF determination. The ADF residue was mineralized and N was determined as described above to measure the ADFN. Gross energy was measured by combustion in a Parr adiabatic bomb calorimeter (model 1241; Parr Instrument Co., Moline, IL).

Statistical Analyses

All results were subjected to ANOVA using the GLM procedure of SAS (1985) according to a 2×2 factorial design, where lamb was the experimental unit. Data on carcass measurements were analyzed using slaughter weight as a covariant. Data on chemical composition of hays were analyzed using hay

Table 1. Chemical composition of feed ingredients

Item	Conventional hay	Macerated hay	Concentrate	Canola meal
DM, %	88.4	88.3	87.7	90.1
Percentage of DM				
CP	15.3	15.9	19.2	37.4
ADF	32.3	33.0	9.1	19.4
NDF	55.6	54.9	15.9	23.9
N-ADF	.07	.07	—	—
Gross energy, kcal/g of DM	4.55	4.51	4.40	4.68
N-ADF, % of N	2.94	2.72	—	—

as the only source of variation. Significance was declared ($P < .05$) and trends at $P \leq .10$ unless noted otherwise.

Results and Discussion

Concentrations of CP, fiber components, and energy (Table 1) were similar for conventional and macerated hays. In general, maceration has had little effect on chemical composition of timothy (Chiquette et al., 1994; Petit et al., 1994). In contrast, maceration has reduced protein and increased fiber content of alfalfa hay (Hong et al., 1988b), presumably due to greater leaf loss (Savoie, 1988). This would agree with the fact that alfalfa windrows are more fragile than timothy windrows, and that maceration increases field losses of alfalfa with little effect on timothy (Savoie et al., 1993). Harvesting losses are composed mainly of leaves, which contain more protein and less fiber than the whole crop (Savoie, 1988); therefore, maceration would increase leaf and CP loss in alfalfa with little effect on timothy.

Dry matter intake of hay, expressed in grams per day, was similar ($P > .10$) among treatments (Table 2). However, DMI of hay, expressed as percentage of BW, was higher for lambs fed LC compared with HC, and it was higher for lambs fed CO than for those fed MM. Feeding the highest amount of concentrate tended to decrease hay intake (4.5%, $P = .14$) and increased total DMI (8%, $P = .003$). Maceration had no effect on hay and total DMI. These results are in general agreement with the fact that feeding increased amount of concentrate decreases forage DMI (Petit and Castonguay, 1994) and that maceration has increased DMI of hay in some cases (Hong et al., 1988a; Petit et al., 1994) but not in others (Chiquette et al., 1994). Previously, maceration was found to increase DMI due to increased fiber digestibility (Hong et al., 1988a; Petit et al., 1994). Increased DMI was not observed in the present experiment, possibly due to the lack of maceration effect on digestibility.

Daily CP intake was similar among treatments (Table 2). Percentage of CP in the diet was higher for lambs fed LC than for those fed HC, and it was higher

for those fed MM than for those fed CO. Forage intake was decreased on the MM treatment and concentrate intake was constant, resulting in greater CP in the MM diets. Intake of DE was increased by feeding HC compared with LC, but maceration had no effect on DE intake.

Initial BW was similar among treatments (Table 3). Final BW differed among treatments ($P < .01$). The targeted final BW was 43 kg, but lambs fed HC and MM were heavier ($P < .01$) than those fed LC and CO, respectively. This is explained by the fact that lambs were sent to slaughter only once a week and the ADG was 13 to 16% higher ($P < .01$) for lambs fed HC. Feeding a higher amount of concentrate has increased the ADG of growing lambs (Petit and Castonguay, 1994), as observed in the present experiment. Generally, maceration improved weight gain of sheep (Koegel et al., 1992) and milk production of goats (Hong et al., 1988a), although no improvement was observed in the present experiment. The gain:feed was similar for lambs fed MM and those fed CO as a result of similar ($P > .10$) ADG and DMI. The gain:feed was in favor ($P = .05$) of lambs fed HC compared with lambs fed LC as a result of both ADG ($P = .003$) and DMI ($P = .14$) being higher for HC.

Time of fattening was decreased by 10% and age at slaughter tended to be decreased ($P = .08$) by feeding higher amounts of concentrate (Table 3). Similar results were reported by Petit and Castonguay (1994). Time of fattening was statistically similar ($P = .23$) for lambs fed CO and MM. There was an interaction ($P < .08$) between type of harvester and feeding level of concentrate for carcass weight, dressing percentage, and muscular conformation of hind leg roast. In general, the highest values were obtained for lambs fed MMHC and COHC, although values were significantly different for muscular conformation of the hind leg roast; intermediate and similar values were observed for lambs fed COLC and COHC; and lowest values were obtained for lambs fed MMLC, although there was no difference between MMLC and COLC. Feeding 100 to 400 g of concentrate has little effect on carcass characteristics of lambs fed conventional grass silage (Petit and Castonguay, 1994). Differences among treatments suggest that feeding

Table 2. Voluntary intake of lambs fed timothy hay harvested with a prototype mower-macerator or a conventional commercial mower conditioner and supplemented with two levels of concentrate

Item	Treatment ^a				SEM	Effect ^b , <i>P</i> =		
	COLC	COHC	MMLC	MMHC		H	C	H × C
Hay DMI, g/d	976	933	953	909	15	.42	.14	.97
Hay DMI, % of BW	3.07	2.89	2.95	2.74	.03	.04	.03	.78
Total DMI, g/d	1,190	1,284	1,167	1,260	15	.42	.003	.97
Total DMI, % of BW	3.75	3.98	3.62	3.80	.03	.03	.02	.77
CP intake, g/d	212	207	215	212	2	.38	.36	.82
CP intake, % of DM	18.0	16.2	18.7	16.8	.1	.0001	.0001	.84
DE intake, Mcal/d	3.84	4.29	3.61	4.10	.09	.22	.01	.91

^aCOLC = Timothy harvested with a conventional mower conditioner fed with a mixture of 100 g of commercial concentrate and 140 g of canola meal, COHC = timothy harvested with a conventional mower conditioner fed with 400 g of commercial concentrate, MMLC = timothy harvested with a prototype mower-macerator fed with a mixture of 100 g of commercial concentrate and 140 g of canola meal, and MMHC = timothy harvested with a prototype mower-macerator fed with 400 g of commercial concentrate.

^bH = main effect of forage harvester, C = main effect of feeding level of concentrate, and H × C = interaction between main effects.

macerated timothy hay requires higher amounts of concentrate than feeding conventional hay to result in desirable carcass characteristics.

Total tissue depth and carcass lean yield were similar among treatments (Table 3). Muscular conformation of loin tended to improve ($P = .09$) when feeding higher amounts of concentrate, but type of harvester had no effect. This would agree with the hypothesis that consumption at more than 200 g/d of concentrate is required to improve carcass muscling of lambs fed forage-based diet (Petit and Castonguay, 1994). Shoulder and average conformation were similar among treatments.

When digestibility was measured in the 5th wk of feeding by collection of feces, lambs tended ($P = .10$) to have higher DM digestibility for the HC ration than for the LC ration (Table 4). Digestibility of energy also tended ($P = .07$) to be higher for HC than for LC, but DE content of the diet was similar. Digestibilities of DM, N, NDF, and energy were similar for CO and MM. Digestibility of ADF tended ($P = .07$) to be higher for CO than for MM. Higher values of digestibility and digestible energy content of forage were reported by Hong et al. (1988a) and Petit et al. (1994) for sheep fed macerated hay compared with conventional hay. However, Chiquette et al. (1994)

Table 3. Body weight, ADG, gain:feed, and carcass characteristics of lambs fed timothy hay harvested with a prototype mower-macerator or a conventional commercial mower conditioner and supplemented with two levels of concentrate

Item	Treatment ^a				SEM	Effect ^b , <i>P</i> =		
	COLC	COHC	MMLC	MMHC		H	C	H × C
Initial BW, kg	21.4	21.9	22.1	22.5	.3	.38	.55	.90
Final BW, kg	42.1	42.7	42.4	43.8	.2	.008	.0002	.14
ADG, g/d	248	279	241	295	7	.71	.003	.308
Gain:feed	.209	.217	.207	.235	.004	.37	.05	.29
Time of fattening, d	87	76	80	73	2	.23	.05	.68
Age at slaughter, d	155	146	150	143	2	.30	.08	.81
Carcass weight, kg	17.3	17.8	16.9	18.3	.1	.86	.01	.07
Dressing, %	40.6	41.5	39.6	42.9	.3	.79	.01	.07
TTD, mm ^c	8.4	7.7	7.6	7.4	.2	.37	.54	.74
Carcass lean yield, % ^d	58.6	58.8	58.9	58.9	.1	.40	.73	.63
Muscular conformation ^e								
Hind leg roast	2.07	2.37	1.97	2.84	.08	.25	.002	.06
Loin	2.95	3.00	2.85	3.07	.03	.83	.09	.17
Shoulder	2.69	2.87	2.78	3.16	.09	.34	.21	.58
Average	2.75	2.87	2.69	2.94	.07	.98	.30	.65

^aCOLC = Timothy harvested with a conventional mower conditioner fed with a mixture of 100 g of commercial concentrate and 140 g of canola meal, COHC = timothy harvested with a conventional mower conditioner fed with 400 g of commercial concentrate, MMLC = timothy harvested with a prototype mower-macerator fed with a mixture of 100 g of commercial concentrate and 140 g of canola meal, and MMHC = timothy harvested with a prototype mower-macerator fed with 400 g of commercial concentrate.

^bH = main effect of forage harvester, C = main effect of feeding level of concentrate, and H × C = interaction between main effects.

^cTTD = total tissue depth on the left carcass, between the 12th and 13th ribs, and 11 cm from the carcass midline.

^dEstimated lean yield % = $[65.80 - (.074 \times \text{WCW})] - (.432 \text{ GR})$, where WCW = warm carcass weight and GR = $[6.38 + (.88 \times \text{TTD})]$.

^eConformation: coded 1, 2, 3, 4, and 5 to represent extremely deficient, deficient, moderate, good, and excellent muscling.

Table 4. Digestibility of timothy hay harvested with a prototype mower-macerator or a conventional commercial mower conditioner and supplemented with two levels of concentrate

Item	Treatment ^a				SEM	Effect ^b , <i>P</i> =		
	COLC	COHC	MMLC	MMHC		H	C	H × C
Digestibility, %								
DM	73.5	75.6	71.1	74.3	.8	.26	.10	.73
N	73.3	72.8	73.9	73.8	.9	.67	.87	.93
ADF	68.3	69.7	63.9	65.3	1.2	.07	.56	.98
NDF	76.5	72.5	72.5	71.2	1.0	.21	.21	.52
Energy	71.0	73.8	68.9	72.6	.9	.34	.07	.80
Energy value, kcal/g of DE	3.23	3.32	3.09	3.25	.04	.22	.13	.73

^aCOLC = Timothy harvested with a conventional mower conditioner fed with a mixture of 100 g of commercial concentrate and 140 g of canola meal, COHC = timothy harvested with a conventional mower conditioner fed with 400 g of commercial concentrate, MMLC = timothy harvested with a prototype mower-macerator fed with a mixture of 100 g of commercial concentrate and 140 g of canola meal, and MMHC = timothy harvested with a prototype mower-macerator fed with 400 g of commercial concentrate.

^bH = main effect of forage harvester, C = main effect of feeding level of concentrate, and H × C = interaction between main effects.

reported that maceration decreased digestibilities of DM, OM, ADF, and NDF of timothy by mature beef steers.

Requirements of energy and values of NE_m and NE_g of DM were calculated using the equations of NRC (1985). The average metabolic BW and requirements of NE_m (Table 5) were lower ($P = .02$) for lambs fed LC than for those fed HC. The amount of DM used to meet the requirements of NE_m was similar among treatments. Energy available for gain was similar for macerated and conventional hays but higher for diets containing higher amounts of concentrate. Expected ADG tended ($P = .07$) to be higher for

lambs fed HC than for those fed LC, and it was numerically lower ($P = .19$) for lambs fed MM than for those fed CO. The observed ADG was improved when feeding more concentrate, as observed in the theoretical situation. The observed ADG were all higher than expected from energy content of the diets. Requirements of NE_g to obtain the observed ADG were higher for lambs fed higher amounts of concentrate. Efficiency of ME utilization for gain was not affected by the amount of concentrate and the type of hay fed.

In summary, maceration had no effect on DMI and digestibilities of DM, CP, and NDF of hay, or on ADG

Table 5. Efficiency of ME utilization by lambs fed timothy hay harvested with a prototype mower-macerator or a conventional commercial mower conditioner and supplemented with two levels of concentrate

Item	Treatment ^a				SEM	Effect ^b , <i>P</i>		
	COLC	COHC	MMLC	MMHC		H	C	H × C
Average metabolic BW, kg ⁷⁵	15.1	15.4	15.0	15.7	.1	.60	.02	.30
DM intake, g/d	1,190	1,284	1,167	1,260	16	.42	.003	.97
NE_m requirements, kcal ^c	845	860	839	879	6	.60	.02	.30
DM used to meet NE_m , g ^d	488	488	519	504	9	.23	.68	.72
DM available for gain, g ^e	701	796	647	755	23	.27	.02	.88
Energy available for gain, kcal ^f	785	958	678	857	42	.20	.03	.97
ADG expected, g ^g	188	228	164	199	10	.19	.07	.90
ADG observed, g	248	279	241	295	7	.71	.003	.38
NE_g required to obtain ADG, kcal ^h	1,037	1,181	1,000	1,280	34	.59	.001	.25
Efficiency of ME utilization for gain, % ⁱ	56.3	57.3	63.0	65.2	2.5	.15	.76	.90

^aCOLC = Timothy harvested with a conventional mower conditioner fed with a mixture of 100 g of commercial concentrate and 140 g of canola meal, COHC = timothy harvested with a conventional mower conditioner fed with 400 g of commercial concentrate, MMLC = timothy harvested with a prototype mower-macerator fed with a mixture of 100 g of commercial concentrate and 140 g of canola meal, and MMHC = timothy harvested with a prototype mower-macerator fed with 400 g of commercial concentrate.

^bH = main effect of forage harvester, C = main effect of feeding level of concentrate, and H × C = interaction between main effects.

^c NE_m requirements = 56 kcal × average metabolic BW (NRC, 1985).

^dDM used to meet NE_m requirements = NE_m requirements/ NE_m of DM (NRC, 1985).

^eDM available for gain = observed DMI - DM used to meet NE_m requirements (NRC, 1985).

^fEnergy available for gain = DM available for gain × NE_g of DM (NRC, 1985).

^gADG = [(Energy available for gain/276) × BW^{-0.75}] × 1,000 (NRC, 1985).

^h NE_g required to obtain ADG = 276 × metabolic BW × ADG (NRC, 1985).

ⁱEfficiency of ME utilization for gain = NE_g required/(DM available for gain × ME of DM) (NRC, 1985).

and gain:feed. Feeding a higher amount of concentrate improved DM digestibility and ADG. The best carcass characteristics were obtained by feeding macerated timothy hay with the highest amount of concentrate. Feeding level of concentrate had no effect on the efficiency of ME utilization for gain.

Implications

There is no advantage of feeding macerated timothy hay to growing lambs because maceration has no effect on average daily gain, dry matter intake, and gain:feed. However, the benefits of macerated timothy hay and higher amounts of concentrate on carcass quality are additive.

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