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Schulze, Anne-Katrine Skovsted; Weisbjerg, Martin Riis; Storm, Adam Christian; Nørgaard, Peder

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Effects of chopping grass silage and of mixing silage with concentrate on feed intake and performance in pregnant and lactating ewes and in growing lambs

Carl Helander[a,∗], Peder Nørgaard[b], Annika Arnesson[a], Elisabet Nadeau[a]

[a] Department of Animal Environment and Health, Swedish University of Agricultural Sciences, P.O. Box 234, SE-532 23 Skara, Sweden
[b] Department of Basic Animal and Veterinary Sciences, Faculty of Health and Medical Sciences, University of Copenhagen, Grønnegårdsvej 3, 1870 Frederiksberg C, Denmark

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ABSTRACT

The effects of chopping grass silage and of mixing grass silage with concentrate on feed intake and performance in pregnant and lactating ewes, and in growing lambs were studied in two experiments (Exp. 1 and Exp. 2). The three experimental diets used in both experiments were: (1) unchopped grass silage and 0.8 kg/d concentrate, fed separately (US); (2) chopped grass silage and 0.8 kg/d concentrate, fed separately (CS); and (3) chopped grass silage mixed with concentrate to the same forage:concentrate ratio as in the CS treatment (CM). Twin bearing/suckling ewes ($n = 7$ per treatment) were individually penned and individually fed during the experiments. The lambs were penned and fed in twin pairs after weaning. The silages used in Experiments 1 and 2 contained 583 and 353 g dry matter (DM) per kg, and 10.9 and 11.4 MJ ME, 139 and 193 g CP, and 580 and 483 g NDF per kg DM, respectively. In Exp. 1, daily DM intake (DMI) by ewes and LWG of lambs were unaffected by chopping silage or mixing silage and concentrate ($P > 0.05$). In Exp. 2, the daily DMI by lactating ewes was 0.6 kg higher in the mixed diet compared with the separate diets (4.4 vs. 3.8 kg; $P < 0.05$). Suckling lambs on the chopped diets in Exp. 2, had 38 g higher daily live weight gain (LWG) than those on the unchopped diet (424 vs. 386 g; $P < 0.05$), whereas suckling lambs on the mixed diet had 63 g higher daily LWG than those on the separate diets (454 vs. 391 g; $P < 0.001$) resulting in 11 days younger age at slaughter ($P < 0.01$). Weaned lambs fed the chopped diets in Exp. 2, had 71 g higher daily LWG than those on the unchopped diets (444 vs. 373 g; $P < 0.01$) resulting in 9 days younger age at slaughter ($P < 0.05$). Averaged over treatments, the daily silage DMI of ewes increased from 1.9 to 2.8 kg in Exp. 1 and from 2.0 to 3.3 kg in Exp. 2 from late pregnancy to lactation. It was concluded that chopping highly digestible grass silage and mixing it with concentrate can increase the DMI of ewes and improve the performance of their lambs.

1. Introduction

Feeding conserved forages during winter is common practice in lamb production in parts of the world where year-round grazing is not possible. In the Nordic countries, sheep in intensive production systems are fed grass silage indoors for approximately half of the year. The silage digestibility and particle size are important factors for feed intake and performance in sheep (Cannas, 2002).

By decreasing grass silage particle size from long (250–370 mm) to intermediate (70–120 mm) and further to short (15–20 mm) or very short (5–15 mm), feed intake is increased in pregnant ewes (Apolant and Chestnutt, 1985;

∗ Corresponding author. Tel.: +46 51167131; fax: +46 51167134.
E-mail addresses: Carl.Helander@slu.se, carlhelander@gmail.com (C. Helander).

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Elizalde and Henríquez, 2009) and lactating ewes (Elizalde and Henríquez, 2009), as is live weight gain (LWG) of suckling lambs (Apolant and Chestnutt, 1985) and feed intake and daily LWG in weaned lambs (Fitzgerald, S., 1984; Fitzgerald, J.J., 1996a,b,c). The increased feed intake can improve body condition score (BCS) in pregnant ewes (Elizalde and Henríquez, 2009), ewe body weight (BW) after lambing and lamb birth weight and LWG of suckling lambs (Apolant and Chestnutt, 1985). Increased digestibility of grass silage has been shown to increase feed intake and to better maintain BW and BCS in pregnant and lactating ewes and to increase LWG of lambs until weaning (Nadeau and Arnesson, 2008).

Feeding systems with mixed rations are mainly used for large sheep flocks, where rational systems for feeding forages and concentrates indoors are most needed. However, feeding of mixed rations, based on grass silage, to sheep has not been thoroughly investigated. The only published study we found showed improved BCS and BW during late pregnancy in ewes fed a mixed ration compared with ewes fed precision-chopped silage and concentrate separately (Chestnutt and Wylie, 1995).

In intensive indoor production in Sweden, lambs are commonly slaughtered at 3–4 months of age, at a carcass weight of ca. 20 kg. In this intensive system with daily LWG of ca. 400 g, there is an obvious demand for high feed efficiency using high quality feeds for both ewes and lambs. Consequently, it is important to evaluate the effects of chopping silage and of feeding mixed rations to ewes in late pregnancy and lactation, when they have high nutritional demands.

The hypotheses for this study were that chopping silage and mixing silage with concentrate increases feed intake in pregnant and lactating ewes, resulting in a better maintained BW and BCS of the ewes, and in increased feed intake and LWG of lambs. The overall aim of the study was to evaluate the effects of chopping grass silage and of mixing grass silage with concentrate on feed intake, BW and BCS in pregnant and lactating ewes and on feed intake, LWG and carcass characteristics in intensively reared lambs. The effect of between-year variation in e.g. silage quality on feed intake, BW and BCS of ewes and on LWG of their lambs was also evaluated.

2. Materials and methods

Two experiments were carried out, Experiment 1 (Exp. 1) in 2008 and Experiment 2 (Exp. 2) in 2009, at Götala Beef and Lamb Research Centre (58°22′ N, 13°29′ E, altitude 120 m above sea level), Swedish University of Agricultural Sciences, Skara, Sweden. The experimental procedures used in these studies were approved by the Research Animal Ethics Committee (Swedish Animal Welfare Agency).

2.1. Animals, feeding and experimental design

Twin-bearing Swedish Finewool × Dorset ewes, mated with a Texel ram, were selected from a commercial farm around eight weeks prior to lambing, taking age (3–5 years old) and BCS into consideration. In each experiment, 21 ewes were housed in individual straw-bedded pens (6.0 m^2) until the lambs were weaned. As the ewes lambed on different dates, the adaptation period to the experimental feeds varied between 14 and 28 days in both experiments. Experimental start was set to 28 days prior to lambing in both experiments and for all ewes.

After weaning (end of lactation), the lambs were studied until slaughter at approximately 15 weeks of age. The ewes were removed from the pens at weaning and their lambs were kept in the same pen until slaughter. Consequently, the lambs were penned and fed as twin pairs from weaning to slaughter.

The experiment had a completely randomised design, with the ewes divided into three groups of seven ewes per treatment, accounting for ewe BW, BCS and age, to make the groups as similar as possible. The groups were then randomly allocated to three different dietary treatments. The experimental diets were: (1) unchopped grass silage and 0.8 kg concentrate, fed separately (US); (2) chopped grass silage and 0.8 kg concentrate, fed separately (CS); and (3) chopped grass silage mixed with concentrate to the same forage:concentrate ratio as in the CS treatment (CM). In the US and CS treatments the silages were fed *ad libitum*, while in the CM treatment the mixture of forage and concentrate was fed *ad libitum*, allowing refusals of 10–15% of offered feed. The particle length of the unchopped silage was 170 ± 110 mm in Exp. 1 and 349 ± 169 mm in Exp. 2, while the mean particle length of the chopped silage was 13 ± 2.7 mm in Exp. 1 and 18 ± 2.3 mm in Exp. 2. Silage feeding was divided between two occasions, the first at 10 a.m. and the second at 4 p.m. The daily concentrate supplementation in the US and CS treatments was kept constant at 0.8 kg during pregnancy and lactation in both experiments and was fed just before morning silage feeding.

The BW at start of the experiments were 77.8, 77.8 and 77.6 in Exp. 1 and 83.0, 83.5 and 84.5 in Exp. 2, for US, CS and CM, respectively. The BCS at start of the experiments were 3.1, 3.1 and 3.2 in Exp. 1 and 3.4, 3.3 and 3.7 in Exp. 2, for US, CS and CM, respectively. In both experiments, lambing occurred from the middle of January to the beginning of February. From two weeks of age, the lambs had access to pens (15 m^2) separate from the ewe, which they shared with four to six other lambs from the same treatment and where they were offered a maximum of 1.0 kg concentrate per lamb until weaning. The lambs were assigned to the same treatment as their mother from weaning at 52 ± 3.1 and 56 ± 5.8 days of age, until slaughter at 102 ± 10.4 and 101 ± 13.2 days of age in Exp. 1 and Exp. 2, respectively. At slaughter, the lambs were given a conformation score according to the EUROP scale, where E to O is the approved interval, and a fatness score from 1− to 5+ where 2−, 2, 2+, 3− and 3 are the approved scores in Sweden. The lambs in treatments US and CS were offered 1.0 kg of concentrate per lamb and day from weaning to slaughter, whereas the CM lambs received a mixed ration with the same forage:concentrate ratio as in the CS treatment.

As the daily quantity of concentrate fed to the US and CS ewes (and US and CS lambs after weaning) remained constant throughout the experiments, the forage:concentrate ratio varied over time. The forage:concentrate ratio in the CM treatment was changed every four-five days to the same forage:concentrate ratio as in the CS treatment, during the previous three days.

2.2. Feeds

The grass silage was produced from a sward consisting mainly of perennial ryegrass (*Lolium perenne* L.), timothy (*Phleum pratense* L.) and meadow fescue (*Festuca pratensis* L.). In Exp. 1, the grass was harvested as a first cut in the beginning of June. In Exp. 2, the grass was harvested as a second cut in the middle of July. In both experiments, the herbage was ensiled unchopped in round bales, which were wrapped with eight layers of plastic film. The chopped silage used in treatments CS and CM was chopped after ensiling, prior to feeding, using a Dunker TV2 cutter/mixer wagon with one vertical mixing auger (Storti, 2012). The silage and concentrate in the CM treatment were mixed using a Cormall stationary mixer with one mixing auger (Cormall, 2012).

The concentrate fed to the ewes in both experiments consisted of 184 g wheat, 174 g heat-treated rapeseed meal, 162 g beet pulp, 50 g dried distillers' grain, 87 g wheat middlings, 33 g barley, 67 g wheat bran, 65 g soy bean meal, 81 g oats, 35 g beet molasses, 16 g triticale, 19 g $CaCO_3$, 13 g fatty acids, 6 g oat bran, 6 g NaCl, 1 g MgO, 6500 IU Vit A, 1000 IU Vit D3, 75 mg Vit E and 0.4 mg NaSe per kg DM.

The concentrate fed to the lambs consisted, on average over the two experiments, of 181 g heat-treated rapeseed meal, 137 g triticale, 123 g oats, 50 g maize fodder meal, 95 g dried distillers' grain, 93 g beet pulp, 38 g wheat, 35 g heat-treated palm kernel, 50 g wheat middlings, 53 g soy bean meal, 21 g malt sprouts, 30 g barley, 24 g beet molasses, 27 g wheat bran, 20 g NaCl, 21 g $CaCO_3$, 6500 IU Vit A, 1000 IU Vit D3, 75 mg Vit E and 0.4 mg NaSe per kg DM.

2.3. Recordings and sampling

The ewes were weighed on two consecutive days at the start and at the end of the experiments and both ewes and lambs were weighed on a scale with 0.5 kg precision once a week during the experiments. In addition, the BCS of the ewes was recorded once weekly throughout the experiments according to Jefferies (1961) as modified by Russel et al. (1969), using a five-point scale with quarter-grade steps, where 5 is obese and 1 is emaciated. The time of slaughter of lambs was based on a minimum live weight (LW) of 45 kg for males and 40 kg for females and the probable fat content in the carcass was estimated by manual assessment by palpating the ribs just behind the front legs during weighing of live lambs.

Offered and refused feedstuffs from ewes and lambs were weighed daily per pen. Samples of feed were taken daily and feed refusals were sampled individually three days per week, pooled to one composite sample for each feed and kept frozen until analysis. Concentrates were sampled twice during late pregnancy and lactation and stored at −25 °C until analysis for chemical composition (Tables 1 and 2). Samples of the unchopped and chopped silages were taken once weekly and pooled to two composite samples per silage before analysis of fermentation characteristics. Daily samples of feed and refusals were pooled into one feed and one refusal sample per treatment and week for determination of dry matter (DM) intake. Additional samples of feeds and refusals were stored at −25 °C and pooled into monthly samples for analysis of chemical composition.

For intake presented as percentage of BW, the BW of the ewe one week after lambing was used, whereas for the lambs the mean BW of the whole period was used. Dietary selection of the concentrate in the CM treatment was determined by analysis of the starch level in the refusals. By knowing the proportion of starch in both feed and refusals, the proportion of concentrate was calculated. In all treatments, some of the feed allocated to the ewes during end of lactation were consumed by the lambs, but such lamb intake was not recorded and was assumed to be equal over treatments.

2.4. Chemical analyses

The monthly composite samples of feed and refusals were analysed for contents of DM, neutral detergent fibre (NDF), ash, CP and in vitro organic matter digestibility (IVOMD). The DM was determined by drying the samples in a drying cabinet at 60 °C for 24 h. The NDF was analysed using an ANKOM[220] fibre analyser (Ankom Technology, Macedon, NY, USA) following the method described by Van Soest et al. (1991). Heat-stable α-amylase was included in the analysis, whereas sodium sulphite was omitted. Results are expressed on an ash-free basis. Ash content was determined at 550 °C for 16 h. Total nitrogen content was analysed using the Kjeldahl nitrogen determination and CP was calculated as total N × 6.25. The IVOMD of the silage was analysed according to Lindgren (1979) and metabolisable energy (ME) was calculated from IVOMD according to Lindgren (1983, 1988). Starch was analysed according to Larsson and Bengtsson (1983). Composite silage samples were thawed and water was added in 1:1 ratio before storing samples at <8 °C overnight. The juice pressed out of the samples, using a hydraulic press, was analysed for fermentation products. Concentrations of lactate, butyrate, acetate, propionate and ethanol were measured using HPLC (Andersson and Hedlund, 1983). Ammonium nitrogen was quantified using an auto-analyser system (Broderick and Kang, 1980). The pH was determined with a Metrohm 654 pH metre (Metrohm AG, Herisau, Switzerland).

2.5. Statistical analyses

Data were analysed statistically in a completely randomised design, using the mixed procedure of SAS (SAS system for Windows, release 9.2; SAS Institute Inc., Cary, NC, USA). In the original analysis, data from both experiments were included in the model. As there were significant interactions between experiment, treatment and physiological status (PS; late pregnancy and lactation) for most of the variables studied, each experiment was analysed separately. Treatment and PS were fixed effects, whereas ewe was treated as a random effect nested within treatment. For a significant *F*-test ($P < 0.05$), pair-wise comparisons between least square means of treatments were made according to Tukey's post hoc test. Contrasts were

Table 1
Chemical composition of silage (unchopped and chopped) and concentrates fed to ewes in Experiments (Exp.) 1 and 2.

	Unchopped silage		Chopped silage		Concentrate	
	Exp. 1	Exp. 2	Exp. 1	Exp. 2	Exp. 1	Exp. 2
DM, g/kg	560	335	580	365	861	871
Ash, g/kg DM	91	92	94	96	82	74
NDF, g/kg DM	580	483	578	480	260	267
CP, g/kg DM	141	187	145	191	205	209
IVOMD[a], g/kg	870	920	860	900	–	–
ME[b], MJ/kg DM	11.0	11.6	10.7	11.3	12.2	12.8
Lactate, g/kg DM	52	73	43	63	–	–
Acetate, g/kg DM	2.0	16	<0.1	14	–	–
Propionate, g/kg DM	0.0	<0.3	0.0	<0.3	–	–
Butyrate, g/kg DM	0.0	0.5	0.0	1.1	–	–
Ethanol, g/kg DM	13	6	14	4	–	–
NH_3–N, g/kg total N	58	69	72	72	–	–
pH	5.7	4.6	5.7	4.7	–	–

For concentrate, $n = 1$. For silage, in both experiments, analysis of acids, ethanol, NH_3–N and pH, $n = 2$. In Exp. 1, for DM, CP, NDF, ME and IVOMD, $n = 4$ in both silages. In Exp. 2, for DM, CP, NDF, ME and IVOMD in unchopped silage, $n = 3$ and in chopped silage, $n = 4$. The starch content of the concentrate was 217 and 232 g/kg DM in Exp. 1 and Exp. 2, respectively.

[a] In vitro organic matter digestibility.

[b] Metabolisable energy.

Table 2
Chemical composition of silage (unchopped and chopped) and concentrates fed to lambs in Experiments (Exp.) 1 and 2.

	Unchopped silage		Chopped silage		Concentrate	
	Exp. 1	Exp. 2	Exp. 1	Exp. 2	Exp. 1	Exp. 2
DM, g/kg	595	350	595	363	878	886
Ash, g/kg DM	99	97	92	94	86	84
NDF, g/kg DM	585	482	578	486	270	273
CP, g/kg DM	134	204	136	191	211	209
IVOMD[a], g/kg	880	900	870	900	–	–
ME[b], MJ/kg DM	11.0	11.2	10.7	11.3	12.2	12.4
Lactate, g/kg DM	48	76	47	76	–	–
Acetate, g/kg DM	0.2	14.6	0.8	15.1	–	–
Propionate, g/kg DM	0.0	<0.3	0.0	<0.3	–	–
Butyrate, g/kg DM	0.0	0.7	0.0	1.8	–	–
Ethanol, g/kg DM	10.5	3.7	14.8	4.4	–	–
NH_3–N, g/kg total N	63	95	89	86	–	–
pH	5.8	4.7	5.7	4.6	–	–

In both experiments, for analysis of concentrates and silages regarding acids, ethanol, NH_3–N and pH, $n = 1$. In Exp. 1, for DM, CP, NDF, ME and IVOMD, $n = 2$. In Exp. 2, for DM, CP, NDF, ME and IVOMD, $n = 3$.
The starch content of the concentrate was 207 and 243 g/kg DM in Exp. 1 and Exp. 2, respectively.

[a] In vitro organic matter digestibility.

[b] Metabolisable energy.

used for analysis of unchopped vs. chopped diets (US vs. CS and CM) and separate vs. mixed diets (US and CS vs. CM). Contrasts were done within pregnancy and within lactation for the ewe data and on the treatment effect for the lamb data. The *P*-values are shown in tables as *** ($P < 0.001$), ** ($P < 0.01$), * ($P < 0.05$) or ns (not significant, $P > 0.05$).

3. Results

3.1. Feed intake of ewes

During pregnancy, in Experiments 1 and 2, no feed intake parameters were affected by chopping silage or mixing silage and concentrate ($P > 0.10$; Tables 3 and 4). During lactation in Exp. 1, the mixed diet increased the daily CP intake by 47 g compared with the separate diets ($P < 0.05$; Table 3). During lactation in Exp. 2, mixing of feed significantly increased intake of silage and total DM, silage and total NDF and total CP and ME ($P < 0.05$; Table 4).

The daily DMI, averaged over treatments, did not change from 28 to 3 days before lambing ($P = 0.9$ in Exp. 1 and Exp. 2). During the last two days prior to lambing in Exp. 1, both chopping and mixing decreased daily DMI by 0.4 kg compared with the unchopped diet and the separate diets, respectively ($P < 0.05$; Fig. 1a and b).

The daily increase in DMI from day 1 to 10 of lactation, in Exp. 1, was 0.03 kg higher in the chopped diets than in the unchopped diet ($P < 0.05$). In Exp. 2, the daily increase in DMI was 0.08 kg and the daily DMI was 3.4 kg, averaged over treatments.

Averaged over treatments in Exp. 1, the daily DMI was 3.5 kg from day 11 to 20 and 3.6 kg from day 21 to 42 of lactation. From day 11 to 20 of lactation in Exp. 2, the chopped diets increased daily DMI by 0.5 kg compared with the unchopped diet ($P < 0.05$) and the mixed diet increased

Table 3
Effects of feeding unchopped silage and concentrate separately (US), chopped silage and concentrate separately (CS) or chopped silage mixed with concentrate (CM) on intake, body weight (BW) and body condition score (BCS) during late pregnancy and lactation of ewes in Experiment 1.

											Contrasts, *P*-values			
Physiological status (PS)	Late pregnancy			Lactation				*P*–values			Late pregnancy		Lactation	
Treatment (T)	US	CS	CM	US	CS	CM	SEM	PS	T	PS × T	US vs. CS + CM	US + CS vs. CM	US vs. CS + CM	US + CS vs. CM
Silage intake														
DM, kg/day	1.88	1.83	1.95	2.74	2.71	2.88	0.09	***	ns	ns	ns	ns	ns	ns
DM, % of BW	2.09	2.07	2.17	3.07	3.07	3.24	0.10	***	ns	ns	ns	ns	ns	ns
NDF, % of BW	1.17	1.24	1.23	1.78	1.80	1.83	0.06	***	ns	ns	ns	ns	ns	ns
Total intake														
DM, kg/day	2.56	2.52	2.49	3.43	3.40	3.64	0.10	***	ns	ns	ns	ns	ns	ns
DM, % of BW	2.86	2.86	2.77	3.84	3.85	4.09	0.12	***	ns	ns	ns	ns	ns	ns
NDF, g/day	1230	1272	1243	1763	1769	1829	54	***	ns	ns	ns	ns	ns	ns
NDF, % of BW	1.37	1.44	1.39	1.98	2.01	2.05	0.06	***	ns	ns	ns	ns	ns	ns
CP, g/day	430	419	405	548	542	593	15	***	ns	ns	ns	ns	ns	*
ME[a], MJ/day	29.4	27.4	28.1	38.1	37.6	40.4	1.1	***	ns	ns	ns	ns	ns	ns
BW, kg														
Mean	98.3	97.7	97.4	86.6	87.0	88.0	3.6	***	ns	ns	ns	ns	ns	ns
Change	10.0	9.7	8.3	−7.5	−2.2	−3.5	1.5	***	ns	ns	ns	ns	*	ns
BCS														
Mean	3.1	3.1	3.2	2.6	2.6	2.8	0.1	***	ns	ns	ns	ns	ns	ns
Change	0.0	−0.1	0.0	−1.0	−0.8	−0.8	0.1	***	ns	ns	ns	ns	ns	ns

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. ns = not significant ($P > 0.05$). For US, CS, and CM, $n = 7$.
[a] Metabolisable energy.

Table 4
Effects of feeding unchopped silage and concentrate separately (US), chopped silage and concentrate separately (CS) or chopped silage mixed with concentrate (CM) on intake, body weight (BW) and body condition score (BCS) during late pregnancy and lactation of ewes in Experiment 2.

											Contrasts, *P*-values			
Physiological status (PS)	Late pregnancy			Lactation				*P*–values			Late pregnancy		Lactation	
Treatment (T)	US	CS	CM	US	CS	CM	SEM	PS	T	PS × T	US vs. CS + CM	US + CS vs. CM	US vs. CS + CM	US + CS vs. CM
Silage intake														
DM, kg/day	1.92	2.03	2.02	3.04	3.18	3.55	0.15	***	ns	ns	ns	ns	ns	*
DM, % of BW	2.17	2.17	2.18	3.46	3.41	3.86	0.13	***	ns	ns	ns	ns	ns	*
NDF, % of BW	1.02	1.01	1.04	1.64	1.67	1.88	0.06	***	ns	ns	ns	ns	ns	**
Total intake														
DM, kg/day	2.62	2.73	2.64	3.73	3.87	4.36	0.16	***	ns	*	ns	ns	ns	*
DM, % of BW	2.96	2.92	2.85	4.25	4.16	4.75	0.14	***	ns	*	ns	ns	ns	**
NDF, g/day	1090	1129	1131	1623	1743	1947	77	***	ns	*	ns	ns	*	*
NDF, % of BW	1.23	1.21	1.22	1.85	1.87	2.12	0.07	***	ns	ns	ns	ns	ns	**
CP, g/day	540	541	537	707	754	811	31	***	ns	*	ns	ns	ns	*
ME[a], MJ/day	31.2	32.0	30.1	44.8	44.3	50.9	1.9	***	ns	**	ns	ns	ns	*
BW, kg														
Mean	96.1	97.9	98.0	89.1	93.5	92.5	3.2	***	ns	ns	ns	ns	ns	ns
Change	11.0	17.9	17.4	0.3	0.7	1.1	1.5	***	*	ns	**	ns	ns	ns
BCS														
Mean	3.3	3.3	3.6	2.8	3.0	3.1	0.1	***	ns	ns	ns	ns	ns	ns
Change	−0.1	0.00	−0.3	−0.7	−0.4	−0.7	0.01	***	*	ns	ns	ns	ns	ns

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. ns = not significant ($P > 0.05$). For US, CS, and CM, $n = 7$.
[a] Metabolisable energy.

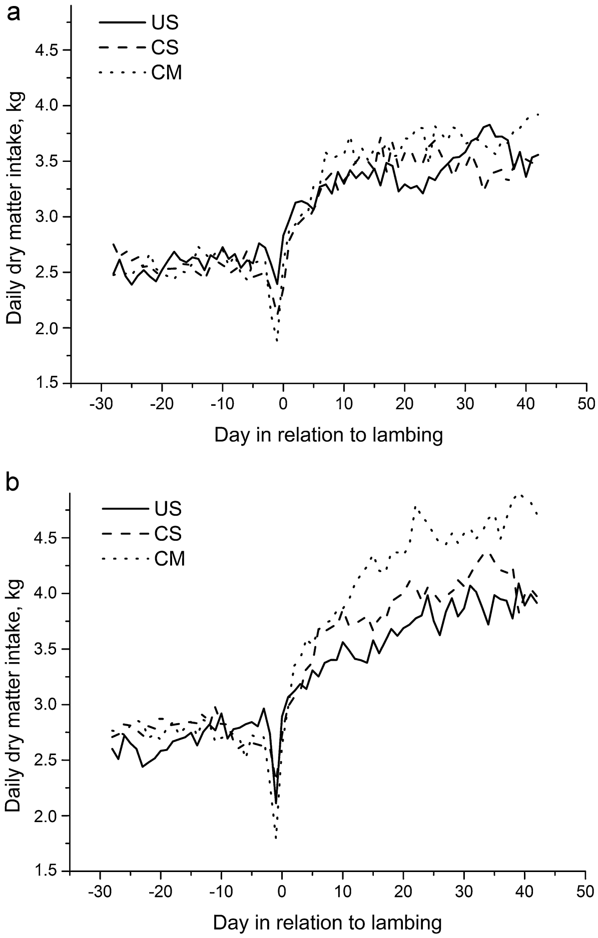

Fig. 1. Daily dry matter intake of twin bearing/suckling ewes fed unchopped silage and concentrate separately (US), chopped silage and concentrate separately (CS) or chopped silage and concentrate mixed (CM) in late pregnancy and lactation in (a) Experiment 1 and (b) Experiment 2.

daily DMI by 0.6 kg compared with the separate diets from day 11 to 42 ($P < 0.05$; Fig. 1a and b).

Averaged over treatments and PS, the ewes increased their silage DMI from 1.9 to 2.8 kg in Exp. 1 and from 2.0 to 3.3 kg in Exp. 2 from late pregnancy to lactation, resulting in increased intakes of NDF, CP and ME in lactation compared with late pregnancy (Tables 3 and 4, Fig. 1a and b).

3.2. *Body weight and body condition of ewes*

During late pregnancy in Exp. 1, the ewes gained 9.3 kg and lost 0.05 units of body condition, when averaged over treatments. In the same period in Exp. 2, ewes fed the chopped diets gained 6.6 kg more BW than those fed the unchopped diet ($P < 0.01$).

During lactation in Exp. 1, the ewes on the unchopped diet lost more BW than those on the chopped diets (7.5 vs. 2.9 kg; $P < 0.05$). In Exp. 2, the ewes gained 0.7 kg during lactation, averaged over treatments. Ewes lost on average 0.8 and 0.6 units of body condition during lactation in Exp. 1 and Exp. 2, respectively. The BCS at end of lactation in Exp. 2, was 0.3 points lower in ewes on the unchopped diet compared with those on the chopped diets (2.5 vs. 2.8; $P < 0.05$), whereas no difference was found in Exp. 1 (2.1 vs. 2.3; $P > 0.1$; Tables 3 and 4).

3.3. *Daily feed intake of lambs*

From birth to weaning, the average individual concentrate intake by the lambs was 7.5, 12.0 and 10.8 kg DM in Exp. 1 and 9.2, 9.1 and 7.5 kg DM in Exp. 2 for the US, CS and CM treatment, respectively. As lambs were fed group-wise until weaning, no statistical comparisons on feed intake were made for this period.

The daily nutrient intake per lamb from weaning to slaughter was 1.2 and 1.2 kg DM, 417 and 411 g NDF, 227 and 263 g CP and 14.2 and 15.1 MJ ME in Exp. 1 and Exp. 2, respectively, when averaged over treatments. No

Table 5
Effects of feeding unchopped silage and concentrate separately (US), chopped silage and concentrate separately (CS) or chopped silage mixed with concentrate (CM) on live weight, live weight gain and carcass traits of lambs in Experiment 1.

	Feed treatment (T)			SEM	Sex (S)		SEM	*P*-values		Contrasts, *P*-values	
	US	CS	CM		♀	♂		T	S	US vs. CS + CM	US + CS vs. CM
Live weight, kg											
At birth	5.4	5.5	5.5	0.2	5.3	5.7	0.15	ns	*	ns	ns
At weaning	25.2	25.8	27.3	0.8	25.1	27.1	0.6	ns	*	ns	ns
At slaughter	45.3	44.4	45.6	0.7	43.7	46.5	0.5	ns	**	ns	ns
Daily live weight gain, g											
Birth to weaning	384	399	415	11	382	418	9	ns	*	ns	ns
Weaning to slaughter	384	370	379	16	347	408	13	ns	**	ns	ns
Birth to slaughter	383	386	401	8	366	414	7	ns	***	ns	ns
Carcass traits											
Dressing, %	42.0	42.3	43.8	0.6	42.7	42.7	0.5	ns	ns	ns	*
Carcass weight, kg	19.0	18.7	19.9	0.3	18.7	19.7	0.2	**	**	ns	**
Conformation[a]	9.5	8.8	8.9	0.3	8.7	9.4	0.2	ns	*	ns	ns
Fatness[b]	7.0	7.9	8.1	0.3	8.1	7.3	0.2	*	**	**	ns
Age at slaughter, days	105	102	101	3	106	99	2	ns	ns	ns	ns

$P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. ns = not significant ($P > 0.05$). For US and CM, $n = 14$, for CS, $n = 12$.

[a] Conformation at slaughter = EUROP scale ($P^- = 1$, $R = 8$, $E^+ = 15$, where 5–15 is the approved interval).

[b] Fatness at slaughter, with 1– = 1, 3 = 8, 5+ = 15, where 4–8 is the approved interval.

Table 6
Effects of feeding unchopped silage and concentrate separately (US), chopped silage and concentrate separately (CS) or chopped silage mixed with concentrate (CM) on live weight, live weight gain and carcass traits of lambs in Experiment 2.

	Feed treatment (T)			SEM	Sex (S)		SEM	*P*-values		Contrasts, *P*-values	
	US	CS	CM		♀	♂		T	S	US vs. CS + CM	US + CS vs. CM
Live weight, kg											
At birth	5.2	5.4	5.7	0.2	5.2	5.6	0.2	ns	*	ns	ns
At weaning	26.9	28.2	29.9	0.8	26.8	29.9	0.6	ns	**	ns	*
At slaughter	44.7	47.3	45.7	0.4	43.7	48.0	0.3	**	***	**	ns
Daily live weight gain, g											
Birth to weaning	386	395	454	12	391	433	9	**	***	*	***
Weaning to slaughter	373	450	437	16	361	479	13	**	***	**	ns
Birth to slaughter	383	425	445	11	379	456	9	**	***	**	**
Carcass traits											
Dressing, %	44.7	43.6	45.9	0.8	44.1	45.4	0.6	ns	ns	ns	ns
Carcass weight, kg	20.0	20.5	20.8	0.4	19.7	21.2	0.2	ns	***	ns	ns
Conformation[a]	10.1	10.9	10.4	0.4	10.3	10.6	0.3	ns	ns	ns	ns
Fatness[b]	7.8	7.7	8.2	0.2	8.3	7.6	0.2	ns	**	ns	ns
Age at slaughter, days	104	99	91	3	103	93	2	**	**	*	**

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. ns = not significant ($P > 0.05$). For US and CM, $n = 12$, for CS, $n = 13$.
[a] Conformation at slaughter = EUROP scale ($P^- = 1$, $R = 8$, $E^+ = 15$, where 5–15 is the approved interval).
[b] Fatness at slaughter, with 1− = 1, 3 = 8, 5+ = 15, where 4–8 is the approved interval.

significant differences in feed intake were found between the treatments.

3.4. Dietary selection

As a measure of dietary selection, proportion of concentrate and silage in feed offered and in refusals of the CM treatment was analysed. Both the ewes and the lambs selected the concentrate, but to a larger extent in Exp. 1 than in Exp. 2. For the ewes, the concentrate proportion was 69 and 47% lower in the refusals than in the feed offered in Exp. 1 and Exp. 2, respectively. For the lambs, the concentrate proportion was 72 and 50% lower in the refusals than in the feed offered in Exp. 1 and Exp. 2, respectively.

3.5. Live weight gain and carcass characteristics of lambs

No significant interactions between treatments and sex were observed in either experiment for lamb live weight (LW), daily LWG or carcass characteristics and the effects of treatment and sex are considered separately.

In Exp. 1, the mixed diet increased carcass weight by 1.1 kg ($P < 0.01$) and dressing percentage by 1.6%-units ($P < 0.05$) compared with the separate diets and the chopped diets increased carcass fatness by 1.0 point compared with the unchopped diet ($P < 0.01$; Table 5).

In Exp. 2, the chopped diets increased daily LWG by 38 g from birth to weaning ($P < 0.05$) and by 71 g from weaning to slaughter ($P < 0.01$), resulting in 52 g higher daily LWG from birth to slaughter ($P < 0.01$), compared with the unchopped diet. The mixed diet increased the daily LWG from birth to weaning by 63 g ($P < 0.001$) and from birth to slaughter by 41 g ($P < 0.01$) compared with the separate diets. At slaughter, the lambs fed chopped diets had 1.8 kg higher LW ($P < 0.01$) and were 9 days younger ($P < 0.05$), compared with the unchopped diet. The lambs fed the mixed diet were 11 days younger at slaughter than the lambs fed separate diets ($P < 0.01$; Table 6).

Male lambs had higher LW at birth (8%), weaning (12%) and slaughter (10%) in both experiments, resulting in higher daily LWG than for female lambs, but the difference in daily LWG between the sexes was smaller from birth to weaning (36 and 42 g) than from weaning to slaughter (61 and 118 g, in Exp. 1 and Exp. 2, respectively). In Exp. 1, the female lambs had 9% higher carcass fat score ($P < 0.01$), had 1 kg lighter carcass weight ($P < 0.01$) and 0.7 units lower carcass conformation score than the male lambs ($P < 0.05$), when averaged over treatments (Table 5). In Exp. 2, female lambs had 8% higher fatness score ($P < 0.01$), were 10 days older ($P < 0.01$) and had 1.5 kg lighter carcass weights than male lambs ($P < 0.001$; Table 6), when averaged over treatments.

4. Discussion

4.1. Effects of chopping silage

4.1.1. Pregnant ewes

The daily feed intake was not clearly affected by chopping silage, as earlier studies indicate (Apolant and Chestnutt, 1985; Chestnutt, 1989; Elizalde and Henríquez, 2009). Even though not possible to fully elucidate the reason for the dissimilar responses, likely suggestions are the different ensiling managements, i.e. the forages in the previous studies were chopped before ensiling/storing, which improves the ensiling process and increases silage digestibility (Huhtanen et al., 2002), leading to increased feed intake in pregnant ewes (Keady et al., 2013; Nadeau and Arnesson, 2008). Furthermore, improved fermentation of silage also has a direct effect on DMI by ruminants (Huhtanen et al., 2002). Thus, the response to chopping cannot be separated from the effect of the silage fermentation characteristics in the previous studies (Apolant and Chestnutt, 1985; Chestnutt, 1989; Elizalde and Henríquez, 2009). On the contrary, the forages used in our experiments were all ensiled unchopped with good hygienic quality and the silage was chopped after opening the bales prior to feeding. Another difference between those earlier studies and the present are that the ewes in our study had clearly higher BCS (3.1–3.7 vs. 2.4–2.5 in Apolant and Chestnutt, 1985; Elizalde and Henríquez, 2009). The ewes in the earlier studies might have had a need for compensating previous underfeeding and therefore the feed intake was enhanced when the silage was fed chopped, as chopping increases intake rate, rumination time and efficiency of rumination (Deswysen et al., 1978; Deswysen and Ehrlein, 1981).

The higher BW gain of the ewes fed chopped silage, either with concentrate fed separately or in a mix than ewes fed unchopped silage, in Exp. 2 of the present study, is in line with Chestnutt (1989), when the ewes were fed early-cut, precision-chopped silage compared with ewes fed late-cut, flail-harvested silage. In that study, however, the effect of chopping length cannot be separated from the effect of increased silage digestibility on intake.

Different from the results in our experiments, Elizalde and Henríquez (2009) showed a smaller decrease in BCS in late pregnancy of ewes fed precision chopped compared to long haylage. Precision-chopping decreased the ammonia content of the haylage, showing less proteolysis indicating enhanced utilisation of eaten feed.

4.1.2. Lactating ewes

In the present study, daily feed intake was not affected by chopping silage. In contrast to our study, Apolant and Chestnutt (1985) showed increased feed intake (1.4 vs. 1.0 kg DMI) in ewes during the first 28 days of lactation due to precision-chopping grass silage of varying qualities. There is a large difference in intake level of the compared experiments. This difference cannot be explained solely by differences in ewe BW (ca. 70 vs. ca. 90 kg), but is nonetheless a major difference between the experiments. Other possible explanations for the different intake levels in the compared experiments are the DM content and the hygienic quality of the silages used. Although pH of the silages used by Apolant and Chestnutt (1985) were low, the low DM (20.6%) indisputably lead to significant DM losses and potentially to secondary fermentation processes inhibiting ewes from fully utilising their intake potential. As ewes fed the chopped diets lost less BW than the ewes fed unchopped silage, during lactation in the first experiment of the present study, an improved utilisation of ingested feed is likely when feeding chopped as compared with unchopped silage to lactating ewes. There were no such differences in the second experiment, where the silage had ca. 100 g lower NDF content per kg DM than in the first experiment. Increased NDF concentration of the silage leads to a longer rumen retention time of the silage in lactating ewes and, thereby, a stronger effect of chopping on feed intake and utilisation.

4.1.3. Growing lambs

The increased daily LWG from 386 to 424 g (+38 g) of suckling lambs from ewes fed the chopped diets in Exp. 2 compared with those fed the unchopped diet are in line with the findings by Apolant and Chestnutt (1985), where chopping silage increased daily LWG from 185 to 243 g (+58 g) as a cause of increased milk yield. The magnitude of the response is larger in the latter and this difference is difficult to explain. However, as indicated by others (e.g. Apolant and Chestnutt, 1985; Deswysen et al., 1978; Nadeau et al., 2012), the silage fermentation quality is greatly improved by chopping the herbage before ensiling.

The response to chopping silage on feed intake and performance in weaned lambs has been thoroughly investigated by others and the increased daily LWG from 373 to 444 g (+71 g) of lambs from weaning to slaughter fed chopped silage diets in our experiments agree with results by Fitzgerald (1984) and Fitzgerald (1996a,b,c), where lamb daily LWG was −6 to 151 g fed silage only and Fitzgerald (1996c), where lamb daily LWG was 90–150 g when supplemented with barley. In contrast to those earlier studies, the feed intake of lambs was not affected by chopping silage in the present study. The increased LWG and lack of increase in feed intake was possibly the result of more efficient rumination by the lambs fed chopped silage in our experiments, as suggested by Deswysen et al. (1978) and Deswysen and Ehrlein (1981), who found that pseudo-rumination was more frequent in lambs fed unchopped silage than in those fed chopped silage. However, by feeding both concentrate and silage in the present study feed efficiency was enhanced resulting in increased daily LWG without increased intake, contradicting the results by Fitzgerald (1996c), where inclusion of barley increased LWG, but kept similar relative intake differences in intake due to chopping. One possible explanation for the different responses to chopping silage in experiments 1 and 2 in the present study is the different characteristics of the silages in the two experiments (Tables 1 and 2), as increasing digestibility has been shown to be one of the most important factors for enhancing production in sheep (Keady et al., 2013).

Taking published knowledge into account, it is clear that chopping silage is beneficial in intensive systems with silage-based feeding systems.

4.2. Effects of mixing silage and concentrate

4.2.1. Pregnant ewes

In our experiments pregnant ewes did not increase their feed intake due to mixing silage with concentrate, which differed from results reported by Chestnutt and Wylie (1995), where ewes in late pregnancy fed a total mixed ration had higher feed intake than ewes fed chopped silage and concentrate separately. The differences between the studies were that the silages used by Chestnutt and Wylie (1995) were chopped before ensiling, which is well-known to improve fermentation as discussed above (Section 4.1). No other published studies could be found and the research area of mixed ration feeding for pregnant ewes needs further attention.

4.2.2. Lactating ewes

The increased total DMI in lactating ewes when mixing silage and concentrate in Exp. 2 was related to higher intakes of both silage and concentrate compared with ewes fed silage and concentrate separately. Possible explanations to the higher intake of the mixed diet are increased outflow rate from the rumen and improved degradation of the forage fibre (Allen, 1996). As degradation of starch from the concentrate was more evenly distributed over time in the mixed diet compared with separate diets the rumen pH fluctuations were minimised, as shown in cattle (Mould et al., 1983; Ørskov, 1999). As hemicellulose, cellulose and lignin are the major dietary components regulating intake in ruminants (Allen, 1996), the rumen degradation of NDF is even more important in lactation than in pregnancy. Therefore, restriction of pH fluctuations in the rumen by simultaneous feeding of starch-rich concentrates with fibre-rich silages will improve forage fibre digestion (Allen, 1996) and also increase the outflow rate from the rumen, enabling higher intake in lactation. The probable reasons for the response in lactation and lack of response in pregnancy in this study are, the higher nutrient demand of lactating ewes and the possible metabolic and physical constraints limiting feed intake in late pregnancy as discussed by e.g. Forbes (1970, 1977) and Hanks et al. (1993).

Milk yield response by the ewes was roughly estimated by differences in daily LWG of lambs from birth to weaning. The expected increased milk yield by the ewes fed the mixed diet in Exp. 2 is likely due to the higher feed intake, but can also be an effect of improved nutrient utilisation (Allen, 1996). Feeding a mixed ration of silage and concentrate gives a more even distribution of energy from carbohydrate metabolism to be used for microbial protein synthesis in dairy cows (Børsting et al., 2003). Increased microbial protein synthesis results in more amino acids being absorbed in the small intestine, to be used for milk production. The ewes and the lambs selected the concentrate in the CM treatment to a larger extent in Exp. 1 than in Exp. 2, which may partly explain why there was a lack of intake and production response to mixing concentrate with silage in Exp. 1, as the ewes consumed the concentrate before the silage, subsequently having no synergy effect of eating silage and concentrate simultaneously.

4.2.3. Growing lambs

The increased LWG from birth to weaning of lambs fed the mixed diet as compared with the separate diets in the second experiment of the present study was probably related to the increased feed intake by the ewes fed the mixed diet, generating higher milk yield than ewes on either of the separate diets. In the first experiment of the present study, the lambs on the mixed diet had heavier carcass weights than the lambs on the separate diets, due to a higher dressing percentage at slaughter. These findings are comparable with those of Czarnik-Matusewicz et al. (1999) where lambs fed a mixed ration of hay, ground barley and rapeseed meal had heavier slaughter weights than lambs fed the feedstuffs separately. However, Czarnik-Matusewicz et al. (1999) showed decreased intake as a cause of the mixed diet, which was not observed in our experiments. No other published studies could be found and the research area of mixed ration feeding for growing lambs needs further investigations.

5. Conclusions

Chopping highly digestible silage increased daily LWG of weaned lambs, without increasing feed intake. Feeding a mixed ration of high quality grass silage and concentrate increased feed intake in lactating ewes and daily LWG of suckling lambs. When less digestible and dryer silage was fed, mixing of silage and concentrate only tended to increase feed intake by lactating ewes with no effect on LWG of the lambs.

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