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Effect of whole-crop pea (*Pisum sativum* L.) silages differing in condensed tannin content as a substitute for grass silage and soybean meal on the performance, metabolism, and carcass characteristics of lambs[1]

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ABSTRACT: Two experiments were conducted to investigate the effect of inclusion of whole-crop pea (WCP) silages, differing in condensed tannin content, as a substitute for grass silage (GS) and soybean meal on lamb metabolism, performance, plasma metabolites, digestibility, and carcass characteristics. In both experiments lambs were offered either solely GS or a 50:50 mix on a DM basis of GS with either low-tannin (LTPS) or high-tannin (HTPS) pea silage ad libitum. Each forage mix was fed with either 400 g/d of low-protein (LP) concentrate or 400 g/d of LP with an additional 200 g/d of pelletized soybean meal (HP), resulting in 6 dietary treatments. Experiment 1 examined the effects of the diets on metabolism, digestibility, and N balance using 6 lambs in 4 periods of 21 d in an incomplete crossover design. Experiment 2 used 48 lambs and examined the effects of the diets on ADG, plasma metabolites, and carcass characteristics over 56 d. Both experiments were analyzed using a 3 × 2 factorial arrangement of treatments. In Exp. 1, lambs offered the LTPS diets had a greater ($P < 0.05$) digestibility of DM and OM than those offered the GS diets. Lambs offered the WCP silages had an increased ($P < 0.05$) N intake, N output, and digestibility of GE compared with those offered GS. Mean N digestibility was greatest ($P < 0.05$) in lambs offered LTPS. Lambs offered HP diets had increased ($P < 0.001$) digestibility of DM, OM, GE and N, and N- intake, output, retention, and digestibility compared with those offered the LP diets. In Exp. 2, there was no effect ($P > 0.05$) of forage type on intake, slaughter BW, or feed conversion efficiency (FCE). However, lambs offered the LTPS had a greater ($P < 0.05$) ADG than those offered the GS diets. Feeding diets containing HP increased ($P < 0.001$) total DMI, slaughter BW, ADG, and FCE. Lambs offered the WCP had a greater ($P < 0.05$) plasma β-hydroxybutyrate and urea concentration compared with those offered the GS diets. Feeding lambs HP diets increased ($P < 0.05$) plasma urea and total protein. Forage mix had no effect ($P > 0.05$) on carcass composition except for fat depth, which was greater ($P < 0.05$) in lambs offered WCP silage. Diets containing the HP increased ($P < 0.05$) carcass weight, hind leg circumference, chop dimensions, and kidney weight. It was concluded that lambs offered LTPS performed better than those offered GS and that LTPS has a concentrate sparing effect. Additionally, the increased tannin concentration in HTPS did not increase performance over lambs offered either GS or LTPS.

Key words: metabolism, performance, silage, tannin, whole-crop peas

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INTRODUCTION

Since the banning of mammalian-derived protein meals (EC, 1994) and fishmeal (EC, 2001) within the European Union, there has been a heavy reliance on imported soybean meal (**SBM**) for ruminant production systems (Merry et al., 2001). Pricing and availability of SBM is regulated by global demand for soy products for use within human diets (Merry et al., 2001), resulting in increased production costs of ruminant products. Consumers within the United Kingdom are opposed to

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genetically modified crops in their food (Loader and Henson, 1998). Furthermore, Anil et al. (1998) reported that because of the increases in whole-crop cereal/corn silage production and a reduction in grass silage (**GS**) production there is a greater need for producing a home-grown protein source because whole-crop cereal/corn silages have less CP than GS.

Ensiled leguminous forages offer the potential to be used as a traceable home-grown protein but have increased RDP (Dewhurst et al., 2003). The production of whole-crop pea (*Pisum sativum* L.; **WCP**) silages has received little attention because of the perception that they are difficult to harvest and ensile (Wilkins and Jones, 2000). Peas with white flowers are indicative of decreased condensed tannin (**CT**) content, whereas those with darker flower colors have greater CT content (Wang et al., 1998). Broderick (1995) and Reed (1995) reported that forages containing CT could improve animal performance through the reduction in RDP due to protein CT complexes. However, increased dietary CT can reduce forage palatability and as a consequence DMI (Robbins et al., 1987), potentially reducing animal performance. There have, however, been no studies on the effect of CT in WCP silages on the intake and performance of growing lambs.

The aim of the current experiments was to investigate the effect of inclusion of WCP silages differing in CT content as a substitute for grass silage and SBM on lamb metabolism, performance, plasma metabolites, and carcass characteristics.

MATERIALS AND METHODS

All animals used in this study were cared for under license in accordance with The Animals (Scientific Procedures) Act 1986 (Her Majesty's Stationery Office, 1986). During all experimental periods, animals had ad libitum access to clean drinking water.

Animals

Fifty-four Suffolk cross wether lambs with a mean BW of 30 kg (SD = 2.9) were used. Before the experiments, all lambs had been grazing perennial ryegrass (*Lolium perenne* L.) pasture ad libitum and had not received concentrates. Before allocation, lambs were treated for intestinal parasites (Allverm, Crown Veterinary Pharmaceuticals, Hertfordshire, UK), inoculated against *Pasteurella* and clostridia (Ovivac P-Plus, Intervet, Buckinghamshire, UK) and weighed. The 6 heaviest lambs [mean BW of 40.4 kg (SD = 1.72)] were selected for Exp. 1, and the remaining 48 lambs [mean BW of 30.3 kg (SD = 3.17)] were used in Exp. 2.

Experimental Diets

The WCP silages, differing in CT content, were produced as described by Sinclair et al. (2009). Briefly, pea cultivars Croma (white flowers; low tannin; **LTPS**) and Racer (colored flowers; high tannin; **HTPS**) were sown in adjacent 2-ha plots, mown at growth stage 206 (Knott, 1987: defined as when the pods on the lowest truss had begun to fill), allowed to wilt for 36 h, and harvested using a precision chop forage harvester that also applied a bacterial- (*Lactobacillus buchneri*) based silage additive (4 L/t; whole-crop legume, Biotal, Cardiff, UK). Processed WCP were ensiled in separate plastic-lined, concrete-walled, roofed clamps. First cut GS was harvested, according to standard commercial practice, on May 29, 2002, from a predominantly perennial ryegrass sward, wilted for 24 h, and ensiled in a plastic-lined, concrete-walled, roofed clamp without the addition of an additive.

The forage portion of the experimental diets was either solely GS or a 50:50 mix on a DM basis of GS with either LTPS or HTPS. An experimental concentrate was formulated for a 35-kg wether lamb consuming ad libitum GS to gain 150 g of BW/d (Agricultural Food and Research Committee, 1993). The concentrate was pelletized and contained (g/kg of DM) 982.5 rolled barley and 17.5 feed-grade urea (**LP**). Each forage mix was fed with either 400 g/d LP or 400 g/d LP with an additional 200 g/d of pelletized SBM (**HP**), resulting in 6 dietary treatments: **GSLP**, 100% GS (DM basis) + 400 g/d of LP; **GSHP**, 100% GS (DM basis) + 400 g/d of LP + 200 g/d of SBM; **LTLP**, 50% GS, 50% LTPS (DM basis) + 400 g/d of LP; **LTHP**, 50% GS, 50% LTPS (DM basis) + 400 g/d of LP + 200 g/d of SBM; **HTLP**, 50% GS, 50% HTPS (DM basis) + 400 g/d of LP; and **HTHP**, 50% GS, 50% HTPS (DM basis) + 400 g/d of LP + 200 g/d of SBM. Silage mixes were freshly prepared daily at 0730 h by weighing silage, removed from each clamp using a shear grab, and mixed by hand. To maintain the DM ratio of the forages, a subsample of each of the silages was dried to a constant weight at 100°C twice weekly. Forages were fed once daily at 0830 h, whereas the concentrate was fed in 2 equal portions at 0800 and 1600 h.

Experimental Procedure

Exp. 1. The 6 lambs were housed individually under continuous artificial lighting in a room maintained at 15°C for the duration of the experiment. In the week preceding the first experimental period, the lambs were housed in 3-m^2 slatted floor pens and fed ad libitum GS with the LP concentrate being introduced in a stepwise fashion from 0 to 400 g/d over 5 d. Lambs were randomly allocated to 1 of the 6 experimental sequence of treatments in an incomplete row and column design with each of the 4 periods lasting 21 d. Each period consisted of 14-d dietary adaptation followed by a 7-d sampling period. Forage refusals were collected daily and availability was adjusted to 1.10 × previous recorded intake. During the first 7 d of each period, lambs were housed in 3-m^2 slatted floor pens. On d 8, lambs had fecal collection harnesses and bags fitted and were transferred to individual metabolism crates as described previously by Richardson et al. (2003).

From d 14 to 21 of each experimental period, total daily fecal and urine output was collected before the morning feed. Total fecal production was weighed, mixed, and a proportion (100 g/kg) stored at −20°C before subsequent analysis. Urine was collected gravimetrically into 200 mL of 2 M H_2SO_4. Urine was filtered through glass wool, its weight recorded and then made up to 4 kg with deionized water. Two portions of 100-mL diluted urine were stored at −20°C before subsequent analysis. Lambs were weighed on d 14 and 21 of each period to determine $BW^{0.75}$. At the end of each period, lambs were removed from the metabolism crates and transferred back to individual pens and their diet switched. Subsamples of all forages and concentrates were taken daily during d 14 to 21 of each period and stored at −20° before subsequent analysis.

Exp. 2. The 48 lambs were blocked by BW and randomly allocated to 1 of the 6 experimental diets within each block. The heaviest 24 lambs commenced the experimental diets 7 d before the lighter 24 lambs, which remained at pasture. Lambs were housed individually in randomly allocated slatted floor pens (3 m^2) in an open-fronted barn. For the first 2 d, lambs were offered ad libitum GS only. Subsequently, from d 3 lambs were offered their allocated forage treatment ad libitum. From d 2, concentrate was introduced in a stepwise fashion over 5 d until the lambs were consuming their full daily allowance. Refusals were collected twice weekly and the forage adjusted to 1.10 × previous recorded intake. There were no concentrate refusals at any time throughout the experiment. Lambs were weighed once weekly at 1030 h and were blood sampled by jugular venipuncture on d 0, 14, 28, and 42 postweighing. Blood samples were collected into Li-heparin tubes (2 × 10 mL Vacutainers, BD, Oxford, UK), centrifuged at 2,800 × g for 10 min at 4°C, and plasma stored at −80°C before subsequent analysis. On d 56, lambs were removed from their pens at 1400 h and transferred into a large straw-bedded pen overnight. The following morning the lambs were weighed and transported to a commercial slaughter house. After electrical stunning, lambs were blood sampled at the point of exsanguination into Li-heparin tubes (2 × 10 mL, BD). Dressed carcasses were split longitudinally and numbered for identification purposes. Hot carcass weight was determined within 1 h of slaughter. Carcasses were chilled overnight at 4°C and reweighed to determine cold carcass weight. The right hand side of each carcass was retained, wrapped in plastic, and stored at +4°C before subsequent analysis. Subsamples of the silages and concentrates were taken weekly and stored at −20°C before subsequent analysis.

Analytical Methods

Silage and concentrate samples were bulked within each sampling period for Exp. 1 and across 3-wk periods for Exp. 2. Subsamples of bulked silage were analyzed for VFA by the method of Zhu et al. (1996). Fecal samples were bulked within each period for each animal in Exp. 1. Feed and fecal samples were dried to a constant weight at 65°C and milled to pass through a 1-mm screen using a cyclone mill (Cyclotec, FOSS, Warrington, UK). Daily samples of urine were bulked within each period for each animal and a subsample analyzed for purine derivatives as described by Chen and Gomes (1995). Nitrogen was determined using the Kjeldahl method (984.13; AOAC, 2000) on feed, feces, and urine. Defrosted silage samples were analyzed for pH using a pH meter (LS120, Thermo Russell) and ammonia N (Ministry of Agriculture, Fisheries and Food, 1986). Dried feed samples were analyzed for OM (Ministry of Agriculture, Fisheries and Food, 1986), NDF (using a heat stable α-amylase and omitting sodium sulfate), and ADF by the methods of Van Soest et al. (1991), water-soluble carbohydrates (Thomas, 1977), starch (Rasmussen and Henry, 1990), and neutral cellulase and gammanase digestibility (**NCGD**; Ministry of Agriculture, Fisheries and Food, 1993). Silage, concentrate, and fecal GE were determined by adiabatic bomb calorimetry (model 1261, Parr Instrument Co., Moline, IL). The CT content of the silages was determined as described previously (Sinclair et al., 2009). Fecal samples were analyzed for NDF using the method of Van Soest et al. (1991) with a heat stable α-amylase without the addition of sodium sulfate and OM (Ministry of Agriculture, Fisheries and Food, 1986). Plasma samples were analyzed for total protein, urea, and β-hydroxybutyrate as described previously (Sinclair et al., 2009). Half carcasses were split between the penultimate and caudal rib and the length, width, and fat depth of the eye muscle area determined using calipers (Brown and Williams, 1979). The eye muscle area was traced and its area determined using software (DT Scan, Delta-T Devices, Cambridge, UK). Hind leg circumference was determined directly with a tape measure. Kidney fat was removed and weighed.

Calculations

Estimated ME was calculated for the WCP silages using the dried alfalfa (*Medicago sativa*) equation of Givens (1989), GS using the equation of Givens et al. (1989), and the concentrates by Ministry of Agriculture, Fisheries and Food (1993) using the determined NCGD values.

Exp. 1. Diet DE was calculated from GE digestibility and multiplied by 0.81 to determine diet ME (Agricultural Research Council, 1980). Forage mix ME was estimated by subtracting the estimated ME of the concentrates [as determined by the Ministry of Agriculture, Fisheries and Food (1993)] from the diet ME.

Exp. 2. Individual ADG were determined by linear regression of weight over time. Feed conversion efficiency (**FCE**) was calculated as total BW gain divided by total DMI over the duration of the experiment. Killing-out proportion was calculated by dividing HCW by slaughter weight.

Statistical Analysis

Both experiments were analyzed as a 3 × 2 factorial design evaluating the effect of forage mix and concentrate type. Dunnetts multiple comparison test was used to compare LTLP, LTHP, HTLP, and HTHP to both GSLP and GSHP. Statistical differences are declared at $P \leq 0.05$.

Exp. 1. The data for intake, digestibility, MPS, diet DE, diet ME, and forage mix ME were analyzed using the MIXED procedure (SAS Inst. Inc., Cary, NC) using the model

$$Y = \mu + F_i + C_j + (F{\cdot}C)_{ij} + P_k + A_l + \varepsilon_{ijkl},$$

where μ is the overall mean, F_i is the effect of forage mix (i = 1 to 3), C_j is the effect of concentrate (j = 1 to 2), F·C is the interaction between forage mix and concentrate, P_k is the fixed effect of period (k = 1 to 4), A_l is the random effect of animal (l = 1 to 6), and ε_{ijkl} is the associated error.

Exp. 2. The data for intakes, growth, and carcass characteristics were analyzed using the MIXED procedure of SAS using the model

$$Y = \mu + F_i + C_j + (F{\cdot}C)_{ij} + B_n + \varepsilon_{ijn},$$

where μ, F_i, C_j, and F·C are the same as for Exp. 1, and B_n is the fixed effect of block (n = 1 to 8). The data for plasma profiles were analyzed by repeated measures, assuming a compound symmetry covariance structure using the Kenwood-Rogers correction for degrees of freedom via the MIXED procedure of SAS using the model

$$Y = \mu + D0 + F_i + C_j + (F{\cdot}C)_{ij} + T_m + (F{\cdot}T)_{im} + (C{\cdot}T)_{jm} + (F{\cdot}C{\cdot}T)_{ijm} + B_n + \varepsilon_{ijmn},$$

where μ, F_i, C_j, B_n, and F·C are as described above; T_m is the fixed effect of time (m = 1 to 4); F·T is the interaction between forage mix and time; C·T is the interaction between concentrate and time; F·C·T is the interaction between forage mix, concentrate, and time; D0 is the covariate effect of each measured plasma parameter on d 0; and ε_{ijn} and ε_{ijmn} are the associated error for the models, respectively. Data were analyzed for 47 lambs because 1 was removed due to health problems not associated with dietary treatment.

RESULTS

The mean chemical composition of the 3 silages and 2 concentrates fed during Exp. 1 and 2 are presented in Table 1. The 3 silages had a comparable OM, pH, WSC, and propionate concentration. The GS had a greater DM and NDF concentration and a decreased CP, NH_3-N, starch, ME, acetate, and butyrate concentration compared with the WCP silages. The HTPS had a greater starch and approximately twice the CT concentration compared with LTPS. In contrast, the LTPS had 0.5 MJ/kg of DM greater ME and 16 g/kg of DM greater acetate concentration compared with HTPS. The LP and HP concentrate were comparable in DM, OM, NDF, GE, and ME with mean values of 838 g/kg, 958 g/kg of DM, 160 g/kg of DM, 18.7 MJ/kg of DM, and 13.4 MJ/kg of DM, respectively. The HP concentrate contained 117 g/kg of DM more CP, 15 g/kg of DM more WSC, and 164 g/kg of DM less starch than the LP concentrate.

Exp. 1

There was no effect of forage mix on either forage or total DMI (Table 2). Mean apparent whole-tract digestibility of DM, OM, and GE along with diet DE, diet ME, and forage mix ME was greater ($P = 0.008$, 0.005, 0.003, 0.015, 0.016, and 0.005, respectively) when LT was fed compared with GS, with intermediate values for HT. Lambs offered LTHP and HTHP had a greater ($P < 0.001$ and <0.001, respectively) DM digestibility compared with GSLP; additionally, lambs offered LTHP had a greater ($P = 0.026$) DM digestibility compared with those offered GSHP. However, lambs offered HTLP had a decreased ($P = 0.027$) DM digestibility compared with those offered GSHP. Lambs offered LTHP and HTHP had a greater OM digestibility compared with both GSLP ($P = 0.047$ and <0.001, respectively) and GSHP ($P = 0.023$ and 0.050, respectively). However, lambs offered HTLP had a decreased ($P = 0.041$) OM digestibility compared with those offered GSHP. On average the apparent whole-tract digestibly of NDF was greatest ($P < 0.01$) when the GS forage was offered (665 g/kg of DM) with no difference between LT and HT ($P = 0.46$; with a mean value of 609 g/kg of DM). Lambs offered LTLP and HTLP had a reduced ($P = 0.012$ and 0.002, respectively) NDF digestibility compared with GSLP; lambs offered LTLP, LTHP, HTLP, and HTHP had less ($P = 0.001$, 0.024, <0.001, and 0.026, respectively) NDF digestibility than those offered GSHP. Lambs offered LTLP, LTHP, and HTHP had a greater ($P = 0.021$, <0.001, and <0.001, respectively) GE digestibility compared with those offered GSLP, with only lambs offered LTHP and HTHP having a greater ($P = 0.018$ and 0.027, respectively) GE digestibility compared with GSHP. Lambs offered HTLP had a decreased ($P = 0.025$) GE digestibility compared with those offered GSHP. Diet DE and ME was greater ($P < 0.001$) in LTHP and HTLP than GSLP, with only lambs offered LTHP having a greater ($P = 0.046$) energy value compared with those offered GSHP. Lambs offered HTLP had a decreased ($P = 0.002$) diet DE and ME compared with those offered GSHP.

Table 1. Mean chemical composition of the grass silage (GS), low-tannin pea silage (LTPS), high-tannin pea silage (HTPS), low-protein concentrate (LP), and high-protein concentrate (HP) fed during Exp. 1 and 2

	Forage			Concentrate	
Item	GS	LTPS	HTPS	LP	HP
DM, g/kg	403	328	320	847	830
OM, g/kg of DM	927	928	901	977	959
CP, g/kg of DM	115	184	197	169	286
NH_3-N, g/kg of total N	86	135	131	n.d.[1]	n.d.
Silage pH	3.8	3.8	4.1	n.d.	n.d.
NDF, g/kg of DM	507	248	259	159	160
WSC,[2] g/kg of DM	21	26	22	21	36
Starch, g/kg of DM	6	63	73	513	349
GE, MJ/kg of DM	17.7	17.4	17.3	18.5	18.9
ME,[3] MJ/kg of DM	11.2	12.7	12.2	13.3	13.4
Condensed tannin, TAE[4]	n.d.	47.5	92.3	n.d.	n.d.
Acetate, g/kg of DM	23	55	39	n.d.	n.d.
Propionate, g/kg of DM	2	1	1	n.d.	n.d.
Butyrate, g/kg of DM	1	4	4	n.d.	n.d.

[1]n.d. = not determined.

[2]Water-soluble carbohydrates.

[3]Estimated ME calculated from laboratory measurements.

[4]Tannic acid equivalents, g/kg of DM.

Lambs offered the LP concentrate had a greater ($P = 0.041$) daily forage DMI and a greater ($P = 0.033$) forage intake per unit of $BW^{0.75}$ compared with those offered the HP concentrate. There was no difference in total DMI when either LP or HP was offered to the lambs. The apparent whole-tract digestibility of DM, OM, NDF, and GE, along with diet DE, diet ME, and forage mix ME, was greater ($P < 0.001$) when lambs were offered the HP concentrate compared with when offered the LP concentrate.

On average lambs offered either the LT or HT forage mix had a greater total N intake ($P = 0.005$ and <0.001, respectively), forage N intake ($P = 0.007$ and 0.001, respectively), total N output ($P < 0.001$ and <0.001, respectively), and urinary N output ($P < 0.001$ and <0.001, respectively) compared with when offered the GS forage (Table 3). Lambs offered all diets containing WCP silage had a greater ($P = 0.011$, <0.001, 0.003, and <0.001 for LTLP, LTHP, HTLP, and HTHP, respectively) total N intake compared with those offered GSLP. Lambs offered LTHP and HTHP had a greater ($P = 0.008$ and 0.015, respectively) total N intake compared with those offered GSHP with lambs offered LTLP and HTLP having a reduced ($P = 0.035$) total N intake compared with GSHP. Forage N intake was greater in lambs offered LTLP and HTLP ($P =$ 0.015 and 0.005, respectively) compared with those offered GSLP. Additionally, lambs offered LTLP, HTLP, and HTHP had a greater ($P = 0.004$, 0.002, and 0.023, respectively) forage N intake compared with those offered GSHP. There were no differences in concentrate N intake, fecal N output, or N retention across forage treatments with mean values of 15.8, 8.1, and 11.2 g/d, respectively. Lambs offered LP diets had a decreased ($P < 0.001$) concentrate N intake compared with those offered GSHP, with lambs offered HP diets having a greater ($P < 0.001$) concentrate N intake compared with those offered GSLP. Total N output of lambs offered all WCP diets was greater ($P = 0.005$ for LTLP and $P < 0.001$ for LTHP, HTLP, and HTHP) than those offered GSLP, with only lambs offered LTHP and HTHP having a greater ($P = 0.004$ and <0.001, respectively) total N output compared with those offered GSHP. Urinary N was greater in lambs offered LTHP and HTHP compared with both GSLP ($P =$ 0.003 and 0.004, respectively) and GSHP ($P < 0.001$). Total N retained was greater in lambs offered LTHP and HTHP ($P = 0.013$ and 0.018, respectively) compared with GSLP. Mean apparent whole-tract N digestibility in lambs offered the LT was greater ($P = 0.021$) than when offered the HT, which in turn was greater ($P < 0.001$) than when offered GS. Apparent whole-tract N digestibility was greater in lambs offered LTLP, LTHP, HTLP, and HTHP ($P < 0.001$, <0.001, =0.014, and <0.001, respectively) compared with those offered GSLP with only LTHP, and HTHP had a greater ($P =$ 0.002 and 0.015, respectively) apparent whole-tract N digestibility than lambs offered GSHP. However, lambs offered HTLP had a decreased ($P = 0.003$) apparent whole-tract N digestibility compared with those offered GSHP. When lambs were offered the HP concentrate, they had a greater ($P < 0.01$) total N intake, concentrate N intake, total N output, urinary N output, N retention, and apparent whole-tract N digestibility than when offered the LP concentrate. In contrast, the forage N intake was greater ($P = 0.040$) when lambs were offered the LP concentrate. There was no difference due to concentrate type on fecal N output. There were

Table 2. Mean intake, apparent whole-tract digestibility of lambs, and energy value of diets determined using lambs offered grass silage (GS) or a 50:50 mix of GS with either low-tannin pea silage (LT) or high-tannin pea silage (HT), ad libitum fed with either 400 g/d of concentrate (LP) or 400 g/d of concentrate supplemented with 200 g/d of soybean meal (HP) in Exp. 1

	GS		LT		HT		SEM[1]			*P*-value[2]		
Item	LP[3]	HP	LP	HP	LP	HP	F	Con	F × Con	F	Con	F × Con
Intake												
Forage DMI, kg/d	0.78	0.75	0.87	0.71	0.88	0.75	0.067	0.064	0.078	0.65	0.041	0.56
Total DMI, kg/d	1.11	1.24	1.21	1.21	1.22	1.25	0.067	0.064	0.078	0.65	0.28	0.56
Forage DMI, g/kg of $BW^{0.75}$	44.8	42.8	49.6	41.3	50.1	44.0	3.43	3.26	3.96	0.51	0.033	0.55
Total DMI, g/kg of $BW^{0.75}$	64.3	71.3	68.9	70.3	69.7^{a}	72.8	3.31	3.14	3.80	0.45	0.10	0.59
Digestibility												
DM, g/kg	736	767	757	794^{ab}	740^{b}	784^{a}	6.0	5.3	8.0	0.023	<0.001	0.66
OM, g/kg	732	760	756	788^{ab}	735^{b}	783^{ab}	6.0	5.2	8.0	0.017	<0.001	0.40
NDF, g/kg	641	688	586^{ab}	641^{b}	566^{ab}	643^{b}	10.3	9.1	13.6	0.002	<0.001	0.50
GE, KJ/MJ	708	742	738^{a}	774^{ab}	713^{b}	771^{ab}	5.9	5.0	8.1	0.009	<0.001	0.29
Energy												
Diet DE, MJ/kg of DM	12.7	13.6	13.2	14.1^{ab}	12.7^{b}	14.0^{a}	0.11	0.10	0.16	0.044	<0.001	0.28
Diet ME, MJ/kg of DM	10.3	11.0	10.7	11.4^{ab}	10.3^{b}	11.4^{a}	0.09	0.08	0.13	0.045	<0.001	0.28
Forage mix ME, MJ/kg of DM	8.9	9.5	9.7^{a}	10.0^{a}	9.1	10.0^{a}	0.12	0.10	0.17	0.015	0.002	0.32

[a,b]Treatment differs ($P < 0.05$) from [a]GSLP or [b]GSHP using Dunnett's multiple comparison test.

[1]Pooled SEM for forage mix (F), concentrate (Con), and their interaction (F × Con).

[2]Probability values for effects of forage mix (F), concentrate (Con), and their interaction (F × Con).

[3]n = 4 for all treatments.

also no forage mix × concentrate interactions for N intake, output, or digestibility. There was an interaction observed for total purine derivatives ($P = 0.002$) with lambs fed HTLP having a greater ($P < 0.001$) value than those fed either GSLP or LTLP, with no differences being observed between GSHP, LTHP, or HTHP. Lambs offered LTHP had greater ($P = 0.010$) total purine derivatives compared with those offered greater GSLP.

Exp. 2

There was no effect of forage mix on mean intake, slaughter BW, and FCE (Table 4). However, lambs offered LTHP and HTHP had a greater ($P = 0.026$ and 0.023, respectively) total DMI than those offered GSLP, and lambs offered HTLP had a decreased ($P = 0.042$) total DMI compared with those offered GSHP. The slaughter BW of lambs offered LTHP and HTHP was greater ($P < 0.001$) than those offered GSLP with lambs offered LTLP having lighter ($P = 0.049$) slaughter BW than those offered GSHP. Mean ADG was greatest ($P = 0.006$) when lambs were offered the LT forage mix and least ($P = 0.006$) when offered the GS, whereas lambs fed HT had an intermediate ADG compared with LT or GS. Lambs offered LTHP and HTHP had a greater ADG ($P < 0.001$ and $=0.002$, respectively) and FCE ($P < 0.001$) than those offered GSLP. There was no effect of concentrate type on forage DMI as kilograms per day or grams per kilogram of $BW^{0.75}$. In contrast, total DMI, slaughter BW, ADG, and FCE were greater ($P < 0.001$) when lambs were offered the HP concentrate. There were no forage mix × concentrate interactions.

Lambs fed LT and HT had a greater mean plasma β-hydroxybutyrate concentration compared with those offered GS ($P < 0.05$; Table 5). Lambs offered LTHP had a greater ($P = 0.018$) plasma β-hydroxybutyrate concentration compared with those offered GSLP. There was no effect of concentrate or forage mix × concentrate interaction on plasma β-hydroxybutyrate concentration. However, there were interactions ($P < 0.05$) observed for plasma urea and total protein concentrations. There was no difference in plasma urea between forage mixes when the HP concentrate was fed. However, when GSLP was fed, plasma urea was less ($P < 0.001$) than when either HTLP or LTLP diets were fed (Figure 1). There was no difference in plasma total protein concentration when lambs were fed WCP-silage-containing diets on d 14, 28, or 42; however, on d 56 lambs fed LTHP had a greater ($P = 0.025$) plasma total protein concentration than those fed LTLP (Figure 2). On d 14, 28, and 42 lambs fed GSHP had a greater ($P = 0.017$, 0.007, and 0.014, respectively) plasma total protein concentration than those fed GSLP; however, on d 56 no difference was observed. On average, lambs offered LTLP and HTHP had a decreased ($P < 0.05$) plasma total protein concentration compared with those offered GSHP.

Table 3. Mean N intake, N output, N retention, and N digestibility of lambs offered grass silage (GS) or a 50:50 mix of GS with either low-tannin pea silage (LT) or high-tannin pea silage (HT), ad libitum fed with either 400 g/d of concentrate (LP) or 400 g/d of concentrate supplemented with 200 g/d of soybean meal (HP) in Exp. 1

	GS		LT		HT		SEM[1]			*P*-value[2]		
Item	LP[3]	HP	LP	HP	LP	HP	F	Con	F × Con	F	Con	F × Con
Total N intake, g/d	23.7	35.7	29.6[ab]	39.3[a]	31.0[ab]	41.1[ab]	1.57	1.48	1.84	0.002	<0.001	0.68
Forage N, g/d	14.5	13.3	20.5[ab]	16.8	21.8[ab]	18.6[b]	1.60	1.50	1.89	0.003	0.040	0.68
Concentrate N, g/d	9.2	22.5	9.2[b]	22.5[a]	9.2[b]	22.5[a]	0.09	0.08	0.13	1.00	<0.001	1.00
Total N output, g/d	15.7	22.1	19.7[a]	26.1[ab]	20.9[a]	28.2[ab]	0.80	0.74	0.97	<0.001	<0.001	0.77
Fecal N, g/d	7.6	8.5	7.5	7.3	8.9	8.3	0.52	0.48	0.61	0.08	0.90	0.33
Urinary N, g/d	8.1	13.6	12.2	18.7[ab]	11.9	19.9[ab]	0.69	0.63	0.86	<0.001	<0.001	0.28
N retained, g/d	7.8	13.7	9.9	13.2[a]	10.2	12.8[a]	1.22	1.11	1.53	0.77	0.004	0.42
N digestibility, g/kg	674	762	742	815[ab]	712[ab]	798[ab]	7.8	7.0	10.0	<0.001	<0.001	0.68
Total purine derivatives, mmol/d	15.8	17.3	16.2	17.8[a]	19.2[ab]	16.6	0.76	0.74	0.83	0.036	0.62	0.002

[a,b]Treatment differs ($P < 0.05$) from [a]GSLP or [b]GSHP using Dunnett's multiple comparison test.

[1]Pooled SEM for forage mix (F), concentrate (Con), and their interaction (F × Con).

[2]Probability values for effects of forage mix (F), concentrate (Con), and their interaction (F × Con).

[3]n = 4 for all treatments.

Table 4. Mean intakes, BW, ADG, and feed conversion efficiency (FCE) of lambs offered grass silage (GS) or a 50:50 mix of GS with either low-tannin pea silage (LT) or high-tannin pea silage (HT), ad libitum fed with either 400 g/d of concentrate (LP) or 400 g/d of concentrate supplemented with 200 g/d of soybean meal (HP) in Exp. 2

	GS		LT		HT		SEM[1]			*P*-value[2]		
Item	LP[3]	HP	LP	HP	LP	HP	F	Con	F × Con	F	Con	F × Con
Forage DMI, kg/d	0.87	0.89	0.90	0.90	0.85	0.90	0.033	0.027	0.046	0.84	0.58	0.80
Forage DMI, g/kg of $BW^{0.75}$	59.9	56.7	60.8	57.2	60.8	57.2	1.76	1.42	2.43	0.95	0.27	0.74
Total DMI, kg/d	1.21	1.37	1.24	1.40[a]	1.18[b]	1.40[a]	0.034	0.027	0.046	0.80	<0.001	0.82
Initial BW, kg	30.0	30.2	29.6	29.8	30.3	30.1	0.027	0.022	0.38	0.43	0.87	0.86
Slaughter BW, kg	38.3	42.7	39.2[b]	44.4[a]	39.6	44.2[a]	0.68	0.55	0.95	0.26	<0.001	0.91
ADG, g/d	137	208	175	257[a]	167	235[a]	11.0	8.8	15.0	0.020	<0.001	0.90
FCE,[4] g of gain/kg of DMI	122	165	134	192[a]	144	184[a]	8.0	6.5	11.2	0.15	<0.001	0.72

[a,b]Treatment differs ($P < 0.05$) from [a]GSLP or [b]GSHP using Dunnett's multiple comparison test.

[1]Pooled SEM for forage mix (F), concentrate (Con), and their interaction (F × Con).

[2]Probability values for effects of forage mix (F), concentrate (Con), and their interaction (F × Con).

[3]n = 8 for all treatments except HTLP, where n = 7.

[4]Feed conversion efficiency.

Table 5. Mean plasma variables of lambs offered grass silage (GS), or a 50:50 mix of GS with either low-tannin pea silage (LT) or high-tannin pea silage (HT), ad libitum fed with either 400 g/d of concentrate (LP) or 400 g/d of concentrate supplemented with 200 g/d of soybean meal (HP) in Exp. 2

	GS		LT		HT		SEM[1]			*P*-value[2]		
Item	LP[3]	HP	LP	HP	LP	HP	F	Con	F × Con	F	Con	F × Con
β-Hydroxybutyrate, mmol/L	0.48	0.57	0.63	0.72[a]	0.62	0.68	0.038	0.032	0.057	0.018	0.11	0.98
Urea, mmol/L	5.15	9.54	6.87[a]	9.56	7.42[a]	9.48	0.231	0.177	0.313	0.004	<0.001	0.003
Total protein, g/L	60.8	64.8	60.7[b]	62.5	62.7	61.8[b]	0.56	0.45	0.79	0.32	0.016	0.014

[a,b]Treatment differs ($P < 0.05$) from [a]GSLP or [b]GSHP using Dunnett's multiple comparison test.

[1]Pooled SEM for forage mix (F), concentrate (Con), and their interaction (F × Con).

[2]Probability values for effects of forage mix (F), concentrate (Con), and their interaction (F × Con).

[3]n = 8 for all treatments except HTLP, where n = 7.

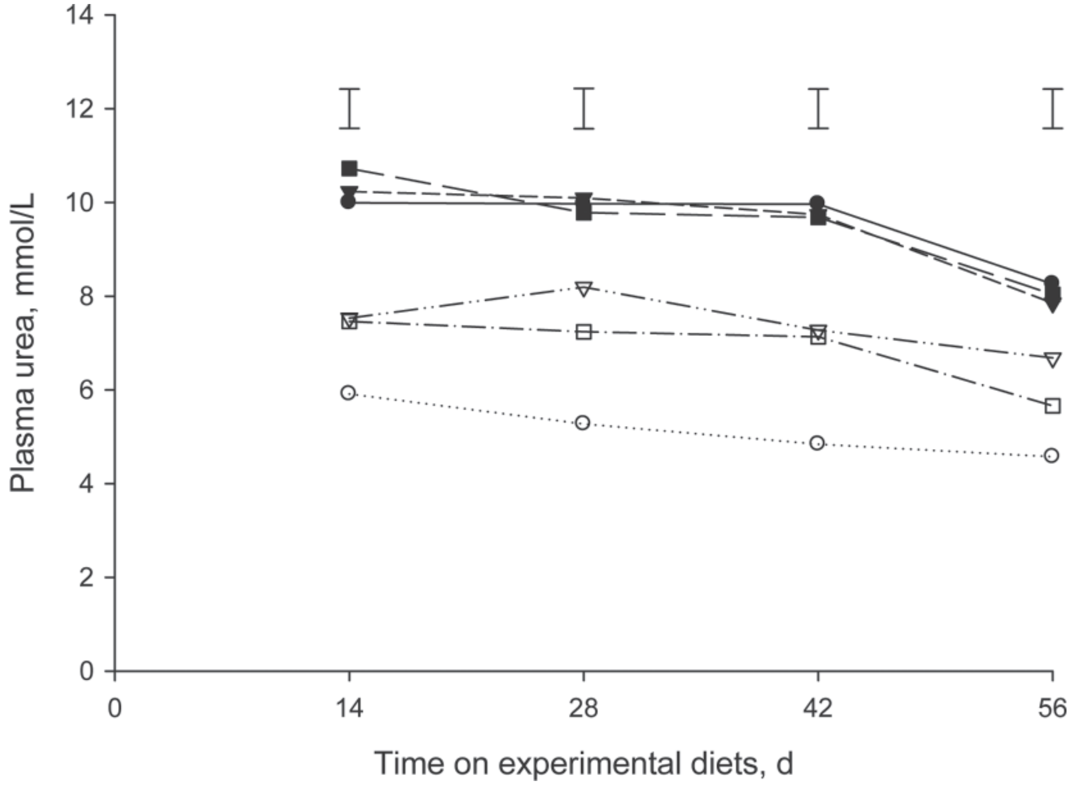

Figure 1. Mean plasma urea concentration of lambs offered grass silage (GS; ○), or a 50:50 mix of GS with either low-tannin pea silage (□) or high-tannin pea silage (▽), ad libitum fed with either 400 g/d of concentrate (open symbols) or 400 g/d of concentrate supplemented with 200 g/d of soybean meal (closed symbols). Error bars represent SE.

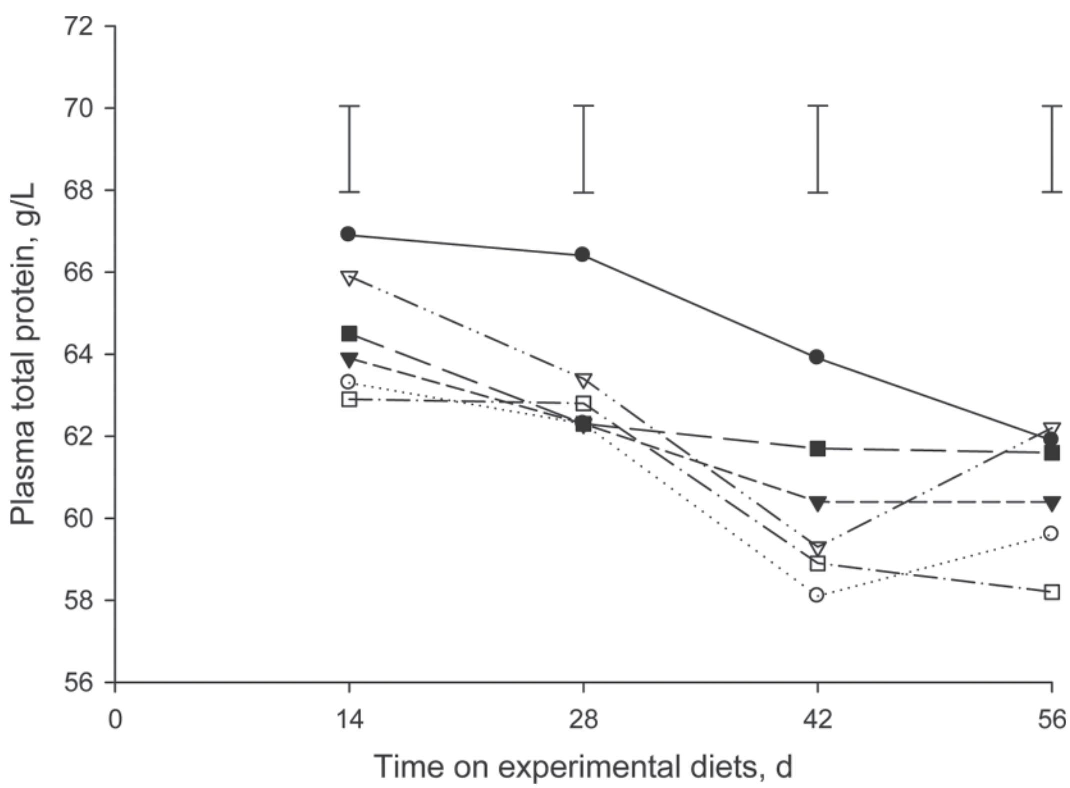

Figure 2. Mean plasma total protein concentration of lambs offered grass silage (GS; ○) or a 50:50 mix of GS with either low-tannin pea silage (□) or high-tannin pea silage (▽), ad libitum fed with either 400 g/d of concentrate (open symbols) or 400 g/d of concentrate supplemented with 200 g/d of soybean meal (closed symbols). Error bars represent SE.

There was no main effect of forage mix on any of the measured carcass traits except for chop length and subcutaneous fat depth, which was greatest ($P < 0.05$) in lambs fed the LT forage mix (Table 6). Lambs offered LTHP and HTLP had a greater HCW ($P < 0.001$ and $= 0.005$, respectively), cold carcass weight ($P = 0.001$ and 0.008, respectively), and hind leg circumference ($P = 0.008$ and 0.003, respectively) compared with those offered GSLP. Subcutaneous fat depth was greater in lambs offered LTHP compared with both GSLP and GSHP ($P = 0.024$ and 0.004, respectively), whereas when lambs were offered HTHP they had a greater ($P = 0.014$) subcutaneous fat depth than those offered GSHP. Kidney weight of lambs offered LTHP was greater ($P = 0.023$) than lambs offered GSLP. When lambs were offered the HP concentrate they had a greater ($P < 0.05$) HCW, cold carcass weight, hind leg circumference, chop length, chop width, and kidney weight compared with when offered the LP concentrate. There were no other effects of concentrate on carcass characteristics, and there were no forage mix × concentrate interactions.

DISCUSSION

This is the first study to investigate the effects of diets containing WCP silages differing in CT content on the intake and performance of growing lambs. This was accomplished using commercially available pea varieties that were morphologically and chemically similar and differed only in CT concentration. Furthermore, this study compares lamb performance and metabolism from forage protein sources against SBM-supplemented diets. The authors acknowledge that the GS was of moderate quality, and if a greater quality GS had been available, this may have resulted in lambs offered GS performing better than reported here.

Forage Quality

The GS was of comparable quality with that used by Sinclair et al. (2009) in all variables except for DM, which was greater in the current study. Overall, the GS was deemed to be of moderate quality due to being harvested at a relatively late stage of maturity. The LTPS and HTPS were comparable in chemical composition except for CT content, which was 1.95-fold greater in the HTPS. The relatively high content of acetate reported for the WCP silages was greater than that reported by Fraser et al. (2001) and is indicative of fermentation dominated by *L. buchneri* (McDonald, 1973). The moderate butyrate and NH_3-N concentrations are indicative of little clostridial activity (Gibson, 1965).

The LTPS and HTPS forages used in the current study were the same as those used by Sinclair et al. (2009), and their chemical composition was comparable despite the studies being more than 7 mo apart. This demonstrates that the WCP silages were well preserved

Table 6. Mean carcass characteristics of lambs offered grass silage (GS), or a 50:50 mix of GS with either low-tannin pea silage (LT) or high-tannin pea silage (HT), ad libitum fed with either 400 g/d of concentrate (LP) or 400 g/d of concentrate supplemented with 200 g/d of soybean meal (HP) in Exp. 2

	GS		LT		HT		SEM[1]			*P*-value[2]		
Item	LP[3]	HP	LP	HP	LP	HP	F	Con	F × Con	F	Con	F × Con
HCW, kg	17.6	20.3	18.5	21.1[a]	18.7	20.5[a]	0.41	0.33	0.57	0.07	<0.001	0.74
Cold carcass weight, kg	17.5	19.1	18.2	20.7[a]	18.4	20.1[a]	0.39	0.32	0.55	0.11	<0.001	0.65
Killing out proportion, kg/kg	0.460	0.456	0.469	0.474	0.472	0.462	0.0093	0.0076	0.0140	0.59	0.75	0.86
Hind leg circumference, cm	40.8	42.1	41.1	42.7[a]	40.7	42.9[a]	0.29	0.24	0.41	0.49	<0.001	0.60
Chop length, cm	6.2	6.2	6.3	6.6	5.9	6.4	0.09	0.08	0.14	0.044	0.015	0.24
Chop width, cm	2.7	2.9	2.8	3.0	2.9	3.0	0.08	0.06	0.10	0.19	0.016	0.81
Subcutaneous fat depth, mm	17.5	13.8	26.3	33.8[ab]	22.8	31.2[b]	2.27	2.32	3.88	0.002	0.21	0.24
Eye muscle area, mm^2	1,298	1,417	1,428	1,476	1,381	1,466	41.6	33.4	56.9	0.24	0.08	0.82
Kidney weight, g	48.7	55.5	50.3	59.4[a]	57.4[a]	56.4	1.80	1.48	2.44	0.19	0.024	0.13
Kidney knob and pelvic fat, g	151	150	146	178	154	160	12.3	9.9	17.1	0.80	0.38	0.61

[a,b]Treatment differs ($P < 0.05$) from [a]GSLP or [b]GSHP using Dunnett's multiple comparison test.

[1]Pooled SEM for forage mix (F), concentrate (Con), and their interaction (F × Con).

[2]Probability values for effects of forage mix (F), concentrate (Con), and their interaction (F × Con).

[3]n = 8 for all treatments except HTLP, where n = 7.

and remained stable. The pea silages used in this experiment were of similar chemical composition to those produced by Mustafa et al. (2000, 2002), Fraser et al. (2001), and Mustafa and Seguin (2003), with the only notable difference being the decreased NDF concentration reported here. Semi-leafless combinable cultivars of peas used in the current study do not rely on the thickness of their stem to remain erect; instead they remain erect by the entanglement of their tendrils and as a result have reduced NDF content compared with their forage cultivar counterparts (Davies et al., 1985).

Digestibility and Energy

Mean forage DMI of lambs offered diets containing WCP silage of 58.9 g/kg of $BW^{0.75}$ (Exp. 2) was comparable with that of Fraser et al. (2001: 57.5 g/kg of $BW^{0.75}$). The digestibility coefficients determined for DM, OM, CP, and GE were on average greater in the forage mixes containing the WCP silages compared with GS. However, Adesogan et al. (2002) reported that bi-cropped pea (cv. Magnus)/wheat silages had decreased DM, OM, CP, and NDF digestibility compared with GS, although this effect may be attributable to the reduced digestibility of the whole-crop wheat (Sinclair et al., 2003). However, in the production of bi-cropped peas and cereals, there is a tradeoff between stages of maturity of the 2 crops at harvest because the plants mature at different rates (Anil et al., 1998). This results in nonoptimal harvest conditions for at least 1 of the crops compared with the optimal stage of maturity at harvest determined for the respective monoculture. Further work is therefore required to evaluate the best methods to maximize whole-tract utilization of ensiled WCP.

The calculated ME, based on in vivo calculations of forage mix ME, of the GS, LTPS, and HTPS was 9.1, 10.5, and 9.8 MJ/kg of DM, respectively. These values were less than those obtained using predictive equations based on NCGD. However, both WCP silages had a greater ME than the GS in both methods of ME prediction. This was expected because of the increased starch concentration in the WCP silages. Determination of ME in vivo requires the use of calorimeters that are not widely available, and as a result published ME values for WCP silages are scarce. Efe Sereno (1989) reported a measured ME of 7.7 MJ/kg of DM for ensiled vining pea residue that only contained 10% of the total grain. Therefore, it would be expected that if all grain had been present, a greater ME would have been observed for WCP silage.

It is unclear from the literature whether legumes have a greater ME than grasses because metabolic studies by Beever et al. (1985) and Cammell et al. (1986) have shown that the ME of perennial ryegrass was 0.34 to 1.46 MJ/kg of DM greater than that of white clover (*Trifolum repens*). In contrast, Varga et al. (1990) demonstrated that ensiled alfalfa has a ME 1.05 MJ/kg of DM greater than ensiled orchardgrass (*Dactylis glomerata*) when determined using calorimeters. More accurate predictive equations from laboratory or in vivo measurements for WCP silages are therefore required.

N Balance

The inclusion of WCP silages into the diets of lambs increased both N intake and N output. There was no difference in the amount of N retained between the 3 forage treatments with an increased N output in the WCP silages attributable to an increase in urinary N. This provides evidence that the N contained within these forages was in excess within the rumen, absorbed into the bloodstream, and excreted by the kidneys (Lobley, 1992) potentially because of a lack of synchrony of energy and protein supply (Sinclair et al., 1993). Sinclair et al. (2009) showed that approximately 0.76 of N in the WCP silages used here was immediately soluble within the rumen, with approximately 0.06 being RUP.

The LT diets had an increased N digestibility compared with HT diets, but with no difference being observed in N retained. It was hypothesized that diets containing a greater concentration of CT would have resulted in reduced RDP and a greater amount of absorbable RUP, which may, in turn, lead to an increased N retention and less N excretion. Indeed, based on in situ degradability measurements of the 2 WCP silages (Sinclair et al., 2009), the HTPS was predicted to supply an additional 6.4 g/kg of DM of absorbable RUP to the small intestine at a rumen outflow rate of 0.05/h. The absence of any effect on N retained of CT concentration in the WCP silages suggests that the difference in concentration of CT between cultivars was either not great enough or that protein tannin complexes did not fully dissociate in the abomasum in the HTPS diets, reducing their digestibility. Mean CT intake of the diets containing LTPS and HTPS was 15.5 and 30.4 g of CT (as tannic acid equivalents)/kg of DMI, respectively. However, differences in CT structure, method of CT extraction, and choice of tannin standard make between-study comparisons difficult. It has been suggested by Broderick (1995) that an optimal CT concentration of 50 g/kg of DMI is beneficial for postruminal N absorption; however, concentrations >55 g of CT/kg of DMI are detrimental to forage intake (Min et al., 2003). Therefore, further studies need to be carried out examining the biological activity of the CT from WCP silages. Adesogan et al. (2004) reported that dry dairy cows offered bi-cropped pea/wheat silages also had an increased N digestibility compared with cows fed GS, although no difference in urinary N excretion was observed.

In the current experiment, the GSLP diet was formulated to meet the energy and MP requirements of the lambs growing at 150 g/d, whereas the supply of energy and MP in the remaining diets was unbalanced and in excess of requirements. It would be expected that if the diets containing WCP silages had been formulated to maximize microbial protein supply, then improved N efficiency may have been observed.

Lamb Performance

Fraser et al. (2004) and Speijers et al. (2004) reported a greater forage DMI when either grazed red clover or alfalfa was offered to lambs in comparison with grazed ryegrass with the same effect observed when these forages were ensiled (Speijers et al., 2005). Forage DMI was unaffected by dietary treatment in the current study. However, the lambs consumed approximately 0.23 kg of DM/d more forage than those reported by Speijers et al. (2005) for lambs of a similar BW. This suggests that either the palatability of the silages used here was greater than that of Speijers et al. (2005) or the differences in intake are attributable to breed effects (Suffolk cross cf. Beulah). There was no difference in DMI of lambs fed diets containing the LTPS or HTPS, demonstrating that the content of CT in these forages was not detrimental to intake.

Work by McClure et al. (1994) and Fraser et al. (2004) has demonstrated that when lambs were offered grazed leguminous forages ad libitum they had a greater ADG than those offered grazed ryegrass. Additionally, Speijers et al. (2004) reported increased ADG for lambs consuming red clover or lotus over those offered ryegrass, but there was no difference when alfalfa was offered. When ensiled legumes were offered, Speijers et al. (2005) reported that the ADG of lambs offered red clover were greater than those offered either GS or alfalfa. This inconsistency between ryegrass and alfalfa may be in part to geographical location, cultivar of alfalfa, or meteorological factors. In the current study, only lambs fed LT had an increased ADG over those lambs offered GS. Feeding diets containing WCP + LP and WCP + HP increased ADG by an average of 34 and 58 g/d above that determined for GSLP and GSHP, respectively. The difference between GSLP and GSHP, due to the inclusion of 200 g/d of SBM, increased ADG by 73 g/d. Therefore, this shows the potential of diets containing WCP silages to have a concentrate-sparing effect because of the increased supply of dietary energy and protein. Previous studies (e.g., Fahmy et al., 1992; Purroy et al., 1992; Manso et al., 1998) have reported increased lamb ADG with increased CP intake from supplemental concentrates. This was also observed in the current study with the inclusion of 200 g/d of SBM. Sinclair et al. (2009) demonstrated that the inclusion of WCP silage in the diets of dairy cows can replace 1 kg/d of SBM without affecting performance. Studies by Salawu et al. (2002) and Adesogan et al. (2004) have also demonstrated that inclusion of bi-cropped cereal/pea silages can have a concentrate sparing effect in dairy cow rations compared with cows fed GS. Growth rate of lambs is affected by the supply of both ME and MP (Agricultural Food and Research Committee, 1993). Using the rumen degradability parameters determined for the WCP silages by Sinclair et al. (2009), those for GS determined by NIR (AFBI, Hillsborough, UK), and reference values for concentrates (Agricultural Food and Research Committee, 1993) at a rumen outflow rate of 0.05/h indicates that all the diets were oversupplying effective RDP except for the GSLP diet, which was limited by fermentable ME. This suggests that to maximize performance from diets containing WCP, the diets should be balanced with a rumen-degradable energy source, such as a cereal or cereal-based forage.

Plasma Metabolites

Plasma metabolites in lambs fed any of the forage treatments were within the normal range expected for sheep (Kahn, 2005). The plasma urea concentrations were, however, increased in lambs offered WCP-silage-containing diets, indicating a potential deficit of rumen fermentable energy and further suggesting that feeding WCP silage in combination with a cereal or a cereal-based forage instead of GS would be beneficial. Fraser et al. (2004) and Speijers et al. (2004) also reported increased plasma urea concentration in lambs consuming grazed legumes in comparison with ryegrass. A similar effect was observed when the forages were ensiled (Speijers et al., 2005). When an additional 200 g/d of SBM was offered to the lambs the plasma urea N concentration exceeded the maximum of 9.3 mmol/L (Kahn, 2005). This effect can be attributed to the oversupply of RDP and absorbable RUP within the small intestine and a deficit of fermentable ME.

Carcass Characteristics

No differences due to forage source were observed in any of the carcass characteristics measured except for an increased fat depth when WCP silage was included and an increased chop length when LTPS was fed. Speijers et al. (2005) reported that lambs offered red clover silage had an increased LM fat depth, measured at the 3rd lumbar vertebrae, over those offered GS, but there was no difference in fat depth between those offered the GS or alfalfa silage. When offered grazed legumes, McClure et al. (1994) and Fraser et al. (2004) reported no difference between legumes and ryegrass in terms of cold carcass weight or chop characteristics. The increased fat depth in the lambs offered the WCP silages in the current study may be associated with a greater dietary energy and protein supply. If the lambs had been slaughtered at a specific fat class or BW, rather than after a defined period of time, then differences in fat depth may not have been evident with a corresponding decrease in days to slaughter.

The extra 200 g/d of SBM received by lambs consuming HP diets resulted in a heavier slaughter weight and as a result an increased HCW and cold carcass weight and increased hind leg circumference. Giustra et al. (1996) reported that as the quality of absorbable

RUP within the small intestine increases, the efficiency of its use in vivo increases. Results from Exp. 1 demonstrated that more dietary N was retained in lambs fed diets containing HP, which may explain the larger carcasses observed in Exp. 2.

Conclusions

It can be concluded from this series of experiments that despite no difference in DMI, lambs offered diets containing LTPS grew faster; had an increased digestibility of DM, OM, GE, and N; and had an increased chop length and subcutaneous fat depth compared with those offered GS diets, with intermediary values for lambs fed HTPS. This can be attributed to a greater supply of both energy and protein from the WCP-silage-containing diets compared with moderate-quality GS. The increased ADG of lambs offered LTPS represents a concentrate-sparing effect, which in turn would result in a shorter time to finish lambs and may increase profitability because of reduction in feed usage.

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