Growth and Carcass Quality of Prolific Crossbred Lambs Fed Silage with Fish Meal or Different Amounts of Concentrate[1,2]

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ABSTRACT: Sixty Romanov × Dorset (RVDP) and sixty Romanov × Suffolk (RVSU) male lambs were used in a 2 × 5 factorial arrangement of treatments including two breed crosses and five diets to determine the effect of breed crosses on performance and to compare growth and carcass characteristics of lambs. Diets consisted of an all-silage diet, silage supplemented with 100 g of fish meal·animal^{-1}·d^{-1}, or silage supplemented daily with concentrate at either 200 g or 400 g per animal, or ad libitum intake. Lambs were fed from an initial weight of 23 kg to a slaughter weight of 45 kg. There was no interaction ($P > .10$) between diet and breed for any parameter measured. Silage DMI was decreased ($P < .05$) by supplementation, but total DMI was similar among diets. The ADG was increased by fish meal and concentrate supplementation, with higher ($P < .05$) ADG observed with ad libitum access to concentrate. Lambs that had ad libitum access to concentrate had an improved gain:feed and required less time to reach market weight but had more carcass fat than lambs fed other diets. Lambs fed only silage had a higher percentage of carcass with poorer muscling than others. The highest percentage of carcasses with excellent to good muscling, normal fat covering, and grades A1 and A2 was obtained with fish meal supplementation. Lambs from the RVSU-crossbreed had better ADG than RVDP lambs but carcass quality of RVDP lambs was better than that of RVSU lambs. Feed costs for the entire trial were higher ($P < .05$) for concentrate available on an ad libitum basis compared with silage fed alone and intermediate for the other diets. These data demonstrate that fish meal supplementation results in improved carcass quality of silage-fed crossbred lambs. Carcass quality of RVDP lambs is better than that of RVSU lambs.

Key Words: Sheep, Grass Silage, Fish Meal, Concentrate, Carcass, Romanov Crosses

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Introduction

Supplementation with low ruminally degradable protein such as fish meal increases weight gain of lambs and, generally, silage intake (Yilala and Bryant, 1985) without any effect on carcass fat (Chestnutt, 1992). Cereal supplements improve lamb performance but decrease silage intake (Povey et al., 1990; Chestnutt, 1992) and increase carcass fat (Chestnutt, 1992).

All the above studies involved lambs of nonprolific breeds, whereas little is known about the most effective way of feeding prolific breeds and their crosses. Weight gain of lambs of prolific breeds (Romanov × Finnsheep) fed a diet of 25% concentrate and 75% silage was lower than that of the nonprolific breeds Suffolk, Coopworth, and DLS, a new breed that was developed in Canada, and both responded in a similar manner to protein supplementation (Fahmy et al., 1992). However, no comparison has been made between concentrate and fish meal supplementation in silage-based diets for lambs of prolific breed crosses. Prolific breeds produce acceptable market lambs but fat cover on the carcass is often inadequate to attain higher grades (Pommier et al., 1990). The two objectives of this experiment were to determine the effect of breed crosses on performance of lambs and to compare growth and carcass characteristics of silage-fed lambs supplemented with either fish meal or different amounts of concentrate.

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Materials and Methods

Animals and Housing. Sixty Romanov × Dorset (**RVDP**) and 60 Romanov × Suffolk (**RVSU**) crossbred male lambs were obtained from three local producers. All the lambs were born between January 20 and February 22, 1992, and were weaned at 50 d. Upon arrival, all lambs received a 2-mL intramuscular injection of antibiotic (Liquamycin®, Rogar/SDI, Montreal, QC) to prevent transport fever. For 2 wk, the lambs were allowed ad libitum access to a medium-quality timothy hay cut at midbloom stage, grass silage, and a 16% CP concentrate containing Bovatec® (18.75% sodium lasalocid, Hoffman-La Roche, Etobicoke, ON) to prevent coccidiosis. Lambs consumed 25 mg/d of lasalocid. Lambs from the three different producers were kept indoors in separate pens. In the 3rd wk, the amount of grain and hay fed was reduced by approximately 15% per day over a 7-d period, and the amount of silage fed was increased similarly. Then lambs within a breed were allotted randomly to 15 pens of four lambs per pen (3.6 m × 1.5 m). Each pen provided adequate feeding space and drinking facilities. Wood shavings were used for bedding.

Experimental Plan. Pens were assigned randomly to a 2 × 5 factorial arrangement of treatments consisting of two breed crosses and five diets, with three pens per treatment. Lambs were weighed every 2 wk. Feed was withheld overnight before weighing. The lambs were fed from an initial weight of approximately 23 kg to a slaughter weight of approximately 45 kg live weight. Average age of lambs at the beginning of the feeding period was 83 d for RVDP and 75 d for RVSU. Intake and gain:feed were determined on a pen basis. Lambs were shipped to a commercial abattoir when they reached approximately 45 kg BW. Fat thickness was measured 4 d before slaughter by ultrasound (Krautkramer USM #2, Krautkramer, Koln, Germany). Lambs were fasted overnight and weighed before shipping. Time required to reach 45 kg BW was recorded and slaughter data were collected on warm carcasses. Slaughter data consisted of carcass weight, dressing percentage, fat covering (coded 1, 2, or 3 to represent excessive, normal, or deficient covering), and conformation (coded 1, 2, or 3 to represent excellent, good, or poor muscling). Categories of the Canadian classification for lamb carcasses were A1, A2, A3, and B (Anonymous, 1989). Differences among A categories are mostly dependent on fat covering, which increases from A1 to A3; carcasses grading B have poorer muscling than those grading A (Anonymous, 1989). The most desirable carcass grade is A1.

Diets and Feeding. The five diets consisted of silage alone (**SI**), silage supplemented with 100 g of fish meal per day (**FM**), and silage supplemented daily with concentrate at either 200 g (**C1**) or 400 g (**C2**) per animal, or ad libitum intake (**C3**). Concentrate contained, on an air-dry basis, 32.5% of a commercial supplement (30% CP: 40% canola meal, 26% soybean meal, 29% oats, 3% molasses, and 2% minerals), 30.0% oats, 30.0% barley, 2.5% minerals, and 5.0% molasses. Diets FM and C2 were designed to provide similar N intakes from the supplement. Forage was harvested at the boot stage at the beginning of June 1991 from the primary growth of an old field containing approximately 67% bromegrass, 12% orchardgrass, 11% quackgrass, and 10% dandelion; grass was ensiled at approximately 20% DM in a noncompacted heap silo without preservative. The silage was fed once daily in quantities to allow daily orts of 5 to 10%. Twenty-five milligrams of lasalocid was fed per lamb per day to prevent coccidiosis. Orts consisted only of silage for FM, C1, and C2 because the supplements were sprinkled on top of the silage and were consumed readily by the lambs. Lambs fed C3 had access to two different feeders, one for silage and the other for concentrate. Concentrate orts for lambs fed C3 were weighed weekly, and fresh concentrate was weighed and added daily. Samples of feed were taken weekly and frozen for chemical analyses. Salt and a mineral-vitamin mix (Ca, 16.0%; P, 10.0%; Na, 12.0%; salt, 30.0%; Mg, 1.0%; Fe, 5,900 mg/kg; Cu, 6.0 mg/kg; Mn, 1,950 mg/kg; Zn, 5,500 mg/kg; I, 80.0 mg/kg; Co, 20.0 mg/kg; F, < 630.0 mg/kg; > 565,000 IU of vitamin A/kg; > 102,500 IU of vitamin D_3/kg; and > 800 IU of vitamin E/kg) were available at all times.

Digestibility Trial. Thirty Arcott Outaouais ram lambs averaging 29.1 ± .4 kg were used in a completely randomized design with six lambs per treatment to determine digestibility of the five diets fed in the lamb growth trial. The lambs were housed in metabolism cages during the digestibility trial. The metabolism cages were 120 cm in length × 52 cm in width. The crates were 30 cm above ground and had slotted floors. No problems with feet, legs, stiffness, or health of the lambs were noticed.

Feeding of the lambs was done as described for lambs in the growth trial. Adaptation to the diets occurred during the first 3 wk and, between d 22 and 31, total collection of feces was conducted. The lambs were fitted with a canvas bag to collect feces. Feed was offered ad libitum throughout the trial and voluntary intake was measured between d 22 and 31. Samples of feed were taken daily during the feces collection period and composited by diet for analyses. Daily output of feces was determined, and a 10% subsample was composited by animal and frozen.

Chemical Analyses. Weekly samples of silage were pooled on a 2-wk basis and weekly samples of supplements on a 6-wk basis; all samples were stored frozen and subsamples were taken before laboratory analyses. Silage DM was determined by toluene distillation (Dewar and McDonald, 1961) without correction for acids in the distillate, and DM in fish meal, concentrate, and feces was obtained by oven drying at 100°C for 48 h. For chemical analyses, samples of forages and feces were dried at 55°C for 96 h and ground to pass a 1-mm screen in a Wiley mill before analyses of fiber and protein N. Wet samples of forages and feces were used for total N and energy analyses. Total N (**TN**) was determined according to methods of the AOAC (1980). Gross energy was measured by combustion in a Parr adiabatic bomb calorimeter (Model 1241, Parr Instrument Co., Moline, IL). Determination of NDF and ADF was done with the nonsequential procedure of Goering and Van Soest (1970) without using sodium sulfite or decalin. Protein N (**PN**) was measured as TCA-insoluble N according to the method of Siddons et al. (1979), and nonprotein N (**NPN**) was considered to be the difference between TN and PN. Juice was squeezed from silages, filtered, and used for determination of pH, ammonia (NH_3) N (Novozamsky et al., 1974), L-lactic acid (Kit 139 084, Boehringer Mannheim, Dorval, QC, Canada), and VFA. Silage VFA concentration was determined by gas chromatography (Varian Model 3400, Varian Can., Ville St-Laurent, QC, Canada) using 1% isovaleric acid as the internal standard.

Statistical Analyses. Intake and gain:feed were determined on a pen basis, whereas data on growth and carcass were determined for each lamb. All data were subjected to analysis of variance using the GLM procedures of SAS (1985) according to a 5 × 2 factorial design with pen used as the experimental unit for intake, gain:feed, BW changes, ADG, and carcass characteristics; when pen effect was not significant for BW changes, ADG, and carcass characteristics, lamb was used as the experimental unit (Montgomery, 1984). Means within a diet effect following a significant F-test were separated using Scheffe's test when there was no interaction between diet and breed ($P > .05$). The maximum likelihood ratio chi-square test of PROC CATMOD® (SAS, 1985) was used to determine any interaction between breed and diet for carcass data on grades, covering, and conformation. Data were pooled for conformation (excellent and good muscling together) and fat covering (excessive and deficient together) to avoid cells with zero entries. When there was no interaction ($P > .05$) between diet and breed, Fisher's exact test of PROC FREQ® was used to compare the main effects on a 2 × 2 basis. Comparisons between diets were made for 1) FM vs SI, 2) FM vs C1, 3) FM vs C2, and 4) FM vs C3 to compare the effects of protein vs concentrate supplementation. Measurements of apparent digestibility were analyzed according to a completely randomized design with five treatments using lamb as the experiment unit and means were separated using Scheffe's test (SAS, 1985).

Results and Discussion

The silage contained 18.1% CP, 29.7% ADF, and 48.9% NDF (Table 1), which is indicative of late vegetative grass (NRC, 1982). Conservation of silage was good, as shown by the low pH and the low concentration of NH_3 N. According to Demarquilly (1990), fermentation of high-moisture silages (< 30% DM) with a pH of 4.0, < 5 to 7% NH_3 N, and approximately 50% insoluble or protein N is considered excellent.

There was no interaction ($P > .10$) between diet and breed for any of the characteristics measured; therefore, only the main effects are presented in the tables. Silage intake was higher ($P < .01$) for the all-silage diet and decreased with increasing amount of concentrate fed; C1 was not different ($P > .05$) from C2 (Table 2). This is in agreement with Yilala and Bryant (1985), Povey et al. (1990), and Chestnutt (1992). The substitution rate, which is the decrease in silage DMI observed per unit increase in supplement DMI, was 2.6, 1.5, 1.4, and 1.2 for SI to FM, SI to C1, SI to C2, and SI to C3, respectively. The substitution rates were higher than those calculated in other experiments (Yilala and Bryant, 1985), which could be due to better silage quality in the present

Table 1. Chemical composition of feed ingredients[a]

Item	Silage	Fish meal	Concentrate
pH	4.17 ± .11	—	—
DM	25.8 ± .7	94.9 ± .6	90.6 ± .1
Percentage of DM			
CP	18.1 ± .8	62.8 ± .2	17.1 ± .3
ADF	29.7 ± .3	—	6.8 ± .2
NDF	48.9 ± .7	—	17.1 ± .3
Lactic acid	3.07 ± .15	—	—
Acetic acid	.19 ± .03	—	—
Gross energy, kcal/g of DM	4.28 ± .04	5.96 ± .02	4.21 ± .01
Percentage of N			
Ammonia N	6.0 ± .5	—	—
Protein N	47.1 ± 1.8	76.8 ± .8	89.6 ± .8

[a]Mean ± SE.

Table 2. Least squares means for voluntary intake of DM of lambs fed silage with fish meal or different amounts of concentrate

Item	Diet[a]					Breed[b]		SEM
	SI	FM	C1	C2	C3	RVDP	RVSU	
DMI, g/d								
Silage	1,309[d]	1,058[e]	1,026[ef]	841[f]	274[g]	909	894	63
Fish meal	0[e]	95[d]	0[e]	0[e]	0[e]	19	19	3
Concentrate	0[g]	0[g]	190[f]	380[e]	872[d]	269	289	38
Total	1,309	1,153	1,216	1,221	1,146	1,197	1,202	83
DMI, % of BW								
Silage	3.86[d]	3.08[e]	3.02[ef]	2.44[f]	.78[g]	2.64	2.63	.17
Fish meal	0[e]	.28[d]	0[e]	0[e]	0[e]	.06	.05	.01
Concentrate	0[g]	0[g]	.56[f]	.97[e]	2.47[d]	.77	.83	.11
Total	3.86	3.36	3.58	3.41	3.25	3.47	3.51	.23
Cost per lamb								
Per day^2	.06[f]	.11[e]	.08[ef]	.10[e]	.18[d]	.11	.11	.01
For the growth trial[c]	6.09[f]	9.08[de]	7.31[ef]	8.13[ef]	11.93[d]	8.58	8.43	.41

[a]SI = silage only, FM = silage and 100 g of fish meal, C1 = silage and 200 g of concentrate, C2 = silage and 400 g of concentrate, C3 = silage and concentrate ad libitum.
[b]RVDP = Romanov × Dorset, RVSU = Romanov × Suffolk.
[c]All prices are in U.S. dollars.
[d,e,f,g,h]Means in the same row within diet or breed that do not have a common superscript differ ($P < .05$).

experiment. Thomas (1987) has reported that the substitution rate increases with an increase in forage quality. In fact, silage DMI of SI was almost twice as high in the present experiment as that reported by others for lambs of nonprolific breeds of similar BW (Yilala and Bryant, 1985; Povey et al., 1990; Chestnutt, 1992). In these experiments, silage fermentation was similar to that of our silage, but CP percentage was less than 16%, DM was approximately 20%, and ADF was more than 35% of DM. This would suggest that intake of high-quality forage such as in the present experiment is more adversely affected by concentrate supplementation than that of poorer-quality silage.

Silage intake for FM was similar ($P > .05$) to that of C1 but different ($P < .01$) from that of the other diets. Silage intake decreased ($P < .01$) with FM supplementation vs the all-silage diet, although it has been found to increase in some cases (Yilala and Bryant, 1985) but not to change in others (Hughes and Mansbridge, 1986; Povey et al., 1990). The effect of FM supplementation on silage DMI seems to be related mainly to CP content of high-moisture silage; increased DMI was observed with silage of 11% CP (Yilala and Bryant, 1985) and constant DMI with silage of approximately 15% CP (Povey et al., 1990; Chestnutt, 1992). In a review by Gill and England (1983) on the effect of FM supplementation on DMI of grass silages by 4-mo-old calves averaging 127 kg at the beginning of the trial, it was concluded that FM increased DMI, which was approximately 18 g/kg BW, as the CP content of the silage decreased below 12.5% CP. Silage in the present experiment contained 18% CP, which might exceed the animal's capacity to use such a high level of N. Fish meal supplementation has been shown to increase blood urea N and ruminal NH_3 N in beef steers fed high-protein silage (Petit and Flipot, 1992a).

Total DMI was similar ($P > .05$) among treatments as a result of a decrease in silage DMI and a parallel increase in supplement DMI. Differences in DMI of silage, FM and concentrate, expressed as percentage of BW, were similar to those of DMI (grams per day). Percentage of silage in the total DM averaged 100, 92, 84, 71, and 24% for lambs fed SI, FM, C1, C2, and C3, respectively (data not shown). Dry matter intake of silage, FM, and concentrate and total DMI were similar ($P > .05$) between breeds.

The costs of feed per lamb per day and per lamb for the entire growth trial were calculated (Table 2) using the prevailing prices at the time this experiment was conducted: US $44, US $192, and US $625 per tonne of DM, respectively, for silage, concentrate, and FM. Silage cost was calculated for silage harvested by custom work considering an average DM loss (field, storage, and feeding losses) of 23% (R. Berthiaume, personal communication). Lambs fed C3 had a higher cost per lamb per day than those fed the other diets. Daily costs were similar ($P > .01$) for lambs fed FM, C1, and C2, but the costs were ($P < .01$) higher for FM and C2 than for SI. Differences among diets for costs for the entire trial were similar to daily costs, although no difference was found between C3 and FM, or between C2 and SI. This would generally agree with Hughes and Mansbridge (1986), who calculated higher profits when lambs were fed protein vs cereal supplements as a result of higher silage DMI of the former.

Initial BW was similar among diets and breeds (Table 3). Final BW differed among diets ($P < .01$) but was similar between breeds. The targeted final BW was 45 kg, but sheep fed C3 were heavier ($P <$

Table 3. Least squares means for BW, ADG, gain:feed, and carcass characteristics of lambs fed silage with fish meal or different amounts of concentrate

	Diet[a]					Breed[b]		
Item	SI	FM	C1	C2	C3	RVDP	RVSU	SEM
Initial BW, kg	23.6	23.2	23.4	23.0	23.2	23.8	22.7	.3
Final BW, kg	44.3[d]	45.6[cd]	44.6[d]	45.8[cd]	47.4[c]	45.4	45.7	.2
ADG, g/d	197.0[f]	270.1[de]	245.1[e]	288.1[d]	373.6[c]	262.9[c]	286.6[d]	6.5
Gain:feed	.15[e]	.24[d]	.20[de]	.25[d]	.33[c]	.23	.24	.02
Time of fattening, d	105[c]	85[d]	89[d]	80[de]	66[e]	87	84	2
Age at slaughter, d	184[c]	164[d]	168[d]	156[de]	148[e]	170[c]	158[d]	2
Carcass weight, kg	19.8[e]	20.5[de]	20.2[de]	21.2[cd]	22.3[c]	20.8	20.8	.1
Dressing, %	44.6[d]	45.1[cd]	45.2[cd]	46.2[cd]	46.9[c]	45.8	45.4	.2
Fat thickness, mm	2.44	2.94	2.71	2.96	2.73	2.95[c]	2.59[d]	.07

[a]SI = silage only, FM = silage and 100 g of fish meal, C1 = silage and 200 g of concentrate, C2 = silage and 400 g of concentrate, C3 = silage and concentrate ad libitum.
[b]RVDP = Romanov × Dorset, RVSU = Romanov × Suffolk.
[c,d,e,f]Means in the same row within diet or breed that do not have a common superscript differ ($P < .05$).

.01) than those fed SI and those fed C1, probably because they were sent to slaughter only once a week and their ADG was higher than that of lambs on other diets. Final BW was similar for lambs fed SI, FM, C1, or C2. The ADG was lower ($P < .01$) for lambs fed SI than for those fed the other diets, and it increased with each increase in the amount of concentrate being fed. Lambs fed FM had an ADG similar ($P > .05$) to that of lambs fed C1 and C2, but their ADG was lower and higher, respectively, than the ADG of lambs fed C3 or SI. Supplementation with concentrate and FM increased ADG, in agreement with results of Yilala and Bryant (1985), Povey et al. (1990), and Chestnutt (1992) for lambs of nonprolific breeds. According to Yilala and Bryant (1985), improved animal growth is related to greater ME intake and N retention.

According to NRC (1985), early-weaned medium-weight lambs of rapid growth potential averaging 34 kg of BW (initial and final BW of 23 and 45 kg, respectively) with an ADG of approximately 350 g should consume approximately 1.35 kg of DM, 220 g of CP, and 1.39 Mcal of NE_g per day. Lambs fed SI, FM, C1, C2, and C3 consumed daily 1.31, 1.15, 1.22, 1.22, and 1.15 kg of DM; 253, 273, 237, 228, and 210 g of CP; and 1.54, 1.34, 1.40, 1.50, and 1.36 Mcal of NE_g, respectively. Intake of NE_g was calculated using data measured in the digestibility trial. Intake of DM represented 85 to 97% of tabulated values. Intake of CP was higher than requirements, except for lambs fed C3, which consumed only 95% of their requirements. Intake of NE_g generally was close to NRC requirements (NRC, 1985) for an ADG of 350 g, but the ADG ranged from 70 to 107% of predictions for fast-growing lambs. All lambs had similar calculated NE_g intakes, which would indicate that this was not the factor limiting growth. Moreover, intake of CP was higher than tabulated requirements (NRC, 1985) and should not have limited growth. Factors other than intake of total protein and energy would therefore seem to be responsible for differences in ADG among diets. Petit and Flipot (1992b) have obtained highly significant correlations between ADG and TN, PN, and NPN intake for beef steers fed high-moisture silage. This would suggest that intake of certain N compounds could have been below requirements and limited ADG of lambs. This would agree with Waldo and Tyrrell (1980, 1983), who have shown that ADG in steers fed silage was associated positively with intake of ruminal fluid-insoluble protein obtained by formaldehyde treatment of silage. Growth of lambs fed high-protein silage may be more dependent on intake of N compounds than on NE_g intake.

The gain:feed was higher for lambs fed C3 than for lambs fed other diets as a result of similar DMI for all diets but higher ADG for lambs fed C3. The gain:feed was similar for lambs fed FM, C1, and C2, and it was higher than that for lambs fed SI. Lambs fed SI and C1 had similar gain:feed. In general, the gain:feed increased with supplementation (Table 3), which agrees with Povey et al. (1990) and Chestnutt (1992).

Time of fattening was decreased by supplementation, which agrees with Povey et al. (1990) and Fahmy et al. (1992). Time of fattening was longer for lambs fed SI than for those fed the other diets as a result of their lower ADG. Time of fattening was similar for lambs fed FM, C1, and C2, and longer than that for lambs fed C3; time of fattening was similar for lambs fed C2 and those fed C3. Carcass weight was lower for lambs fed SI than for those fed C2 or C3. Lambs fed FM, C1, and C2 had similar carcass weight, as did those fed C2 and C3. Carcass weight was higher for lambs fed C3 than for those fed SI, FM, or C1. Dressing percentage was higher for lambs fed C3 than for those fed SI. There was no difference in dressing percentage among lambs fed FM, C1, C2, and C3, or among lambs fed SI, FM, C1, and C2. Fat thickness was similar among diets.

High levels of concentrate supplementation increased dressing percentage but FM supplementation

Table 4. Percentage of carcasses (n) of lambs fed silage with fish meal or different proportion of concentrate classified for conformation, fat covering, and grading of carcass

Item	Diet[a]					Breed[b]	
	SI	FM	C1	C2	C3	RVDP	RVSU
Conformation[c]							
Total n[d]	(24)	(24)	(24)	(23)	(24)	(60)	(59)
1	.8 (1)	0 (0)	0 (0)	.8 (1)	3.4 (4)	2.5 (3)	2.5 (3)
2	13.5 (16)	19.3 (23)	16.8 (20)	17.7 (21)	16.0 (19)	46.2 (55)	37.0 (44)
1 + 2[fh]	14.3 (17)	19.3 (23)	16.8 (20)	18.5 (22)	19.4 (23)	48.7 (58)	39.5 (47)
3[fh]	5.9 (7)	.8 (1)	3.4 (4)	.8 (1)	.8 (1)	1.7 (2)	10.1 (12)
Fat covering[e]							
Total n	(24)	(24)	(24)	(23)	(24)	(60)	(59)
1	1.7 (2)	.8 (1)	.8 (1)	2.5 (3)	5.0 (6)	3.4 (4)	7.6 (9)
2[fgh]	15.1 (18)	19.3 (23)	19.3 (23)	16.0 (19)	14.3 (17)	46.2 (55)	37.8 (45)
3	3.4 (4)	0 (0)	0 (0)	.8 (1)	.8 (1)	.8 (1)	4.2 (5)
1 + 3[fgh]	5.1 (6)	.8 (1)	.8 (1)	3.3 (4)	5.8 (7)	4.2 (5)	11.8 (14)
Grade							
Total n	(24)	(24)	(23)	(22)	(24)	(59)	(58)
A1	5.1 (6)	8.6 (10)	7.7 (9)	4.3 (5)	7.7 (9)	12.8 (15)	20.5 (24)
A2[h]	7.7 (9)	10.3 (12)	7.7 (9)	11.1 (13)	6.0 (7)	32.5 (38)	10.3 (12)
A3[g]	1.7 (2)	.9 (1)	.9 (1)	2.6 (3)	6.0 (7)	3.4 (4)	8.6 (10)
B[fh]	6.0 (7)	.9 (1)	3.4 (4)	.9 (1)	.9 (1)	1.7 (2)	10.3 (12)

[a]SI = silage only, FM = silage and 100 g of fish meal, C1 = silage and 200 g of concentrate, C2 = silage and 400 g of concentrate, C3 = silage and concentrate ad libitum.
[b]RVDP = Romanov × Dorset, RVSU = Romanov × Suffolk.
[c]Conformation: coded 1, 2, or 3 to represent excellent, good, or poor muscling.
[d]When information was not collected by the slaughterhouse, the total n for each diet and each breed is less than 24 and 60, respectively.
[e]Fat covering: coded 1, 2, or 3 to represent excessive, normal, or deficient covering.
[f]FM vs SI, $P < .05$.
[g]FM vs C3, $P < .05$.
[h]RVDP vs RVSU, $P < .05$.

did not affect dressing percentage, which agrees with results of Chestnutt (1992). However, slaughter weight of lambs fed C3 was higher than that of lambs fed other diets, which could explain the highest values of carcass weight and dressing percentage observed for lambs fed concentrate on an ad libitum basis as reported by Chestnutt (1992). Povey et al. (1990) observed that inclusion of concentrate increased dressing percentage, final live weight, and carcass weight of lambs fed silage to a similar degree of finish.

There was no interaction between diet and breed for ADG, in agreement with Fahmy et al. (1992), who observed that lambs of different genetic backgrounds responded similarly to various protein supplements. Differences between breed crosses showed that ADG was higher for RVSU than for RVDP, and that RVSU lambs were slaughtered at a younger age with less fat thickness than RVDP lambs. This agrees with Aziz et al. (1993), who found that RVSU lambs had higher ADG and lower fat (intermuscular, kidney, and channel fat) than RVDP lambs. The gain:feed, time of fattening, carcass weight, and dressing percentage were similar among diets between breed crosses. Differences in age at slaughter among diets were similar to those observed for time of fattening as a result of similar initial age for lambs (78 d). Age at slaughter was higher for RVDP than for RVSU as a result of RVDP lambs being older (83 d) than RVSU (75 d) lambs at the beginning of the trial, and of lower ADG for RVDP than for RVSU lambs.

Conformation of carcasses was grouped to compare carcasses with excellent and good muscling (coded 1 and 2, respectively) to carcasses with poor muscling (coded 3, Table 4). Lambs fed FM had a higher percentage of carcass with excellent and good muscling than lambs fed SI. Lambs fed SI had the highest percentage of carcasses with poor muscling. Conformation of carcasses of lambs fed FM was similar to that of lambs fed C1, C2, or C3. Although no statistics were performed on the following comparison, lambs fed C1 had a percentage of carcasses with excellent to good muscling intermediate between lambs fed FM, C2 and C3, and those fed SI. This would suggest that consumption at more than 200 g/d of concentrate is required to improve carcass muscling.

Fat covering of carcasses was grouped to compare carcasses with excessive or deficient covering (coded 1 and 3, respectively) to carcasses with normal covering (coded 2, desirable character). Lambs fed SI and C3 had more carcasses with less desirable fat covering (excessive or deficient) than lambs fed FM. Lambs fed FM had a similar percentage of carcasses with desirable fat covering than lambs fed C1 and C2. Fitzgerald (1986) reported that lambs fed 500 g/d of concentrate had a higher fat score than those fed only silage, with no difference between 250 and 500 g/d of concentrate, which would generally agree with our results.

Diet had no effect on the number of carcasses grading A1 and A2. However, lambs fed C3 had more carcasses grading A3 (fat carcass) than lambs fed FM, and lambs fed SI had more carcasses grading B (poor carcass) than lambs fed FM.

Fish meal and concentrate supplementation improved carcass quality, as previously reported by Fitzgerald (1986) and Chestnutt (1992). However, ad libitum access to concentrate resulted in excessive fat covering of carcasses and more carcasses grading A3 than lambs fed FM and C1. This agrees with results of Chestnutt (1992), who reported that rapid gains achieved by feeding high amounts of concentrate lead to increased carcass fat. However, rapid gains achieved through FM supplementation had no effect on carcass fat (Chestnutt, 1992), as observed in the present experiment. This would suggest that FM supplementation improves protein rather than fat deposition in the carcass, resulting in highly desirable carcass characteristics (excellent to good muscling, normal fat covering, and grades A1 and A2).

Conformation of RVDP lambs was better than that of RVSU lambs with more carcasses with excellent and good muscling, and fewer carcasses with poor muscling than RVSU lambs. There was a higher percentage of carcasses with normal fat covering for RVDP than for RVSU lambs. Both breeds had similar A1 and A3 grades, but RVDP lambs had more carcasses grading A2 and less grading B than RVSU lambs. Carcass quality of RVDP lambs was better than that of RVSU lambs, as shown by better muscling, more normal fat covering, and more carcasses grading A1 and A2.

Differences among treatments in DMI of FM, concentrate and silage, and total DMI during the digestibility trial generally were similar to those observed for the growth trial (Table 5). Apparent digestibility of DM was high and similar among diets. Concentrate and FM supplementation had no effect on apparent DM digestibility, but FM supplementation increased apparent N digestibility, in agreement with Yilala and Bryant (1985). Apparent digestibilities of ADF and NDF were lower for lambs fed C3 than for those fed the other diets. This is in agreement with Yilala and Bryant (1985), who observed that apparent fiber digestibility was decreased by concentrate supplementation, which probably results from decreased ruminal pH (Petit and Veira, 1991) and lower activity of cellulolytic bacteria. Apparent digestibilities of ADF and NDF were similar for SI, FM and C1, and for C1 and C2. There was no difference in apparent energy digestibility among diets.

In conclusion, concentrate supplemented at ad libitum intake resulted in higher ADG and carcass fat than FM supplementation at 10% of DM. Feeding only silage resulted in carcasses with poor muscling. The highest percentage of carcasses with excellent to good muscling, normal fat covering, and grades A1 and A2 was obtained with FM supplementation. Lambs from the RVSU crossbreed had better ADG than RVDP lambs. Carcass quality of RVDP lambs when lambs were slaughtered at 45 kg live weight was better than that of RVSU lambs, as shown by better muscling, more normal fat covering, and more carcasses grading A1 and A2. Feed costs for the entire trial were higher ($P < .05$) for concentrate available on an ad libitum basis compared with silage fed alone, and intermediate for the other diets.

Table 5. Least squares means for digestibility of lambs fed silage with fish meal or different amounts of concentrate

	Diet[a]					
Item	SI	FM	C1	C2	C3	SEM
Digestibility, %						
DM	75.9	75.9	75.6	77.1	76.6	.6
N	74.8^{c}	80.3^{b}	74.0^{c}	75.1^{c}	74.0^{c}	.8
ADF	77.6^{b}	77.6^{b}	73.8^{bc}	70.8^{c}	52.9^{d}	1.1
NDF	77.7^{b}	77.0^{b}	72.8^{bc}	70.2^{c}	55.0^{d}	1.2
Energy	74.6	74.6	74.4	76.8	76.2	.7
Feces DM, %	30.0^{c}	34.9^{b}	29.9^{c}	29.7^{c}	30.9^{bc}	1.0
N intake, g/d	34.6^{c}	42.8^{b}	37.8^{bc}	35.4^{c}	35.4^{c}	.8
DMI, g/d						
Silage	1,037	914	925	644	282	54
Fish meal	0	118	0	0	0	9
Concentrate	0	0	227	454	848	60
Total	1,037	1,032	1,152	1,098	1,130	45
DE intake, Mcal/d	3.34	3.30	3.68	3.61	3.66	.14

[a]SI = silage only, FM = silage and 100 g of fish meal, C1 = silage and 200 g of concentrate, C2 = silage and 400 g of concentrate, C3 = silage and concentrate ad libitum.

[b,c,d]Means in the same row that do not have a common superscript differ ($P < .05$).

Implications

Feeding only silage results in carcasses with poorer muscling than feeding silage supplemented with fish meal, demonstrating that high-quality silage needs low ruminally degradable protein supplementation to improve carcass quality of prolific crossbred lambs. Ad libitum access to concentrate results in the highest average daily gain but in excessive fat covering of the carcass. Fish meal supplementation results in the highest number of carcasses with highly desirable characteristics. Romanov × Suffolk lambs had better performance than Romanov × Dorset lambs but carcass quality of Romanov × Dorset lambs was better than that of Romanov × Suffolk lambs.

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