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Evaluating the effects of finishing diet and feeding location on sheep performance, carcass characteristics, and internal parasites

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Abstract

A 3 yr experiment was conducted to evaluate the influence of diet and feeding location on animal performance, carcass characteristics, whole blood counts, and internal parasite burden of lambs assigned to 1 of 4 treatments: 1) confinement fed 71% alfalfa, 18% barley pellet, 5% molasses, 0.013% Bovatec, 6.1% vitamin/mineral package diet (CALF), 2) confinement fed 60% barley, 26% alfalfa pellet, 4% molasses, 2.5% soybean-hi pro, 0.016% Bovatec, 7.4% vitamin/mineral package diet (CBAR), 3) field fed 71% alfalfa, 18% barley pellet, 5% molasses, 0.013% Bovatec, 6.1% vitamin/mineral package diet (FALF), and 4) field fed 60% barley, 26% alfalfa pellet, 4% molasses, 2.5% soybean-hi pro, 0.016% Bovatec, 7.4% vitamin/mineral package diet (FBAR). A year × location interaction was detected for ending body weight (BW), average daily gain (ADG), and dry matter intake (DMI); therefore results are presented by year. In all years, cost of gain and DMI were greater for CALF and FALF than for CBAR and FBAR feed treatments ($p \leq 0.03$). In yr 2 and 3 field treatments had greater ending BW and ADG than confinement treatments. For all years, diet did not affect ending BW or ADG. In yr 1 dressing percent and rib eye area were greater for field finished lambs than confinement finished ($p \leq 0.02$) and Warner-Bratzler shear force was greater for CALF and FALF ($p = 0.03$). In yr 2 lambs in FALF and FBAR treatments had greater leg scores and conformation than CALF and CBAR ($p = 0.09$). In yr 1, FALF had a greater small intestine total worm count than all other treatments. In yr 1, ending Trichostrongyle type egg counts were greater for FALF ($p = 0.05$). In yr 2, ending Nematodirus spp. egg counts were greater for FALF and lowest for CBAR ($p < 0.01$). Abomasum Teladorsagia circumcinta worm burden was greater in CALF than all other treatments ($p = 0.07$) in yr 2. While field finishing lambs with a grain- or forage-based diet we conclude that it is possible to produce a quality lamb product without adverse effects to animal performance, carcass quality or increasing parasite burdens.

Keywords: Carcass, Confinement, Field, Finishing, Parasites, Sheep

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Availability of data and material
Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions
Conceptualization: Boles JA, Hatfield PG.
Data curation: Ragen DL, Butler MR.
Formal analysis: Ragen DL, Butler MR.
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All animal procedures were approved by the Montana State University Agricultural Animal Care and Use Committee (Protocol #2013-AA07 approved October 29, 2013).

INTRODUCTION

Integrated crop and livestock systems as an alternative to confinement feedlot operations have gained popularity in recent years. The excretion and concentration of manure at concentrated animal feeding operations has resulted in environmental concerns associated with nuisance issues (odors, disease vectors), water quality, and air quality [1]. Conversely, the application of manure to soil provides potential benefits including improving the fertility, structure, water holding capacity of soil, increasing soil organic matter and reducing the amount of synthetic fertilizer needed for crop production [2–4]. Incorporating livestock into cropping systems may offer alternative uses of crops and provide new grazing opportunities for livestock producers [5]. It also offers an alternative to traditional stubble management, and enables improved pest management [6–8]. In Montana, sheep producers commonly manage their flock on rangeland or pasture during the grazing months of spring and summer and feed harvested forages during the fall and winter. Lambs raised for meat production are typically finished in a confinement feedlot operation [9].

Internal parasitism of grazing livestock is a significant world-wide disease problem [10,11]. Gastrointestinal parasites (GIP) in the abomasum and small intestine cause extensive protein loss in the digestive tracts of sheep [12] and failure to control GIP results in poor animal growth rates and thrift, and can result in animal mortality [13]. Previous research has reported that gastrointestinal nematode eggs per gram (EPG) were lowest in lambs fed in confinement, moderate in semi-confinement, and highest in grazing lambs [14]. Research by Ebrahim [15] revealed that blood samples taken from sheep infested with GIP had a significant decrease in hemoglobin, packed cell volume and red blood cell count values, while white blood cell count was significantly increased, compared to blood samples from a group of sheep that were parasite-free.

Previous research has only focused on grazed or harvested forage as the diet for finishing livestock and there is an increasing demand for non-confinement, forage-fed animals which are stimulating market interest in alternative production systems [16,17]. Providing a finishing ration to livestock on cropland is an unconventional way to finish livestock while adding manure to the soil. The objectives of this 3 yr study were to compare the effects of finishing diet and location on the performance, carcass characteristics, whole blood counts, and parasite loads of weaned, crossbred lambs.

MATERIALS AND METHODS

Ethics statement

All animal procedures were approved by the Montana State University Agricultural Animal Care and Use Committee (Protocol #2013-AA07 approved October 29, 2013).

Sampling

Ninety crossbred lambs (ewes and wethers; Blackface × Western whiteface; 6-mo-old; body weight [BW] = 35.6 ± 5.7 kg) and 18 Targhee lambs (ewes; 6-mo-old; BW = 35.8 ± 5.2 kg) were used in yr 1 (September 25 to November 25) of the study. Targhee ewe lambs were used because of an insufficient number of crossbred lambs in yr 1. The Targhee ewes were evenly distributed through all treatments. One hundred and eight crossbred lambs (ewes and wethers; Blackface × Western whiteface; 5-mo-old; BW = 31.8 ± 4.7 kg) were used in yr 2 (September 3 to November 3) of the study. One hundred and eight crossbred lambs (ewes and wethers; Blackface × Western whiteface; 5-mo-old; BW = 36.8 ± 5.7 kg) were used in yr 3 (September 1 to November 5) of the study. For yr 1, yr 2 and yr 3, lambs were transported to the Fort Ellis Research Facility (45°40'N, 111° 2'W,

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altitude 1,468 m) in Bozeman, Montana, USA on September 19th, September 1st, and August 30th, respectively. Mean monthly air temperature at the site ranges from −5.6℃ in January to 19℃ in July and the total annual precipitation (113-yr average) is 465 mm. On d 0 all lambs were placed in a dry lot pen and held off of feed and water overnight. On d 1 lambs were weighed, and paint-branded for identification purposes. Lambs were then stratified by BW and sex and allocated to treatments. In all years, the four treatments consisted of: 1) confinement fed 71% alfalfa, 18% barley pellet diet (CALF), 2) confinement fed 60% barley, 26% alfalfa pellet diet (CBAR), 3) field fed 71% alfalfa, 18% barley pellet diet (FALF), and 4) field fed 60% barley, 26% alfalfa pellet diet (FBAR) (Table 1).

For all three years of the study, pen was the experimental unit with nine lambs per pen in confinement (4 pens total). Field was the experimental unit with six fields per treatment (12 fields total), with six lambs per field. Harvest occurred at the end of the 60 d finishing period for yr 1 and yr 2; carcass data was not collected in yr 3 as lambs were not harvested the third year of the study.

All lambs on CBAR and FBAR treatment diets had a step-up period of 2 weeks, during which a combination of the barley and alfalfa pellets were fed to lambs in 2 to 3 day increments (25–75, 35–65, 45–55, 55–45, 65–35, 75–25, 85–15, and 100–0 percent respectively). Lambs being field finished, both FALF and FBAR, were on organic wheat stubble fields measuring 15. 2 m by 44.2 m and fed from self-feeders. Self-feeders were moved to a different area of the field at ~30 d to help distribute manure and urine. The winter wheat stubble fields used for this experiment were part of a common 5-yr crop rotation planted at the site: 1) safflower under-sown to biennial sweet clover, 2) sweet clover cover crop/green manure, 3) winter wheat, 4) lentils, and 5) winter wheat. Further details of the farm management practices used at the research site can be found in [18–21].

Confinement finishing took place in dry lot pens and used a GrowSafe feed intake system (GrowSafe Systems, Airdrie, AB, Canada) to measure intake. GrowSafe is a feed intake acquisition technology using an electronic radio frequency identification (RFID) system that has enabled researchers and producers to monitor individual animal intake and behavior to more precisely evaluate feed efficiency and health status [22]. GrowSafe records feeding behavior traits such as total intake, frequency and duration of feeding, and eating rate for each individual animal through

Table 1. Nutrient concentration of treatment diets, % DM basis, and cost of treatment diets

Item	Yr 1		Yr 2		Yr 3	
	Treatment[1]		Treatment		Treatment	
	ALF[2]	BAR[3]	ALF	BAR	ALF	BAR
DM (%)	89.91	90.14	90.13	89.66	89.71	89.38
CP (%)	20.6	17.5	18	18	21.3	16.3
ADF (%)	30.6	15.6	33.3	21	32.5	16.9
NDF (%)	43	28.7	42.4	31.9	39.8	30.4
TDN (%)	67.7	84.8	64.6	78.6	63.6	83.3
NEm (Mcal/lbs)	0.68	0.89	0.64	0.81	0.63	0.87
NEg (Mcal/lbs)	0.41	0.59	0.37	0.55	0.36	0.58
Cost/ton ($)	452.00	407.20	411.60	366.40	406.40	341.60

[1]Diets were provided for ad libitum intake.

[2]ALF: pellet containing 71% alfalfa, 18% barley, 5% molasses, 0.013% Bovatec, and 6.1% vitamin/mineral package; fed in both confinement and in the field.

[3]BAR: pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, 0.016% Bovatec, and 7.4% vitamin/mineral package; fed in both confinement and in the field.

DMI, dry matter; CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber; TDN, total digestible nutrients; NE_m, net energy for maintenance.

the use of RFID tags that provide a continuous transmission of data to a computer located at the facility. The lambs in each confinement treatment, CALF and CBAR, were housed together in an 11.3 by 7.1 m pen with one GrowSafe bunk; modifications were made to the beef cattle stanchions through elevated platforms for sheep.

Prior to all weigh days, animals were kept in a separate dry lot pen where feed and water were withheld overnight for approximately 16 h. Each lamb's BW was recorded at start and at the end of the trial. Average daily gain (ADG) was calculated for the entire ~2 mo trial period for each year. Daily dry matter intake (DMI) was determined between days that BW was recorded for all lambs and the average ratio of gain to feed (G:F) was calculated between weigh days by dividing ADG by average daily DMI. Cost of gain was calculated by multiplying G:F by cost per kg of feed. Feed cost was determined by the purchase price of the treatment diets which was based on current market value (Table 1). The higher price of feed in yr 1 was due to a persistent drought that increased the demand for hay as well as lingering winter temperatures that wilted spring crops.

Carcass data

Carcass data was only collected for yr 1 and yr 2. At the end of yr 1 and yr 2, 32 wether lambs (8 from each treatment) were transported to Pioneer Meats in Big Timber, MT where harvest occurred the following day, using standard industry practices for a small packing plant. After harvest, carcasses were hung by the Achilles tendon, a hot carcass weight was recorded, and dressing percentage was measured. Carcasses were chilled for 24 h at 4℃ and then transported to the Montana State University Meat Lab for further processing and data collection.

An experienced evaluator obtained individual-level carcass data. These measurements included back fat depth, rib-eye area, leg score, conformation, flank streaking, and quality grade. Additionally, a sample of four rib chops were obtained from the posterior portion of the left longissimus thoracis, vacuum-packaged and frozen at −20℃ for later tenderness analysis. Warner-Bratzler shear force (WBSF) was determined on cooked and chilled rib chops. Samples were defrosted for 24 h at 4℃, dried, weighed, and broiled in an electric oven until an internal temperature of 35℃ was reached. Temperature was monitored using a Digi Sense Scanning Thermometer from Cole Palmer (Vernon Hills, IL, USA) fitted with copper constantan needle thermocouples (Omega Engineering) placed in the geometric center of the chop. All chops were turned over when the temperature reached 35℃ and continued cooking until a final internal temperature of 71 ± 1℃ was reached at which point chops were removed from the heat source. Samples were bagged and allowed to chill at 4℃ for at least 1 h. Samples were then reweighed to determine cook loss, and two circular cores measuring 1.27 cm in diameter were obtained parallel to the fiber direction using a hand-held coring device (cork borer) with a total of 6 cores collected from 3 chops. Cores were allowed to reach room temperature prior to being sheared perpendicular to the fiber direction using a TMS-90 Texture System (Food Technology, Rockville, MD, USA) fitted with a Warner-Bratzler shear attachment (crosshead speed 200 mm//min). The average of the maximum force necessary to shear all cores per carcass was used for statistical analysis.

Blood collection

Blood samples were collected into serum and EDTA vacutainers from the jugular vein of lambs on d 0 and d 60 for yr 1 and yr 2 of the study. Immediately after collection, blood was put on ice and transported to the Montana Veterinary Diagnostic Lab for a complete blood count (CBC). The blood count was performed on a CELL-DYN 3700 System (Abbott Laboratories, Abbott Park, IL, USA).

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Internal parasites

To evaluate which species, and the amounts of parasites that occurred in the lambs, a fecal egg count (FEC) was performed on rectal grab samples using the Modified McMaster's technique [23]. Samples were collected on days 0 and 60 in both yr 1 and yr 2. Trichostrongyle type or *Nematodirus* were identified and counted individually. One egg inside the grid of the slide represented 50 EPG of fresh feces.

During harvest, at the end of yr 1 and yr 2, the abomasum and first meter of the small intestine were collected at random from 4 lambs from each of the four treatments to be used for a total worm count analysis using the modified methods of Wood et al. [24]. The two organs and their contents were separated and washed thoroughly with tap water in a 20 liter bucket. The water level was brought to 10 liters and both the water and organs were left to settle for ≥ 15 minutes. Next, the top one half to two thirds of the water was decanted and the process was repeated twice, returning the water level to 10 liters each time. After the third wash, the organ was rinsed again and disposed of and the water level was then returned to 10 liters for a final settling. After all washings had occurred and the fourth wash was decanted, the water level was returned to 10 liters, then mixed with a stir rod and 4–100 mL aliquots were taken and stored in jars with 100 mL of 10% formalin for later identification of adult worms in the gastrointestinal tract. The worms were plated onto slides with lactophenol and placed under a compound microscope for identification of species, via anatomical structure, and total number of each parasite was recorded.

Feed analysis

The feed was sampled weekly by grab sampling, composited for the entire experiment, and stored in sealed sample bags for analysis at a later date. All feed samples for all years, including pelleted rations and wheat stubble samples, were sent to Midwest Laboratories for nutrient analysis. Moisture, crude protein, acid detergent fiber (ADF), neutral detergent fiber (NDF), total digestible nutrients (TDN), net energy (Gain, Lactation, Maintenance), and relative feed value (RVF) were estimated using the F10: Relative Feed Value package (Table 1).

In addition to the analysis by Midwest Laboratories, all samples were analyzed for organic matter. Two 2-g samples of the 1-mm ground forage were weighed and placed in a muffle oven at 550℃ for 15 h to determine ash weights for calculation of OM content [25].

Data analyses

The study design was a two by two factorial. The model included the effect of year, feeding location, and type of feed. Response variables for performance were: final lamb BW, ADG, feed efficiency, DMI, and cost per kg of gain. Response variables for carcass quality characteristics were: dressing percentage, hot carcass weight, back fat, rib eye area, leg score, conformation, flank streaking, quality grades, and WBSF. A year × feed × location interaction was detected for dressing percentage, abomasum *T. circumcinta* counts, small intestine *Nematodirus* counts, and total small intestine counts. Year × feed interactions were detected for ending white blood cell counts and abomasumal *T. circumcinta* counts. Year × location interactions were detected for DMI, ending BW, ADG, dressing percentage, and abomasum *H. contortus* counts. The data was then analyzed within year using the GLM procedure of SAS (SAS Inst, Cary, NC, USA). Beginning lamb BW was used as a covariate in the analysis of final BW and ADG. Treatment means were compared using the Least Squares Means (LSMeans) procedure when a significant p value was found ($p \leq 0.10$).

FECs were transformed to the logarithmic base 10 scale prior to analysis. The GLM procedure was run with beginning count as a covariate but it added nothing to the model and was removed. Total worm counts were also logarithmic base 10 transformed and Proc GLM was used for analysis.

RESULTS AND DISCUSSION

Performance

In North America, confinement-finished lamb-meat production promotes rapid growth and is based on diets containing high levels of grain concentrates. The majority of research has reported that lambs grow faster on concentrate-based diets than on forage-based diets [26–35] and *ad libitum* consumption of concentrates results in fatter lambs compared to those fed forage diets when the lambs are slaughtered at a constant final weight [27,36,37]. However, there is a rapidly increasing demand for grass-fed or organically produced livestock [38] and in the U.S. retail sales of pasture-finished beef have risen from $17 million in 2012 to $272 million in 2016 [39].

A year × location interaction was detected for ending BW, ADG, and DMI; therefore results are presented by year. In yr 1, there were no interactions between location and feed ($p > 0.29$) for all response variables (Table 2). There was also no effect of location ($p > 0.42$) on ending BW, ADG, DMI, G:F, and cost of gain. Cost of gain and DMI were greater for CALF and FALF than for CBAR and FBAR feed treatments ($p < 0.01$) across all years. G:F ratio was greater for CBAR and FBAR than CALF and FALF (0.15, 0.14, 0.12, and 0.13 G:F respectively; $p = 0.01$).

In yr 2, there were no interactions between location and feed ($p > 0.32$) for all response variables (Table 3). Location had an effect on ending BW and ADG, and both FALF and FBAR were greater than CALF and CBAR ($p < 0.01$). Dry matter intake, G:F ratio, and cost of gain had both a location and feed effect and differed among all treatments ($p < 0.01$; Table 3).

In yr 3, there was a location × feed interaction for ending BW and ADG ($p = 0.09$ and $p = 0.08$, respectively) (Table 4). Ending BW and ADG were greater for both FALF and FBAR than CALF and CBAR ($p < 0.01$). Feed had an effect on DMI and was greater for FALF and CALF which were similar ($p = 0.03$). This difference in DMI was expected as it has been reported that the decrease in DMI as a result of feeding higher proportion of concentrate can be attributed to the regulatory effect of dietary energy intake. Generally, animals eat food mainly to satisfy their desire for energy [40]. G:F did not differ among treatments ($p = 0.53$). Cost of gain had both a location

Table 2. Performance of crossbred lambs consuming either a forage or grain based diet while in confinement or on wheat stubble fields in yr 1[1)]

Item	Treatment[2,3)]				SEM	*p*-value			
	Confinement[4)]		Field[5)]			Model	Location[6)]	Feed[7)]	Location × Feed
	CALF	CBAR	FALF	FBAR					
Ending BW[8)] (kg)	50.6	50.5	51.3	49.5	0.78	0.49	0.85	0.24	0.30
ADG (kg/d)	0.25	0.25	0.26	0.23	0.01	0.49	0.83	0.21	0.30
DMI (kg/d)	2.09[a]	1.67[b]	2.09[a]	1.62[b]	0.05	< 0.01	0.59	< 0.01	0.64
Gain to feed	0.12[b]	0.15[a]	0.13[b]	0.14[a]	0.01	0.01	0.74	0.01	0.36
Cost of gain ($/kg)	4.33[a]	3.09[b]	3.95[a]	3.14[b]	0.21	0.00	0.42	< 0.01	0.29

[1)]Start date for all treatments was September 26th.

[2)]Pen is the experimental unit, 3 sheep per replicate confinement, 6 sheep per replicate field; six replicates per treatment.

[3)]Diets were provided to allow for *ad libitum* intake.

[4)]CALF: pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; CBAR: pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[5)]FALF: field fed pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; FBAR: field fed pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[6)]Location, confinement or field finish.

[7)]Feed, alfalfa or barley pellets.

[8)]End date for field and confinement treatments was November 25th.

[a, b]Least Square Means within a row with different superscripts differ ($p < 0.10$).

BW, body weight; ADG, average daily gain; DMI, dry matter.

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Table 3. Performance of crossbred lambs consuming either a forage or grain based diet while in confinement or on wheat stubble fields in yr 2[1)]

Item	Treatment[2,3)]				SEM	*p*-value			
	Confinement[4)]		Field[5)]			Model	Location[6)]	Feed[7)]	Location × Feed
	CALF	CBAR	FALF	FBAR					
Ending BW[8)] (kg)	46.0[b]	45.8[b]	49.6[a]	49.2[a]	0.87	0.01	< 0.01	0.74	0.84
ADG (kg/d)	0.24[b]	0.23[b]	0.30[a]	0.29[a]	0.01	< 0.01	< 0.01	0.72	0.71
DMI (kg/d)	2.03[b]	1.58[d]	2.24[a]	1.74[c]	0.07	< 0.01	0.01	< 0.01	0.66
Gain to feed	0.11[d]	0.15[b]	0.13[c]	0.16[a]	0.01	< 0.01	< 0.01	< 0.01	0.85
Cost of gain ($/kg)	4.00[a]	2.74[c]	3.42[b]	2.00[d]	0.21	< 0.01	< 0.01	< 0.01	0.32

[1)]Start date for all treatments was September 4th.

[2)]Pen is the experimental unit, 3 sheep per replicate confinement, 6 sheep per replicate field; six replicates per treatment.

[3)]Diets were provided to allow for *ad libitum* intake.

[4)]CALF: pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; CBAR: pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[5)]FALF: field fed pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; FBAR: field fed pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[6)]Location, confinement or field finish.

[7)]Feed, alfalfa or barley pellets.

[8)]End date for field and confinement treatments was November 4th.

[a–d]Least Square Means within a row with different superscripts differ ($p < 0.10$).

BW, body weight; ADG, average daily gain; DMI, dry matter.

Table 4. Performance of crossbred lambs consuming either a forage or grain based diet while in confinement or on wheat stubble fields in yr 3[1)]

Item	Treatment[2,3)]				SEM	*p*-value			
	Confinement[4)]		Field[5)]			Model	Location[6)]	Feed[7)]	Location × Feed
	CALF	CBAR	FALF	FBAR					
Ending BW[8)] (kg)	51.75[a]	50.51[a]	52.84[b]	53.73[b]	0.75	< 0.01	< 0.01	0.78	0.09
ADG (kg/d)	0.22[a]	0.21[a]	0.24[b]	0.25[b]	0.01	< 0.01	< 0.01	0.81	0.08
DMI (kg/d)	2.08[a]	1.86[b]	2.14[a]	2.00[b]	0.07	0.03	0.11	< 0.01	0.57
Gain to feed	0.13	0.10	0.10	0.11	0.01	0.53	0.65	0.70	0.17
Cost of gain ($/kg)	4.15[a]	3.36[b]	3.72[a]	2.75[c]	0.22	< 0.01	< 0.01	< 0.01	0.65

[1)]Start date for all treatments was September 1st.

[2)]Pen is the experimental unit, 3 sheep per replicate confinement, 6 sheep per replicate field; six replicates per treatment.

[3)]Diets were provided to allow for *ad libitum* intake.

[4)]CALF: pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; CBAR: pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[5)]FALF: field fed pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; FBAR: field fed pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[6)]Location, confinement or field finish.

[7)]Feed, alfalfa or barley pellets.

[8)]End date for field and confinement treatments was November 5th.

[a–c]Least Square Means within a row with different superscripts differ ($p < 0.10$).

BW, body weight; ADG, average daily gain; DMI, dry matter.

and feed effect and was highest for CALF and FALF ($4.15 /kg and $3.72 /kg, respectively; $p < 0.01$) than CBAR and FBAR with FBAR having the lowest cost of gain ($2.75 /kg; $p < 0.01$). Even though the cost of gain was greater for alfalfa fed lambs, a survey conducted by Ripoll et al. [41] reported that 70.4% of consumers surveyed believe that grass-fed lamb is better and may be willing to pay a premium price for what they perceive as a "higher-quality product". Also, Jacques et al. [42] concluded that using forage finishing systems may improve processing efficiency by reducing the amount of external fat to be removed by preventing excessively fat carcasses from

lambs slaughtered. However, in our study there was no difference in back fat thickness among treatments ($p \leq 0.33$; Tables 5 and 6).

In yr 2 and 3, both field treatments had greater ending BW and ADG than the confinement treatments. In yr 1, extreme weather conditions (temperatures down to −29℃ for ~1 week) may have affected animals in the field and had an impact on animal performance. Our results are in agreement with those of Phillips et al. [43] who reported that lambs can be adequately finished on a forage-based diet (alfalfa or kenaf) and doing so does not adversely affect performance or feed intake. McClure et al. [32] and Aurosseau et al. [44] also determined that finishing lambs on high-quality forages can yield similar ADG to those achieved in confinement feeding a concentrate diet while producing comparable carcasses.

Carcass

A year × location and a year × location × feed interaction was detected for dressing percentage; therefore, results are presented by year. In yr 1, there was no interaction between location and feed ($p > 0.09$) for all response variables (Table 5). Dressing percent differed by location but not feed; dressing percent was greater for FALF and FBAR than for CALF and CBAR (51.92%, 52.85%, 49.18%, and 46.45% respectively; $p < 0.02$). Rib eye area differed by location but not feed; rib eye area was greater for FALF and FBAR than for CALF and CBAR (6.03, 6.32, 5.30, and 5.33 cm^2 respectively; $p < 0.02$; Table 5). WBSF was greater for CALF and FALF than CBAR and FBAR (3.8, 3.8, 2.7, and 3.1kg respectively; $p = 0.01$). All other carcass measurements did not differ among treatments. Nichols et al. [45] reported that lambs overwintered on stubble fields graded choice after confinement feeding; however, they did not investigate alternatives to confinement feeding.

Table 5. Carcass characteristics of crossbred lambs consuming either a forage or grain based diet while in confinement or on wheat stubble fields in yr 1[1)]

Item	Treatment[2,3)]				SEM	*p*-value			
	Confinement[4)]		Field[5)]			Model	Location[6)]	Feed[7)]	Location × Feed
	CALF	CBAR	FALF	FBAR					
Carcass weight (kg)	25.1	24.2	25.9	26.6	1.13	0.46	0.16	0.90	0.44
Dressing percent	49.18^{b}	46.45^{b}	51.92^{ab}	52.85^{a}	1.54	0.02	0.01	0.54	0.22
Back fat thickness (cm)	0.34	0.38	0.43	0.28	0.07	0.56	0.94	0.49	0.21
Ribeye area (cm^2)	5.30^{b}	5.33^{b}	6.03^{a}	6.32^{a}	0.21	< 0.01	< 0.01	0.45	0.55
Leg score[8)]	406	413	434	422	8.56	0.13	0.04	0.72	0.28
Conformation[8)]	413	419	434	413	8.08	0.20	0.34	0.34	0.09
Flank streaking[9)]	294	237	256	259	23.99	0.39	0.73	0.25	0.21
Quality grade[8)]	425	407	406	409	15.08	0.77	0.57	0.61	0.47
WBSF (kg)	3.8^{a}	2.7^{b}	3.8^{a}	3.1^{b}	0.30	0.03	0.56	< 0.01	0.53

[1)]Start date for all treatments was September 26th; End date for field and confinement treatments was November 25th.

[2)]Pen is the experimental unit, 3 sheep per replicate confinement, 6 sheep per replicate field; six replicates per treatment.

[3)]Diets were provided to allow for *ad libitum* intake.

[4)]CALF: pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; CBAR: pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[5)]FALF: field fed pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; FBAR: field fed pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[6)]Location, confinement or field finish.

[7)]Feed, alfalfa or barley pellets.

[8)]325, Good minus; 350, Good; 375, Good plus; 425, Choice minus; 450, Choice; 475, Choice plus; 525, Prime minus; 550, Prime; 575, Prime plus.

[9)]100 to 199, Practically Devoid; 200 to 299, Traces; 300 to 399, Slight; 400 to 499, Small.

[a,b]Least Square Means within a row with different superscripts differ ($p < 0.10$).

WBSF, Warner-Bratzler shear force.

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Table 6. Carcass characteristics of crossbred lambs consuming either a forage or grain based diet while in confinement or on wheat stubble fields in yr 2[1)]

Item	Treatment[2,3)]				SEM	*p*-value			
	Confinement[4)]		Field[5)]			Model	Location[6)]	Feed[7)]	Location × Feed
	CALF	CBAR	FALF	FBAR					
Carcass weight (kg)	24.5	23.5	25.6	24.4	1.01	0.54	0.33	0.28	0.90
Dressing percent	49.71	50.85	51.49	50.31	0.95	0.59	0.52	0.98	0.23
Back fat thickness (cm)	0.25	0.24	0.33	0.32	0.04	0.33	0.07	0.79	0.94
Ribeye area (cm^2)	5.91	5.73	6.25	6.32	0.20	0.15	0.03	0.79	0.56
Leg score[8)]	419[ab]	406[b]	438[a]	431[a]	8.92	0.09	0.02	0.30	0.73
Conformation[8)]	419[ab]	406[b]	438[a]	431[a]	8.92	0.09	0.02	0.30	0.73
Flank streaking[9)]	259	289	324	288	35.39	0.61	0.35	0.92	0.33
Quality grade[8)]	403	419	443	413	21.65	0.59	0.42	0.72	0.28
WBSF (kg)	4.2	4.3	4.1	3.7	0.48	0.76	0.45	0.67	0.56

[1)]Start date for all treatments was September 4th; End date for field and confinement treatments was November 4th.

[2)]Pen is the experimental unit, 3 sheep per replicate confinement, 6 sheep per replicate field; six replicates per treatment.

[3)]Diets were provided to allow for *ad libitum* intake.

[4)]CALF: pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; CBAR: pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[5)]FALF: field fed pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; FBAR: field fed pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[6)]Location, confinement or field finish.

[7)]Feed, alfalfa or barley pellets.

[8)]325, Good minus; 350, Good; 37, Good plus; 425, Choice minus; 450, Choice; 475, Choice plus; 525, Prime minus; 550, Prime; 575, Prime plus.

[9)]100 to 199, Practically Devoid; 200 to 299, Traces; 300 to 399, Slight; 400 to 499, Small.

[a,b]Least Square Means within a row with different superscripts differ ($p < 0.10$).

WBSF, Warner-Bratzler shear force.

There was no difference in quality grade amongst treatments or years; all treatments graded in the good-plus to choice-minus range ($p \leq 0.77$; Table 5).

In yr 2, there were no interactions between location and feed ($p > 0.23$) for all variables. Lambs in FALF and FBAR treatments tended to have greater leg scores and conformation than CALF and CBAR ($p = 0.09$). All other carcass measurements did not differ among treatments (Table 6). In our study we observed lambs in the field treatments exercising more than lambs in confinement pens; further research should be conducted to corroborate these observations and determine if exercise has an effect on leg scores and conformation. Our results are in conflict with the results of Jones et al. [46], where confinement fed lambs produced heavier carcasses and larger rib eye areas than pasture fed lambs. Our results are also in disagreement with Purchas et al. [47] who reported that WBSF values were significantly lower for *M. seminembranosus* in the pasture vs. grain treatments of 50 kg harvest weight lambs (4.04, 4.67 kg, respectively). In our study, location did not have an effect on tenderness but WBSF was greater for CALF and FALF than CBAR and FBAR (3.8, 3.8, 2.7, and 3.1 respectively; $p = 0.01$). Both Duckett et al. [48] and Realini et al. [49] reported that WBSF values were similar between forage and concentrate-fed animals. In our trial the forage-based treatment diet and grain-based treatment diet were both in concentrate-form with the same particle size. Past studies have only investigated forage-fed (in pasture or hay form) vs. concentrate-fed diets and therefore may not be comparable to our study. Forage particle size influences feed intake, saliva production, rumination, and the passage rate of feed in the rumen, as well as bio-hydrogenation pathways and fatty acid composition in lamb meat [50].

Blood

A year × feed interaction was detected for ending white blood cell counts; therefore, results are presented by year. In yr 1, there were no interactions between location and feed ($p > 0.12$) for all variables (Table 7). Both hematocrit and mean cell hemoglobin concentration were affected by feed and were greater for CALF and FALF than CBAR and FBAR ($p < 0.08$). This agrees with the results of Gawel and Grzelak [51] who reported that alfalfa concentrate may be important as a dietary supplement for animals and may improve the hematological indices of blood. Mean cell hemoglobin and red cell distribution width differed by location; FALF and FBAR were both greater than CALF and CBAR ($p < 0.06$). All other blood counts did not differ between treatments. The principal clinical sign of *Haemonchus contortus (H. contortus)* infections is anemia, due to the blood-letting activities of the parasite [52]. The cool season parasite *T. circumcinta* (formerly *Ostertagia circumcinta*) interferes with absorption of nutrients and may cause weight loss and possibly diarrhea [53].

In yr 2, there were no interactions between location and feed ($p > 0.38$) for all variables (Table 8). Red blood cell counts were affected by feed and were greater for CALF and FALF than CBAR and FBAR ($p < 0.07$). The tendency for CALF to have greater white blood cell counts in yr 2, compared to other treatments, may be influenced by its abomasum *T. circumcinta* worm burden which was greater in CALF than all other treatments ($p = 0.07$). This would agree with the results of Ebrahim [15] who reported that blood samples taken from sheep infested with GIP had greater white blood cell counts than sheep that were parasite-free. Kowalczuk-Vasilev et al. [54] reported that the use of iron-rich alfalfa concentrate in feeding lambs significantly improved hematological blood indices: hematocrit, hemoglobin and erythrocytes (RBC), and may be due to more efficient iron absorption. Hematocrit and mean cell hemoglobin differed by location and FALF and FBAR were greater than CALF and CBAR ($p < 0.08$). Variation in factors that affect the rumen bacterial

Table 7. Whole blood counts of crossbred lambs consuming either a forage or grain based diet while in confinement or on wheat stubble fields in yr 1[1)]

Item[6)]	Treatment[2,3)]				SEM	*p*-value			
	Confinement[4)]		Field[5)]			Model	Location[7)]	Feed[8)]	Location × Feed
	CALF	CBAR	FALF	FBAR					
White blood cell	7.34	7.69	7.46	7.02	0.43	< 0.01	0.44	0.90	0.28
Red blood cell	12.99	12.66	12.92	12.62	0.32	0.13	0.82	0.23	0.95
Hemoglobin	14.07	20.13	14.21	13.68	2.56	0.26	0.14	0.19	0.12
Hematocrit	42.00^{a}	40.56^{b}	42.19^{a}	41.28^{ab}	0.63	0.01	0.38	0.03	0.62
Mean cell volume	32.36	32.21	41.72	32.83	7.67	0.70	0.43	0.47	0.49
Mean cell hemoglobin	10.83^{ab}	10.62^{b}	11.05^{a}	10.97^{ab}	0.18	< 0.01	0.06	0.34	0.66
Mean cell hemoglobin concentration	33.43^{ab}	33.19^{b}	33.65^{a}	33.25^{b}	0.23	< 0.01	0.45	0.08	0.68
Red cell distribution width	25.80^{b}	25.62^{b}	26.00^{b}	27.26^{a}	0.59	< 0.01	0.06	0.27	0.14

[1)]Start date for all treatments was September 26th; End date for field and confinement treatments was November 25th.

[2)]Pen is the experimental unit, 3 sheep per replicate confinement, 6 sheep per replicate field; six replicates per treatment.

[3)]Diets were provided to allow for *ad libitum* intake.

[4)]CALF: pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; CBAR: pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[5)]FALF: field fed pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; FBAR: field fed pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[6)]All items are ending counts.

[7)]Location, confinement or field finish.

[8)]Feed, alfalfa or barley pellets.

[a,b]Least Square Means within a row with different superscripts differ ($p < 0.10$).

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Table 8. Whole blood counts of crossbred lambs consuming either a forage or grain based diet while in confinement or on wheat stubble fields in yr 2[1)]

Item[6)]	Treatment[2,3)]				SEM	p-value			
	Confinement[4)]		Field[5)]			Model	Location[7)]	Feed[8)]	Location × Feed
	CALF	CBAR	FALF	FBAR					
White blood cell	7.41[a]	6.62[ab]	7.21[a]	6.46[b]	0.38	< 0.01	0.58	0.02	0.96
Red blood cell	12.28[ab]	11.97[b]	12.55[a]	12.08[b]	0.25	0.03	0.37	0.07	0.70
Hemoglobin	13.26[b]	12.93[b]	13.82[a]	13.34[b]	0.21	< 0.01	0.01	0.03	0.66
Hematocrit	38.84[b]	38.84[b]	40.10[a]	39.28[ab]	0.55	0.06	0.08	0.39	0.38
Mean cell volume	31.72	32.20	32.20	32.62	0.53	< 0.01	0.33	0.33	0.94
Mean cell hemoglobin	10.82[ab]	10.74[b]	11.04[a]	11.05[a]	0.12	< 0.01	0.02	0.75	0.66
Mean cell hemoglobin concentration	34.15[ab]	33.39[c]	34.39[a]	33.92[b]	0.24	< 0.01	0.06	< 0.01	0.48
Red cell distribution width	26.11	25.96	26.10	26.58	0.56	0.22	0.53	0.74	0.52

[1)]Start date for all treatments was September 4th; End date for field and confinement treatments was November 4th.

[2)]Pen is the experimental unit, 3 sheep per replicate confinement, 6 sheep per replicate field; six replicates per treatment.

[3)]Diets were provided to allow for *ad libitum* intake.

[4)]CALF; pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; CBAR; pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[5)]FALF; field fed pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; FBAR; field fed pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[6)]All items are ending counts.

[7)]Location, confinement or field finish.

[8)]Feed, alfalfa or barley pellets.

[a,b]Least Square Means within a row with different superscripts differ ($p < 0.10$).

community (diet composition, feed types, feeding strategy) can have a robust effect on rumen metabolism, which can impact both productivity and health of ruminants [55]. Hemoglobin and mean cell hemoglobin concentration had an effect of both location and feed therefore they differed between all treatments ($p < 0.06$). All other blood counts did not differ between treatments (Table 8).

Parasites

A year × location and year × feed interaction was detected for *H. contortus* worm counts along with a year × feed × location interaction for *T. circumcinta* worm counts, *Nematodirus* worm counts and small intestine total worm counts, therefore, results are presented by year ($p < 0.01$). In yr 1, there were no interactions between location and feed ($p > 0.72$) for all variables. Ending *Trichostrongyle* egg counts differed at $p < 0.05$. Ending *Nematodirus* spp. egg counts did not differ between treatments, although there was a tendency ($p = 0.11$) for CALF and FALF to be greater than CBAR and FBAR (Table 9).

In yr 1, there was an interaction between location and feed for small intestine total worm count ($p < 0.01$). FALF had a greater small intestine total worm count than all other treatments, CBAR was intermediate, and CALF and FBAR had the lowest counts (176, 18, 2, 0 small intestine worm count; $p = 0.01$). An interaction between location and feed was also present for *Nematodirus* worm counts ($p < 0.01$). FALF was greater ($p < 0.03$) than all other treatments, CBAR was intermediate and differed from all other treatments ($p = 0.03$) and FBAR and CALF were the lowest ($p = 1.00$). All other worm burdens in the abomasum and first meter of the small intestine did not differ among treatments (Table 10).

In yr 2, there were no interactions between location and feed ($p > 0.24$) for all parasite variables. Ending *Trichostrongyle* type egg counts did not differ between all treatments (Table 11). Ending *Nematodirus* spp. egg counts were affected by location and feed and were greater for FALF and CALF (20.62 and 9.99 EPG respectively; $p > 0.30$), however CALF did not differ from FBAR

Table 9. Ending counts of internal parasite eggs per gram (EPG) in crossbred lambs consuming either a forage or grain based diet while in confinement or on wheat stubble fields in yr 1[1)]

Item[6)]	Treatment[2,3)]				SEM	*p*-value			
	Confinement[4)]		Field[5)]			Model	Location[7)]	Feed[8)]	Location × Feed
	CALF	CBAR	FALF	FBAR					
Trichostrongyle type EPG	6.95	3.86	9.98	3.95	0.52	0.05	0.70	0.16	0.73
Nematodirus spp. EPG	10.57	3.34	12.98	2.67	0.58	0.11	0.98	0.02	0.72

[1)]Start date for all treatments was September 26th; End date for field and confinement treatments was November 25th.

[2)]Pen is the experimental unit, 3 sheep per replicate confinement, 6 sheep per replicate field; six replicates per treatment.

[3)]Diets were provided to allow for *ad libitum* intake.

[4)]CALF: pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; CBAR: pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[5)]FALF: field fed pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; FBAR: field fed pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[6)]All counts had an addition of a constant of 1 then were LOG transformed.

[7)]Location, confinement or field finish.

[8)]Feed, alfalfa or barley pellets.

Table 10. Worm burden in the abomasum and first meter of the small intestine in crossbred lambs consuming either a forage or grain based diet while in confinement or on wheat stubble fields in yr 1[1)]

Item[6)]	Treatment[2,3)]				SEM	*p*-value			
	Confinement[4)]		Field[5)]			Model	Location[7)]	Feed[8)]	Location × Feed
	CALF	CBAR	FALF	FBAR					
Abomasum total count	3	24	111	10	1.09	0.20	0.25	0.88	0.07
Teladorsagia circumcincta	3	24	111	10	1.09	0.20	0.25	0.88	0.07
Small intestine total count	2^{bc}	18^{b}	176^{a}	0^{c}	0.94	0.01	0.48	0.08	< 0.01
Teladorsagia circumcincta	2	0	0	0	0.59	0.47	0.38	0.38	0.38
Nematodirus	0^{c}	18^{b}	176^{a}	0^{c}	0.72	< 0.01	0.12	0.12	< 0.01

[1)]Start date for all treatments was September 26th; End date for field and confinement treatments was November 25th.

[2)]Pen is the experimental unit, 3 sheep per replicate confinement, 6 sheep per replicate field; six replicates per treatment.

[3)]Diets were provided to allow for *ad libitum* intake.

[4)]CALF: pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; CBAR: pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[5)]FAL: field fed pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; FBAR: field fed pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[6)]All Counts had an addition of a constant of 1 then were LOG transformed.

[7)]Location, confinement or field finish.

[8)]Feed, alfalfa or barley pellets.

[a–c]Least Square Means within a row with different superscripts differ ($p < 0.10$).

(5.60 EPG; $p > 0.44$), and CBAR was lowest and differed from all other treatments (0.52 EPG; $p < 0.03$). It is unknown why CBAR had the lowest EPG in yr 2 but there was a tendency for both barley treatment groups to have lower EPG than the field treatments. It is widely accepted that a high grain diet causes a drop in ruminal pH and may cause drastic shifts in the rumen microbial community [56–59]. Ruminal bacterial and protozoal populations increase or decrease in response to pH changes [57], however, the effect of pH on internal parasites has not been studied. It is possible that a lamb's rumen environment is less favorable to internal parasites while consuming a high grain (barley) diet and thus we see lower EPG in these lambs; more research is needed to investigate this relationship.

In yr 2, there were no interactions ($p > 0.11$) between location and feed for all parasite variables. Abomasum *H. contortus* worm burden was greater in CALF than all other treatments ($p = 0.07$). All other worm burdens in the abomasum and first meter of the small intestine did not differ

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Table 11. Ending counts of internal parasite eggs per gram (EPG) in crossbred lambs consuming either a forage or grain based diet while in confinement or on wheat stubble fields in yr 2[1)]

Item[6)]	Treatment[2,3)]				SEM	*p*-value			
	Confinement[4)]		Field[5)]			Model	Location[7)]	Feed[8)]	Location × Feed
	CALF	CBAR	FALF	FBAR					
Trichostrongyle type EPG	50.92	10.97	28.51	18.31	0.51	0.29	0.92	0.04	0.24
Nematodirus spp. EPG	9.99[ab]	0.52[c]	20.62[a]	5.60[b]	0.53	< 0.01	0.02	< 0.01	0.40

[1)]Start date for all treatments was September 4th; End date for field and confinement treatments was November 4th.

[2)]Pen is the experimental unit, 3 sheep per replicate confinement, 6 sheep per replicate field; six replicates per treatment.

[3)]Diets were provided to allow for *ad libitum* intake.

[4)]CALF: pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; CBAR: pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[5)]FALF: field fed pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; FBAR: field fed pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[6)]All counts had an addition of a constant of 1 then were LOG transformed.

[7)]Location, confinement or field finish.

[8)]Feed, alfalfa or barley pellets.

[a–c]Least Square Means within a row with different superscripts differ ($p < 0.10$).

Table 12. Worm burden in the abomasum and first meter of the small intestine in crossbred lambs consuming either a forage or grain based diet while in confinement or on wheat stubble fields in yr 2[1)]

Item[6)]	Treatment[2,3)]				SEM	*p*-value			
	Confinement[4)]		Field[5)]			Model	Location[7)]	Feed[8)]	Location × Feed
	CALF	CBAR	FALF	FBAR					
Abomasum total count	49	15	12	44	1.50	0.88	0.93	0.98	0.44
Teladorsagia circumcincta	41	15	12	44	1.48	0.90	0.98	0.94	0.47
Haemonchus contortus	6[a]	0[b]	0[b]	0[b]	0.57	0.07	0.11	0.11	0.11
Small Intestine total count	29	0	3	3	1.10	0.23	0.74	0.14	0.16
Teladorsagia circumcincta	2	0	0	0	0.58	0.43	0.34	0.34	0.34
Nematodirus	8	0	3	3	1.14	0.60	0.86	0.32	0.37

[1)]Start date for all treatments was September 4th; End date for field and confinement treatments was November 4th.

[2)]Pen is the experimental unit, 3 sheep per replicate confinement, 6 sheep per replicate field; six replicates per treatment.

[3)]Diets were provided to allow for *ad libitum* intake.

[4)]CALF:pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; CBAR: pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[5)]FALF: field fed pellet containing 71% alfalfa, 18% barley, 5% molasses, and 6% vitamin/mineral package; FBAR: field fed pellet containing 60% barley, 26% alfalfa, 4% molasses, 2.5% soybean-hi pro, and 7.5% vitamin/mineral package.

[6)]All counts had an addition of a constant of 1 then were LOG transformed.

[7)]Location, confinement or field finish.

[8)]Feed, alfalfa or barley pellets.

[a,b]Least Square Means within a row with different superscripts differ ($p < 0.10$).

among treatments (Table 12). Marley et al. [60] determined that legume forages have the potential to contribute to the control of abomasal but not small intestine nematode parasites in finishing lamb systems. This is in contrast to our results where alfalfa-fed lambs in confinement had greater abomasum *T. circumcinta* worm counts than other treatments.

Parasite results are in conflict with those of Cai and Bai [14] who reported that gastrointestinal nematode EPG were lowest in lambs fed in confinement and highest in grazing lambs. FEC in our study appeared to trend with barley fed animals having lower counts than those of alfalfa fed animals. Studies have shown that the degree of parasite infestation in sheep may be reduced by some plant species [61–63]. Research has focused on the effects of secondary plant compounds (e.g. condensed tannins) [64] on the reduction of parasites in the gut but the underlying mechanisms

for such effects have not been determined. Overall in our study FEC worm counts taken from all slaughtered lambs were low and likely did not adversely influence the weight gains and hematocrit levels of the lambs.

Integrated crop and livestock systems as an alternative to confinement feedlot operations may increase marketing opportunities for sheep producers. While field finishing lambs with a grain- or forage-based diet, we conclude that it is possible to produce a quality lamb product without adverse effects to animal performance, carcass quality or increasing parasite burdens.

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