Sheep & Goat
Research Journal
Volume 18: 2003

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The Effects of Energy Source and Ionophore Supplementation on Lamb Growth, Carcass Characteristics and Tenderness

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Summary

Commercial Hampshire x Dorset crossbred lambs (n = 96) were used in a 3 x 2 factorial experiment to determine the effects of energy source (high concentrate (HC), high forage (HF), a combination of concentrate and forage (MIX)); and ionophore supplementation (monensin; Rumensin [Elanco Animal Health, Greenfield, IN] fed at a rate of 176 mg per kg of feed) on lamb growth and carcass characteristics. The wethers (n = 48) were harvested and the effects of energy source and ionophore supplementation on carcass characteristics and palatability attributes were evaluated.

Energy source affected (P < .05) dry matter intake, average daily gain (ADG), feed efficiency (FE), and days on feed. Lambs fed the HF diet had the lowest (P < .05) ADG (204 g), the least (P < .05) desirable FE (0.139 g/f), and consequently the most (P < .05) days on feed (106 d). Carcasses from lambs fed the HF diet also had less (P < .05) bodywall thickness, less kidney and pelvic fat, a smaller ribeye area, and lighter liver weights. *Longissimus dorsi* samples from the lambs on the HC diet had significantly (P < .05) higher Warner-Bratzler shear force values than the lambs on the HF and MIX diets. The sensory panel found *longissimus dorsi* samples from lambs that received the MIX diet significantly (P < .05) more tender when compare to those from lambs that received the HC and HF diets.

Monensin decreased (P < .05) backfat by 1.22 mm (20%) and dressing percentage by 3.1%. Monensin had no adverse effects (P > .05) on sensory attributes. Therefore, feeding monensin to lambs fed various diets resulted in no adverse carcass characteristics and a slight decrease in back fat depth.

Key words: Ionophore, Lamb, Growth, Carcass, Tenderness

Introduction

The meat industry is faced with the dual challenge of reducing fat content of meat carcasses without negatively affecting the palatability of the product. It is generally recognized that excess subcutaneous fat and seam fat results in carcass waste, while intramuscular fat aids in palatability. Researchers agree that tenderness and flavor are important in overall palatability; however, the degree of importance often varies (Batcher, 1969; Safari et al., 2001). Previous reports suggest that higher degrees of intramuscular fat or higher quality grades correspond to more desirable ratings for juiciness, tenderness and overall acceptability of fresh meat (Wheeler et al., 1994; Mbanzamihigo et al., 1995; Gwartney et al., 1996; Wheeler et al., 1999; Wood et al., 1999).

Smith and Crouse (1984) suggest that different fat depots are not regulated in a coordinated manner which could allow for altering one depot without affecting another. They showed that acetate provides 70 to 80% of the acetyl units to lipogenesis in subcutaneous fat, and conversely glucose, whose precursor is propionate, was shown to provide 50 to 75% of the acetyl units in the intramuscular depot. Thus, manipulating the concentration of acetate and propionate has potential in altering fat deposition in lambs and hence influence the value of the final product.

Ionophores have been proven to alter fatty acid concentrations in the rumen. Many researchers have investigated the ionophore monensin and have found that through its basic mode of action, modifying the movement of ions across biological membranes, it increases propionate production in the rumen while decreasing acetate and butyrate percentages (Van Nevel and Demeyer, 1977; Chalupa et al., 1980; Huston et al., 1990; Surber and Bowman, 1998).

The objectives of this research were to evaluate the effects of monensin on growth performance of lambs during the finishing stages, carcass characteristics and palatability traits.

Materials and Methods

Ninety-six commercial Hampshire x Dorset crossbred lambs, with an equal number of ewes and wethers, were used in a 3 x 2 factorial experiment to determine the effects of energy source and ionophore supplementation on growth. At the initiation of the study, lambs were sorted by sex and then randomly assigned to treatments within a block based on body weight. The three different energy sources used in the study are presented in table 1 and consisted of high-concentrate (HC), high-forage (HF), and a combination of concentrate and forage (MIX). Each diet was tested in the absence of ionophore and with the inclusion of an

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ionophore supplementation (monensin; Rumensin [Elanco Animal Health, Greenfield, IN] fed at a rate of 176 mg per kg of feed) in accordance with the Investigational New Animal Drug (INAD 10794) from the Food and Drug Administration.

Growth Performance

Initial body weight, taken as the average of two consecutive day's weight prior to feeding, was used to block the lambs, within each group, into a heavier and lighter weight group. There were four replicate pens per treatment with four lambs per pen. Following an initial 14-day adaptation period, lambs were fed ad libtum, with refused feed removed and the weight recorded on a daily basis prior to offering new feed. Lambs were weighed every 14 days prior to feeding to calculate average daily gain (ADG) and feed efficiency (FE). Once the average weight of the wether pen was approximately 60 kg the wether pen and the corresponding ewe lamb pen were taken off test. The wethers were weighed and transported to the Ohio State University Meat Science Laboratory in Columbus, OH where they were restricted from feed consumption but given free access to water for 12 hours prior to harvest. Only wethers were used in the remainder of the study to evaluate effects on carcass traits and sensory. The ewe lambs were weighed and returned to the flock.

Carcass Traits

Prior to harvest, live weights were recorded for each lamb. After harvest, each animal's hot carcass, liver and heart weights were taken and recorded. After a 24 hour chill period, an USDA grader collected the following grade factors: lean color, flank color, flank firmness, flank streaking, overall conformation, leg conformation and quality grade. After carcasses were aged an additional six days (0° to 4° C) the carcasses were ribbed between the 12th and 13th rib to expose the *longissimus dorsi*. The following measurements were taken and recorded: marbling score, ribeye area, subcutaneous fat thickness, and body wall thickness. For each of these traits, data was collected from both the left and right sides and averaged.

Carcass Fabrication

At seven days post-harvest, the kidneys and associated kidney and pelvic fat were removed from each carcass and weighed. The *longissimus dorsi* and *semimembranosus* muscles were excised from the right side of each lamb carcass. The *longissimus dorsi* (from the 13th rib to the posterior end) and *semimembranosus* were cut into 2.5 cm thick chops. Chops from the *longissimus dorsi* were designated for lipid extraction, Warner-Bratzler shear force (WBS), and sensory panel evaluations from anterior to posterior end, respectively. Chops from the *semimembranosus* were designated for WBS.

Lipid Extraction

All external fat, bone, and epimysium was removed from the most anterior chop of the longissimus dorsi and the sample was ground for approximately 30 seconds on low speed using a Waring Commercial Laboratory Blender (Waring Products Division, New Hartford, CT). Samples weighing 10 g were dried at 100° C for 18 h. After cooling, petroleum ether was used to extract lipid from the samples according to procedures outlined by Ockerman (1985).

Warner-Bratzler Shear Force

The second and third most anterior chops of the *longissimus dorsi* were weighed and cooked on an impingement oven (Lincoln Impinger, Food Service Products Inc., Fort Wayne, IN) to an internal temperature of 66° C. After cooking, the chops were weighed and percent cook loss was determined. Following the procedures outlined by AMSA (1995), the chops were cooled to room temperature and three core samples, 1.27 cm in diameter, were taken parallel to the longitudinal orientation of the muscle fibers of each chop. The cores were subject to a Warner-Bratzler shear (WBS) machine (Salter, G-R Elec. Mfg. Co., Manhattan, KS) and WBS values were collected for each core sample. The mean value from six cores was reported as the final WBS for the *longissimus dorsi*.

The second most anterior steak of the *semimembranosus* was weighed and cooked on an impingement oven (Lincoln Impinger, Food Service Products Inc.) to an internal temperature of 66°C. Then cook loss and WBS was collected as previously described.

Sensory Panel

The fourth and fifth most anterior chops of the *longissimus dorsi* were cooked on an impingement oven (Lincoln Impinger, Food Service Products Inc.) to an internal temperature of 66° C and served warm to an eight member trained sensory panel. The panelists evaluated samples using an eight point hedonic scale for tenderness (1- extremely tough, 8 - extremely tender) and juiciness (1- extremely dry, 8 - extremely juicy) (AMSA, 1995).

Statistical Analysis

Statistical analysis was performed using the MIXED procedures in SAS (SAS, 1999) for a randomized complete block, 3 x 2 factorial experiment. The model included sex and initial weight as block effects and energy source and ionophore supplementation as dependent variables. Growth performance data was analyzed using pen as the experimental unit and carcass traits and sensory evaluation data was analyzed using individual carcass as the experimental unit. The two-way interaction of energy source x ionophore supplementation was also included in initial models, however, the energy source x ionophore supplementation interaction was removed from subsequent analysis if it was not significant ($P > .05$). Simple correlations were computed using the CORR procedures in SAS (SAS, 1999).

Results and Discussion

Throughout all analyses, the interaction between energy source and ionophore supplementation was not significant ($P > .05$). Therefore, it was removed from the model and only the main effects are presented and discussed.

Growth Performance

Results for growth traits are presented in table 2. Lambs that received the HC and MIX diets had a higher ($P < .05$) ADG than lambs that received the HF diet. This finding is in agreement with several previous studies that have reported animals offered a high-concentrate diet ad libitum generally have a greater ADG than animals fed or grazed legumes (Tatum et al., 1988; McClure et al., 1994; Murphy et al., 1994). Additionally, lambs that received the HC diet had a more desirable FE than the HF diet lambs, while the MIX diet lambs were intermediate ($P < .05$). These results can be explained, in part, by the findings of Fluharty et al. (1999), who reported that lambs consuming alfalfa had greater omasum, abomasum, small intestine, cecum, and large intestine weights than did lambs fed an all-concentrate diet. The metabolic activity of visceral organs is a function of both the rate of activity and the size of the organs. Ferrell and Jenkins (1985) previously reported that the proportion of protein synthesis is greater in the combination of the gastrointestinal tract (19 to 23%) and the liver, kidney, and pancreas (16 to 17%) than occurs in striated muscle (24 to 28%). Furthermore, Ferrell et al. (1986) reported that the maintenance energy requirements of visceral organs is positively related to the size of the organs and is related to the level of nutrition, which helps explain the findings of Fluharty et al. (1999) that grams of N retained per day were 248% greater with lambs fed an all-concentrate diet than with lambs fed alfalfa. Therefore, the findings of the present study are in agreement with previous research. Dry matter intake (DMI) was lowest ($P < .05$) for the HC diet lambs; however, this was due to the increased ADG which also led to less days on feed for these lambs.

In this study, ionophore supplementation did not significantly ($P > .40$) affect ADG or FE. The present findings are in disagreement with Huston et al. (1990), who observed an increase in weight gain for lambs fed monensin. The researchers observed an increase in weight gain for lambs supplemented with monensin at a rate of 33 mg/kg of feed which was a greater gain than that observed for lambs fed monesin at a rate of 66 mg/kg of feed. Huston et al. (1990) concluded that this difference was due to lower intake of the high monensin supplement. In the current study ionophore supplementation did not result in a decreased DMI even though the supllmentation rate was at a greater level (176 mg/kg). The differing results between the two studies may partially be due to the difference in the age, physiological maturity, and thus growth pattern of the lambs when the trials were initiated, as well as the duration of the time on feed. The lambs used in the research conducted by Huston et al. (1990) were approximately 12 months of age and 40 kg at the start of the trial, which lasted for 36 days and overall had a lower ADG. The lambs used in the current study were approximately 4 months of age and the duration of the trial was much longer. The results of this study are in concordance with the findings of Fluharty et al. (1999), who evaluated the supplementation of the ionophore lasalocid and reported no differences in ADG or FE due to ionophore supplementation (149g/kg). Although, it should be noted that Fluharty et al. (1999) reported a small, but significant increase in DMI for lambs that were supplemnted with the ionophore lasalocid in a trial that was designed similarly to the current trial. However in their trial, the lambs that received the concentrate diet were limit fed.

Carcass Traits

The results for carcass traits are presented in table 3. Energy source was a significant ($P < .05$) main effect for body wall (BW), kidney and pelvic fat (KP), and ribeye area (REA). Carcasses from the HC and MIX diet lambs had higher ($P < .05$) amounts of BW and KP than the HF diet lambs. Carcasses from the HC and MIX diet lambs also had a significantly larger REA than the HF diet lambs. Also, liver weights were significantly ($P < .05$) higher for carcasses from HC diet lambs and MIX diet lambs compared with those from HF diet lambs.

These results are in agreement with research which showed that cattle (Smith et al., 1987) and lambs (Crouse et al., 1978) fed high-energy diets had a more rapid fat deposition and showed greater back fat thickness and kidney and pelvic fat than those fed a roughage diet.

The HF diet lambs had the highest ($P < .05$) degree USDA flank streaking and the HC diet lambs had the lowest ($P < .05$) degree. However, the differences observed in the USDA flank streaking were not present in either marbling scores or percent lipid. Also, no significant differences were found for official USDA quality grade, maturity, lean color, flank firmness, overall conformation or leg conformation.

Ionophore supplementation significantly ($P < .05$) reduced carcass back fat depth and dressing percent and had no effect ($P > .05$) on the other carcass traits. The decrease in dressing percent may partially be due to the decrease in back fat depth. Although the difference for back fat depth, which was the equivalent of a 20% reduction, was statistically different for ionophore supplementation, the small absolute difference between the means (1.22 mm) is not likely to result in a difference in the merchandising value of these lamb carcasses. However, for a group of lambs with different genetics or are subjected to different management strategies which allow for back fat to be much greater at the time of marketing, a 20% reduction in back fat could impact the value of thier carcasses.

The back fat differences observed due to the supplementation of monesin can be explained by the mode of action of monensin and the resulting change in ruminal VFA concentrations. Researchers have shown that monensin increases propionate production in the rumen while decreasing acetate and butyrate percentages (Van Nevel and Demeyer, 1977; Chalupa et al., 1980; Huston et al., 1990; Surber and Bowman, 1998). Smith et al. (1984) reported that backfat thickness and the activities of several enzymes involved in lipogenesis were greater in animals fed a high concentrate, corn based diet versus those fed a forage based, alfalfa pellet diet, even though the metabolizable energy intake was higher with the pelleted forage diet. Therefore, the end products of ruminal fermentation as well as net energy intake are interrelated in terms of adipocyte formation. Furthermore, Smith and Crouse (1984) fed either a corn silage (low energy) or ground corn (high energy) diet to young, growing steers from weaning, at 8 months of age, to a terminal age of 16 or 18 months of age, and reported that acetate provided 70 to 80% of the acetyl units for lipogenesis in subcutaneous adipose tissue, but only 10 to 25% of the acetyl units for lipogenesis in intramuscular adipose tissue. Conversely, glucose (from propionate) provided 1 to 10% of the acetyl units for lipogenesis in subcutaneous adipose tissue, but 50 to 75% of the acetyl units for lipogenesis in intramuscular adipose tissue. The authors concluded that different regulatory processes control fatty acid synthesis in intramuscular and subcutaneous adipose tissue. Therefore, the enzymes responsible for fatty acid synthesis, and the resulting lipogenesis and adipocyte hypertrophy, are regulated by the end products of ruminal fermentation, which are determined by diet. Therefore, the altered volatile fatty acid concentration in the rumen due to monensin was likely the cause for the decrease in back fat in the present study.

Meat Quality

Warner-Bratzler shear force values and results of the sensory panel are presented in tables 4 and 5, respectively. Samples of the *longissimus dorsi* from lambs that received the MIX diet were found to be more tender ($P < .05$) than samples from lambs that received the HC diet by the sensory panel. This was also detected by the WBS values, which were negatively correlated ($R = -.69$; $P < .0001$) to sensory tenderness (data not presented in tabular form). This finding is in agreement with a study conducted by Notter et al. (1991), which observed various management systems and meat characteristics. The researchers found lambs fed to slaughter on a concentrate diet had the highest shear force values when compared to two other systems that fed lambs all forage diets. Although not significantly different ($P > .20$), there was a numerical decrease in WBS value for both the *longissimus dorsi* and *semimembranosus* due to monensin supplementation (table 4).

There was no correlation with the objective (percent lipid) or subjective (marbling) measurements for intramuscular fat and juiciness or tenderness for the *longissimus dorsi*. This could be due to the fact neither energy source nor ionophore supplementation produced significant differences in the amount of intramuscular fat which hindered the sensory panel to find differences in the samples due to amounts of intramuscular fat.

Implications

Energy source had a significant impact ADG, FE and days on feed, with the HC diet being supierior to the MIX and HF diet for both FE and days on feed. However, the HC diet also resulted in an increase in toughness. Monensin slightly improved or did not adversely affect carcass characteristics and had no adverse affects on sensory attributes. Monensin supplementation resulted in decreased back fat and dressing percent. The decrease in back fat might result in practical or economical advantage when feeding lambs beyond their ideal marketing endpoint, which would result in excess back fat under normal conditions. However, further research should be conducted to determine if these changes could be amplified with various levels of ionophore supplementation.

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Table 1. Diet composition.

Item	High-concentrate no monensin	High-concentrate with monensin	High-forage no monensin	High-forage with monensin	Mixed diet no monensin	Mixed diet with monensin
Ingredient, % DM basis						
Whole shelled corn	70.00	70.00	---	---	42.50	42.50
Alfalfa silage	--.--	--.--	70.00	70.00	42.50	42.50
Ground corn	6.74	6.721	20.29	20.271	1.59	1.571
Soybean hulls	1.85	1.85	--.--	--.--	--.--	--.--
Soybean meal	18.75	18.75	7.60	7.60	11.75	11.75
Urea	.30	.30	.30	.30	.35	.35
Limestone	1.35	1.35	--.--	--.--	--.--	--.--
Monosodium phosphate	--.--	--.--	.60	.60	.30	.30
Trace mineral salt[a]	.45	.45	.45	.45	.45	.45
Vitamin A, 30,000 IU/g	.01	.01	.01	.01	.01	.01
Vitamin D, 3,000 IU/g	.01	.01	.01	.01	.01	.01
Vitamin E, 44 IU/g	.05	.05	.05	.05	.05	.05
Selenium, 201 ppm	.09	.09	.09	.09	.09	.09
Dynamate[b]	--.--	--.--	.20	.20	--.--	--.--
Ammonium chloride	.40	.40	.40	.40	.40	.40
Rumensin 80[c]	--.--	.019	--.--	.019	--.--	.019
Calculated composition						
Crude protein, %	18.18	18.18	18.02	18.02	18.18	18.18
Calcium, %	.55	.55	1.09	1.09	.70	.70
Phosphorus, %	.40	.40	.43	.43	.41	.41
NE_m Mcal/kg	2.08	2.08	1.47	1.47	1.73	1.73
Ne_g Mcal/kg	1.43	1.43	.89	.89	1.12	1.12

[a] Contained > 95%NaCl, .35% Zn, .28% Mn, .175% Fe, .035% Cu, .007% I, and .007% Co.
[b]Magnesium sulfate and potassium sulfate, contained ≥ 22% S, 18% k, 11%Mg (International Minerals and Chemical, Terre Haute, IN).
[c]Contained 176 mg monensin per kg (Elanco Animal Health, Greenfield, IN).

Table 2. Mean values for growth performance traits by energy source and ionophore supplementation.

	Energy source[a]				Ionophore supplementation[b]		
Performance trait	HC	MIX	HF	SEM	Control	Monensin	SEM
No. of lambs	32	32	32		48	48	
Initial weight, kg	34.25	34.35	34.29	.08	34.36	34.23	.07
Final weight, kg	54.38	56.39	56.09	1.11	56.39	54.83	.90
DMI, kg/d	1.29^{d}	1.59^{c}	1.46^{c}	.07	1.47	1.42	.05
ADG, g/d,	301^{c}	287^{c}	204^{d}	14	270	258	11
FE, gain/feed, kg/kg	$.231^{c}$	$.181^{d}$	$.139^{e}$	.009	.184	.183	.007
Days on feed	68^{d}	77^{d}	106^{c}	4	85	82	3

[a]high-concentrate (HC), concentrate and forage (MIX), high-forage (HF).
[b]Control (0 mg monensin per kg feed), Monensin (176 mg monensin per kg feed).
[c,d,e]Means in the same row, within an effect, bearing different superscript letters differ ($P < .05$).

Table 3. Mean values for carcass traits by main effects.

	Energy source[a]				Ionophore supplementation[b]		
Carcass trait	HC	MIX	HF	SEM	Control	Monensin	SEM
No. of lambs	16	16	16		24	24	
Dressing percent	57.5	58.1	57.5	.7	59.2^{f}	56.1^{g}	.6
Hot carcass weight, kg	31.25	32.16	30.82	.82	32.22	30.61	.67
Liver weight, g	1015^{f}	931^{f}	826^{g}	31	912	935	25
Heart weight, g	211	200	204	6	204	206	4
Fat depth, mm	5.56	5.52	5.12	.45	6.01^{f}	4.79^{g}	.37
Body wall thickness, cm	2.26^{f}	2.28^{f}	1.87^{g}	.10	2.17	2.10	.08
Kidney and pelvic fat, g	941^{f}	913^{f}	602^{g}	78	764	872	68
Rib eye area, cm^2	6.56^{f}	6.23^{f}	5.69^{g}	.15	6.07	6.24	.12
USDA conformation[c,d]	395	396	381	8	390	392	6
USDA leg conformation[c,d]	386	396	378	7	389	385	6
USDA flank firmness[c,d]	9.4	9.8	9.4	.5	9.1	10.0	.4
USDA flank streaking[c,e]	263^{g}	314^{fg}	342^{f}	21	290	323	17
USDA Quality grade[c,e]	325	338	319	11	325	329	9
USDA flank color[c,e]	155	145	211	34	195	146	28
Marbling[d]	423	417	357	27	403	395	22
Lean color	148	150	155	3	151	150	2
Lipid %	3.69	4.41	3.72	.31	4.01	3.87	.25

[a]high-concentrate (HC), concentrate and forage (MIX), high-forage (HF).
[b]Control (0 mg monensin per kg feed), Monensin (176 mg monensin per kg feed).
[c]factors were called by a USDA grader.
[d]10 = Ch^-, 11 = Ch°, 12 = Ch^+, 13 = Pr^-, 14 = Pr°, 15 = Pr+.
[e]400 = $Modest^{00}$, 300 = $Small^{00}$, 200 = $Slight^{00}$, 100 = $Traces^{00}$.
[f,g]Means in the same row, within an effect, bearing different superscript letters differ ($P < .05$).

Table 4. Mean values for Warner-Bratzler shear force of the *longissimus dorsi* and *semimembranosus* by main effects.

	Energy source[a]				Ionophore supplementation[b]		
	HC	MIX	HF	SEM	Control	Monensin	SEM
No. of lambs	16	16	16		24	24	
Longissimus dorsi	4.87[c]	3.39[d]	3.70[d]	.37	4.09	3.89	.30
Semimembranosus	5.46	4.71	4.97	.26	5.22	4.87	.22

[a]high-concentrate (HC), concentrate and forage (MIX), high-forage (HF).
[b]Control (0 mg monensin per kg feed), Monensin (176 mg monensin per kg feed).
[c,d]Means in the same row, within an effect, bearing different superscript letters differ ($P < .05$).

Table 5. Mean values for sensory traits of the *longissimus dorsi* by main effects.

	Energy source[a]				Ionophore supplementation[b]		
	HC	MIX	HF	SEM	Control	Monensin	SEM
No. of lambs	16	16	16		24	24	
Juiciness[c]	4.9	5.2	4.6	.2	4.9	4.8	.2
Tenderness[d]	4.2[f]	5.3[e]	4.6[ef]	.3	4.5	4.9	.2

[a]high-concentrate (HC), concentrate and forage (MIX), high-forage (HF).
[b]Control (0 mg monensin per kg feed), Monensin (176 mg monensin per kg feed).
[c]juiciness = 1- extremely dry, 8 - extremely juicy.
[d]tenderness = 1- extremely tough, 8 - extremely tender.
[e,f]Means in the same row, within an effect, bearing different superscript letters differ ($P < .05$).