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Effect of Dietary Supplementation of Ferrous Sulfate on Performance and Carcass Characteristics of Finishing Lambs

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Abstract

The objective of this study was to evaluate the effects of including elevated levels of FeSO4 in lambs diet on DMI, growth, and carcass characteristics. Twenty-four Gulf Coast wether lambs (26.3 ± 3.63 kg initial BW, and 8 to 9 months of age) were assigned to one of 2 blocks based on their BW were randomly allocated to 1 of the 3 dietary treatments, giving 8 lambs per treatment. Animals were grouped in 2 pens per treatment (4 lambs/pen) with pen serving as the experimental unit. Treatment diets containing supplemental FeSO4 at 0, 75, or 150 mg/kg of DM were fed lambs. Treatment diets consisted of dry-rolled corn, SBM, and fescue/bermudagrass hay and were formulated to be isonitrogenous and isocaloric and to meet or exceed the NRC requirements of a finishing lamb. Lambs were slaughtered, and data were collected after a 48-h chill. Both growth and carcass quality data were analyzed using the GLM procedures. Dry matter intake, final BW, and ADG were not different among treatments (P = 0.5, 0.9, and 0.7, respectively). Also, no differences were observed in HCW (P = 0.9), CCW (P = 0.8), body wall fat (P = 0.6), 12th rib fat (P = 0.9), K&P fat (P = 0.9) and REA (P = 0.7) among treatments. These results support our hypothesis that the addition of 75 or 150 mg FeSO4 /kg in finishing lamb diets do not impact DMI, growth rate, and carcass characteristics of meat sheep.

Key Words: Iron, lamb, growth.

Introduction

Iron (Fe) is an essential component of several cytochromes and iron-sulfur proteins involved in the electron transport chain and several important biological processes (Parish and Rhinehart, 2008; Ganz and Nemeth, 2006). The element is often found in high levels in ruminant diets due to naturally high levels of Fe in soil and therefore in feedstuffs (Standish et al., 1971). Some common ruminant feedstuffs high in Fe are alfalfa (300 mg/kg of DM), corn gluten feed (400 mg/kg of DM), distillers dried grains with soluble (DDGS) (600 mg/kg of DM), and soy hulls (600 mg/kg of DM; NRC, 1996; DePeters et al., 2000; Parish and Rhinehart, 2008; Kerr et al., 2001).

There is little evidence that dietary Fe deficiency occurs in ruminants (Koong et al., 1970; Standish et al., 1971). However, excessive Fe, which can lead to the production of free radicals and expose sensitive tissues to oxidative stress (Ganz and Nemeth, 2006), causes toxicity which manifests as diarrhea, acidosis, hypothermia, depressed DMI and reduced ADG (Parish and Rhinehart, 2008). It is widely known that excess dietary Fe in ruminants, which can occur frequently when animals are exposed to excessive levels of Fe through forage, water or soil ingestion (Campbell et al., 1998; Humphries et al., 1983), affects utilization of other minerals such as Cu, P, Zn and Mn and consequently reduces productivity in ruminants (Standish et al., 1969, 1971; Koong et al., 1970; Campbell et al., 1998; Humphries, 1983).

The recommended dietary requirement of sheep, beef cattle, and dairy cattle for Fe is 30-50, 50, and 15-30 mg/kg, respectively (NRC, 1996, 2001; CSU, 2010). However, amount of Fe in cattle diets is often much greater. Superfluous dietary Fe may come from a variety of sources, including numerous ruminant feed ingredients such as dicalcium phosphate (~10,000 mg of Fe/kg of DM) and soy hulls (~600 mg of Fe/kg of DM;

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Kerr et al., 2001). In addition, many grasses contain more than 100 mg of Fe/kg of DM, and legumes such as white clover have been reported to contain greater than 200 mg of Fe/kg of DM (NRC, 1996; Greene, 2000; Parish and Rhinehart, 2008). In the past, to our best knowledge, there was very little literature that examined the influence of feeding increased levels of Fe on carcass characteristics of cattle and sheep. Therefore, we hypothesized that supplementing lamb diets with elevated levels of Fe as FeSO4 will have no negative impact on DMI, growth rate, and carcass characteristics of meat sheep. The specific objective was to investigate the effects of varying levels of dietary FeSO4 inclusion on DMI, final BW, ADG, and carcass characteristics of lambs including final BW, hot carcass weight (HCW), cold carcass weight (CCW), 12th rib fat, body wall fat, kidney and pelvic (K&P) fat, and rib-eye area (REA).

Materials and Methods

All animal care and handling procedures followed the farms' written guidelines set forth by FASS (1999) and all procedures involving animals were approved by the Animal Care and Use Committee of Alabama A&M University (AAMU).

Experimental Animals and Facilities

The objective of this study was to evaluate the effects of feeding increased levels of FeSO4 during the finishing phase on growth performance and carcass characteristics of finished wether lambs. The study was conducted at AAMU Winfred Thomas Agricultural Research Station. A total of twenty-four Gulf Coast lambs (26.3± 3.63 kg initial BW, and 8 to 9 months of age) were assigned to three feeding treatments. Before initiation of this study, lambs were vaccinated for clostridial disease (Convexin 8, Schering-Plough, Kenilworth, NJ). During the trial, lambs were grouped and housed in dirt outdoor pens (4 lambs/pen). Pens were equipped with plastic feeders and water buckets. Treatment diets were offered once daily for ad libitum intake, and lambs were allowed free access to fresh, clean water. Feeders were checked daily and cleaned of contaminated feed (e.g., fecal contamination, wet feed caused by precipitation). Feed refusals were weighed, dried, analyzed for DM, and used to calculate DMI, and animal weights were recorded every 28 d.

Experimental Design and Treatments

Lambs were blocked by weight and randomized within blocks to the three treatments. Treatments had two replicates of four lambs each (n = 8/dietary treatment). A finishing diet containing dry-rolled corn, soybean meal (SBM), and fescue/bermudagrass hay was fed as the control diet which contains 282-336 mg Fe/k of DM (Table 1). Seventy-five or 150 mg FeSO4 /kg of DM were added to the finishing weather diet (Table 1). The finishing diet was formulated to be isonitrogenous and isocaloric (on a NEg basis) and to meet or exceed the NRC (2007) requirements of a finishing lamb. Lambs were allowed 7-day adjustment period in the stalls and 7- day transition period to the Fe supplemented diets followed by 135 d feeding period during which experimental diets were offered.

Data Collection Procedures

Lambs Initial and final BW were the average of 2 BW taken on consecutive days. After the 135 d finishing period, lambs were transported (346 km) to The Auburn University Lambert-Powell Meat Laboratory (Auburn, AL) for slaughter and subsequent carcass data collection. Carcass data collected by trained

Table 1. Ingredient and chemical composition of different concentrates containing fescue/bermudagrass hay and varying levels of ferrous sulfate fed to finishing lambs[1].

Item	Composition of treatment diets		
	0 (control)	75 $FeSO_4$ mg/kg	150 $FeSO_4$ mg/kg
Ingredient	**Amount, %**		
Concentrate	63.0	64.4	63.8
Fescue/bermudagrass hay	37.0	35.6	36.2
Total	100	100	100
Concentrates ingredients, % of DM			
Cracked corn	49.5	49.5	49.5
Soybean meal (48% CP)	12.2	12.2	12.2
$FeSO_4$ mg/kg	---	75	150
Sheep Premix[2]	1.3	1.3	1.3
Nutrient composition of treatment diets, g/100g DM			
DM	88.0	89.5	88.2
CP	16.7	16.0	17.5
EE	4.3	4.7	4.4
NDF	34.6	34.6	34.6
ADF	20.1	21.9	22.0
Ash	4.0	4.8	4.0

[1] All values are on dry matter basis (unless otherwise indicated). [2] (%) Ca 9.0, P 8.0, Salt 41.0, K 0.10, Mg 1.0; (mg/kg) Cu 1,750, Se 25.0, Zn 7,500, and (IU/kg) Vitamin A 308,644, Vitamin D 24,251 and Vitamin E 1,653.

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personnel after a 48-h chill (temperature <2°C, humidity near 100%), included final BW, HCW, CCW, 12th rib fat, body wall fat, K&P fat, and REA.

Statistical Analysis

The experiment was arranged as a randomized complete block, with pen as the experimental unit, and data were analyzed according to linear and quadratic orthogonal contrasts. Assumptions of normality were tested in the experiment using the UNIVARIATE procedure (SAS Inst. Inc., Cary, NC). The GLM procedure of SAS was used to statistically analyze performance and carcass characteristics in the experiment. The effects of treatment and block were included in the model statement for each experiment. In the experiment, least squares means were generated and separated using the PDIFF option of SAS for significant main effects. The protected F-test was used to determine overall significance where P-values of 0.05 were considered significant.

Results

Lambs Overall Performance and Carcass Characteristics

The results of the current study are reported in Tables 2 and 3. Lambs on all treatments had similar initial BW as designed (Table 2). There was no impact on DMI, ADG, final BW (P= 0.5, 0.7, 0.9, respectively; Table 2) when we included 75 or 150 mg FeSO4/kg of DM in lamb diets. This may be explained by the fact that basal diet was adequate in Fe (305 mg of Fe/kg of DM) even though 50% the basal dietary Fe was provided by forages, which are generally considered poor sources of available Fe. Also, no impact on HCW, CCW, 12th rib fat, body wall fat, K&P fat, and REA was observed when 75 or 150 mg FeSO4/kg of DM was included in lamb diets (P = 0.9, 0.8, 0.9, 0.6, 0.9, 0.7, respectively; Table 3).

Discussion

To our best knowledge, the present study is the most recent study which provided data concerning the influence of the inclusion of increasing levels of FeSO4 in lamb diet on feed intake and growth, and the first study which determined the impact of adding different levels of FeSO4 in finishing diets on lamb carcass characteristics. The study investigated the effects of the inclusion of 75 and 150 mg FeSO4/kg of DM on DMI, ADG, and carcass characteristics including final BW, HCW, CCW, 12th rib fat, body wall fat, K&P fat, and REA. Our hypothesis, that including 75 and 150 mg FeSO4/kg of DM in the finishing diets of meat lambs will have no negative impact on DMI, growth rate, and carcass characteristics of meat sheep was supported by the results of the experiment.

Previously, acute Fe deficiency symptoms including anorexia, depressed growth and emaciation accompanied by an increase in hemoglobin, red blood cell (RBC) count and packed cell volume values were noticed when 10 mg Fe/kg of DM were included in finishing lamb diets (Lawlor et al., 1965). The authors suggested that levels of 40 and 70 mg/kg of DM of Fe seemed adequate to meet the dietary requirement of the lambs for normal performance. Feed efficiency for 56-d period was significantly reduced when calves' diets were supplemented with higher level of Fe (750 mg FeSO4/kg of DM; Hansen et al., 2010); but, conversely, feed efficiency and health of calves were not affected when high amounts of dietary Fe (4000 mg FeCO3/kg of DM) were added to the diets. The source of Fe used in the current study, FeSO4, represents a highly soluble form of supplemental Fe. It is possible that use of a less soluble form of supplemental Fe, such as Fe carbonate (FeCO3), or a highly insoluble form, such as ferric oxide (Fe2O3), might have affected the feed intake and efficiency of gain of these calves in a different manner (Hansen et al., 2010).

Feed Intake

There were no differences in feed intake between treatments. The mean DMI were 1.9, 1.9 and 1.8 kg/d for 0, 75 or 150 mg FeSO4/kg of DM, respectively. The lack of differences in DMI among treatments may be due to similar NDF intakes among treatments. The NDF concentration is regarded as the main dietary constraint for reduced DMI in ruminants (Van Soest, 1994). We noticed slight decrease in DMI in lambs fed high Fe diet. It is possible that the large amount of FeSO4 in the diet in the current study reduced the palatability of the diet. Standish et al. (1971) who studied the effects of including excess dietary Fe on

Table 2. The effects of feeding different levels of ferrous sulfate to finishing lambs on feed intake, initial body weight, average daily weight gain, and final body weight[1].

Item	Treatment diets			SEM	P-value[2]	
	0 (control)	75 $FeSO_4$ mg/kg	150 $FeSO_4$ mg/kg		Linear	Quadratic
Feed intake						
Days on feed	135	135	135	-	-	-
DMI, kg/d	1.9	1.9	1.8	0.1	0.5	0.6
BW						
Initial BW, kg	26.4	26.8	27.4	2.5	0.8	0.9
ADG, kg/d	0.2	0.1	0.1	0.01	0.7	0.6
Final BW, kg	46.4	44.9	46.5	3.8	0.9	0.8

[1]Eight lambs were assigned to each treatment (n = 8/dietary treatment). [2]Based on orthogonal contrasts for equally spaced treatments.

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Table 3. The effects of feeding different levels of ferrous sulfate to finishing lambs on carcass characteristics[1].

Item	Treatment diets			SEM	P-value[2]	
	0 (control)	75 $FeSO_4$ mg/kg	150 $FeSO_4$ mg/kg		Linear	Quadratic
HCW, kg	20.4	16.8	20.8	2.2	0.9	0.3
CCW, kg	19.6	16.1	20.5	2.5	0.8	0.3
12th Rib fat, cm	0.2	0.2	0.2	0.1	0.9	0.6
Body wall fat, cm	1.0	0.7	0.9	0.1	0.6	0.1
K&P fat, kg	0.6	0.9	0.6	0.4	0.9	0.6
REA, cm^2	4.3	3.8	4.6	0.4	0.7	0.3

[1]Eight lambs were assigned to each treatment (n = 8/dietary treatment). [2]Based on orthogonal contrasts for equally spaced treatments.

tissue mineral composition of sheep concluded that the FeSO4 supplemented diet was the least palatable with the ferric citrate diet as the next least, and there were small differences in DMI between the treatments.

The results of the present study agree with previous literature (Standish et al., 1971; Mcguire et al., 1985; Prabowo et al., 1988; Miller et al., 1991; Weiss et al., 2010). Prabowo et al. (1988) investigated the effects of dietary Fe on performance and mineral utilization. They noticed no affect on DMI for lambs when up to 1200 mg FeCO3/kg of DM was added to forage based diet. Mcguire et al. (1985) also detected no significant effect on DMI when up 1000 mg/kg dietary Fe was included in young calves' diets in a study during which the authors investigated the influence of high dietary Fe on the element's metabolism. Dry matter intake for calves was not affected when supplemental Fe was added at 2000 mg/kg of DM (Miller et al., 1991). However, when no milk was fed, the authors observed reductions in DMI for calves fed 2000 or 4000 mg /kg of DM. Likewise, Weiss et al. (2010) noticed no influence on cows DMI when Fe was added in diets in a trial during which they measured the Fe status of cows in late gestation and early lactation and examined whether measures of Fe status and milk production were affected by feeding supplemental organic Fe during early lactation.

However, in disagreement with the results of the present study, a significant reduction in DMI was noticed when as little as 400 mg FeSO4 /kg of DM was added to steer calves' diets in a study during which Standish et al. (1969) examined the influence of dietary Fe on performance and tissue mineral composition. Koong et al. (1970) also noticed a depression in DMI when increasing dietary FeSO4 was added in calves' diets in a trial during which they investigated the impact of feeding elevated levels of Fe on calves' performance. The authors suggested that the maximum level of dietary Fe which the calf may consume without marked depression in DMI was 2,000 mg/kg. Similarly, Lawlor et al. (1965) noticed significant reduction in DMI for lambs when 10 mg Fe/kg of DM was added to growing lambs diets. A significant reduction in DMI was also reported by Hansen et al. (2010) when they examined the effect of high dietary Fe on metal transporters involved in Fe and Mn metabolism.

Weight Gain

There were no differences in BW gain between treatments. The mean ADG and final BW were 0.2 kg/d and 46.4 kg for 0 mg FeSO4/kg of DM, 0.1 kg/d and 44.9 kg for 75 mg FeSO4/kg of DM, and 0.1 kg/d and 46.5 kg for 150 mg FeSO4/kg of DM (Table 2). These results agree with previous literature (Mcguire et al., 1985; Prabowo et al., 1988; Miller et al., 1991; Weiss et al., 2010). Standish et al. (1971) reported no significance weight changes when higher level of FeSO4 was included in sheep diet. Prabowo et al., (1988) also did not notice difference in weight when up to 1200 mg FeCO3 /kg of DM was added to a forage based diet. Similarly, no difference in rate of gain was detected when calves were fed concentrate, Fe- or Cu-supplemented diets and the Mo-supplemented calves gained at a much slower rate when Gengelbach et al. (1994) evaluated the effects of Cu depletion on performance and Cu status of beef cows and calves. Mcguire et al. (1985) also found no significant effect on ADG when up to 1000 mg/kg of DM dietary Fe was included in young calves' diets. Also, no differences in ADG was observed when elevated levels of Fe were included in cow diets in a trial during which Santos et al. (2005) evaluated the effects of source of gossypol and supplemental FeSO4 on plasma gossypol in Holstein steers. Likewise, ADG was not reduced when high levels of dietary Fe (2000 mg/kg of DM) was included in calves' diets. Prabowo et al. (1988) also reported no impact on ADG for lambs when up to 1200 mg FeCO3 /kg of DM was added to a forage based diet.

However, the results of the present study contrast with previous literature (Gennard et al., 1957; Lawlor et al., 1965; Standish et al., 1969; Koong et al., 1970; Hansen et al., 2010). Lawlor et al., (1965) observed acute Fe deficiency symptoms, including depressed growth, when 10 mg/kg of DM Fe was included in finishing lamb diets. Koong et al. (1970) also noticed significant depression in ADG with increasing dietary FeSO4 in calf diets. They suggested that the maximum level of dietary FeSO4 which the calf may consume without marked depression in BW is 2,000 mg/kg of DM. Similarly, Standish et al. (1969) noticed that ADG was depressed when as little as 400 mg/kg Fe was included in steer calves' diets. Likewise, a significant reduction in ADG was noticed when calves were fed diets high in Fe (Hansen et al., 2010). Gennard et al. (1957) investigated the dietary requirements of dairy calves for Fe and Cu. Surprisingly, they noticed that animals on the zero level of supplemental Fe became anemic and gained less than those on the 30 and the 60 mg Fe /kg of DM diets.

Carcass Characteristics

There were no differences in carcass characteristics between treatments. The mean HCW, CCW, 12th rib fat, body wall fat, K&P fat, and REA were 20.4 kg, 19.6 kg, 0.2 cm, 1.0 cm, 0.6 kg, and 4.3 cm2 for 0 mg $FeSO_4$ /kg of DM, 16.8 kg, 16.1 kg, 0.2 cm, 0.7 cm, 0.9 kg and 3.8 cm2 for 75 mg $FeSO_4$ /kg of DM, 20.8 kg, 20.5 kg, 0.2 cm, 0.9 cm, 0.6 kg, and 4.6 cm2 for 150 mg $FeSO_4$ /kg of DM (Table 3). For unknown reasons, despite the fact DMI wasn't significantly different, we observed an increase in HCW, CCW, body wall fat, and REA in lambs fed 75 $FeSO_4$ /kg of DM diets compared to lambs fed 0 and 150 mg $FeSO_4$ /kg of DM diets. Also, for reasons we aren't able to determine, K&P fat was higher in lambs fed 75 $FeSO_4$ /kg of DM diets compared to lambs fed 0 and 150 mg $FeSO_4$ /kg of DM diets.

Conclusion

The addition of 75 or 150 mg $FeSO_4$ /kg of DM in finishing lamb diets did not impact the feed intake, growth rate, or carcass characteristics of finishing lambs. Contrary to other studies, no Fe deficiency symptoms were observed when 0 mg Fe/kg of DM was included in lamb diets that included fescue/bermudagrass hay. This may be explained by the fact that many grasses contain greater than 100 mg Fe/kg of DM, a level that is widely considered adequate to supply lambs with their dietary requirements of Fe. At the time of the study, there was no extensive published data on the influence of feeding increasing levels of Fe on carcass characteristics of sheep. Hence, the authors were not able to compare the results of their study with previous results. It is recommended that validation studies be completed to confirm these findings.

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