DEVELOPMENT OF HIGH SELENIUM LAMB AS A HUMAN HEALTH FOOD

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Impact Statement

Lambs supra-supplemented with selenium have skeletal muscle selenium concentrations at levels that may prevent lung, colorectal, and prostate cancer in humans. These results indicate that future efforts are needed to ascertain the likely level of demand for a high-selenium lamb product, and the marketing techniques required to deliver that product to the consumer.

Introduction

Selenium (Se) deficiency in humans is not considered to be an issue in the United States, however, recent research suggests that humans who consume in excess (2 to 4 fold) of the recommended dietary allowance (RDA = 55 μg Se/d) of Se may reduce their chance for developing lung, colorectal, and prostate cancer by 30, 50, and 70%, respectively (Clark et al., 1996). Although tablets of Se as selenite or high Se yeast are available, the American Dietetic Association encourages people to consume nutrients through food whenever possible, including meats and grains.

Taylor et al. (2002) documented that circulating plasma Se concentration of finishing beef steers was elevated by feeding high Se (60 to 70 $\mu g \bullet kg^{-1}$ BW $\bullet$ d^{-1}) wheat, hay, or sodium selenate supplement by d 21 of feeding. Additionally, Lawler et al. (2004) reported that beef steers fed feedstuffs naturally high in Se (65 $\mu g \bullet kg^{-1}$ BW $\bullet$ d^{-1}) had Se concentration in semitendinosus muscle greater than those fed control or selenate supplemented animals. The inability of the sodium selenate supplement to increase muscle Se concentration is likely linked to the organic sources of Se containing primarily selenomethionine, which accumulates in tissue to a greater extent than other forms of Se. Results by Lawler et al. (2004) were similar to those of Hintze et al. (2001), reporting that a moderate sized portion of high Se beef would supply the Se necessary to achieve the cancer protection benefits described by Clark et al. (1996). However, the research by Lawler et al. (2004) was conducted over a 126 d finishing period and the minimum length of time to achieve elevated Se concentration was not determined. Additionally, even though the four state region has soils high in Se, the variability of Se concentration in forages (and subsequently grazing livestock) indicate that a feeding program for finishing livestock is necessary to ensure animals of both low and high Se status can achieve the desired Se concentration in skeletal muscle (Lawler et al., 2002). We are aware of no research evaluating the influence of supra-supplementation of selenium to finishing lambs on muscle and plasma selenium status.

Research by Lawler et al (2004) indicates that hot carcass weight, longissimus muscle area, backfat thickness, marbling score, quality grade, and yield grade of beef steers was not affected by supra-Se supplementation during the finishing time period. However, kidney, pelvic, and heart fat tended to be higher for animals supplemented with high Se wheat compared to animals supplemented with high Se hay or sodium selenate. We are aware of no research evaluating the affects of supra-Se supplementation on lamb carcass characteristics.

Our four state team's goal is to develop feeding strategies for finishing lambs that increase the Se content of lamb skeletal muscle to levels that will provide for cancer protection in humans while utilizing locally grown forages and grains. The marketing of these lamb meats as high Se organic supplements will provide marketing cooperatives an opportunity to develop a niche market for high Se lamb meat, and provide the beef industry with a model of feeding Se to finishing beef steers for the development of additional niche marketing.

Materials and Methods

In year 1 of a two year study, a randomized complete block design was used to evaluate the influence of duration of supra-Se supplementation in finishing rations on a) lamb skeletal muscle Se concentration; b) finishing period body weight gain and feed efficiency; and c) carcass characteristics. The North Dakota State University Institutional Animal Care and Use Committee reviewed and approved animal care and use protocols used during this study. One-hundred forty four wethers (74 ± 0.4 lbs initial BW) were blocked by weight and stratified by breed (western white-faced and western white-faced X Suffolk) and assigned randomly to one of 16 pens (9 lamb/pen) for an eight-four day finishing phase. Pens were then assigned to one of 4 treatments (4 replications/treatment); supra-selenium supplementation for the final 56, 28, 14, or 0 days of feeding prior to harvest. Wethers were wormed on day 0 and managed for antibiotic-free status. Diets were 84% corn and 15% supplement provided daily at 8:00 am to ensure ad libitum intake (NRC, 1985; Table 1). Diets were isonitrogenous and isocaloric (Table 1). Feed offered was recorded daily and feed refusals collected and recorded when significant amounts of refused feed accumulated in the feeders. Selenium for supra-selenium supplementation treatments (14, 28, and 56 days) was provided as selenoyeast to provide 75 $\mu g \cdot kg^{-1}$ BW • d^{-1} Se (approximately 1.9 ppm ration concentration; Table 1). Initial and final weights were two-day weights, and single day interim weights were taken once every 14 days to aid in monitoring health and potential Se toxicity.

Blood (jugular venipuncture into EDTA) was collected on day 0 and 84 to determine the change in circulating Se status. Blood samples were centrifuged, plasma collected, and frozen. Plasma samples were frozen at -30°C until analysis for Se. Wethers were harvested at Iowa Lamb Corp. in Hawarden, IA. Skeletal muscle samples (approximately 5 g of front foreleg) were removed for the determination of Se concentration. Skeletal muscle samples were frozen at -30°C until analysis for Se. Skeletal muscle samples (0.3 - 0.5 g) and plasma samples were analyzed for Se by a commercial laboratory (Utah Veterinary Diagnostic Laboratory). Additionally, carcass characteristics and presence of lung lesions were evaluated following harvest. Carcass weight, backfat, bodywall thickness, and ribeye area were measured. Yield and quality grade were determined subjectively by a USDA grader. Feed to gain ratios and ADG were calculated. Dry matter intake (DMI), body weight (BW), feed:gain (F:G), ADG, blood and skeletal muscle Se concentration, and carcass characteristic data were analyzed as a randomized complete block design with the GLM procedure of SAS (SAS Inst. Inc., Cary, NY) using pen as the experimental unit. The model included block and treatment. Orthagonal contrast statements included 1) Control vs supra-Se supplementation; 2) linear effect of supra-Se supplementation; and 3) quadratic effect of supra-Se supplementation.

Results

There was no block by treatment interaction for response variables tested ($P \geq 0.15$). Length of supra-selenium supplementation did not affect performance measures of final weight, gain, F:G, and ADG ($P \geq 0.15$; Table 2), carcass characteristics (fat depth, body wall thickness, and REA; $P \geq 0.13$; Table 2) or carcass quality ($P \geq 0.11$; Table 2). However, DMI linearly decreased ($P = 0.02$) as length of supplementation increased. Additionally, hot carcass weight responded quadratically ($P = 0.04$).

Initial plasma Se concentration was similar for all lambs on day 0 ($P \geq 0.71$; Table 3). Final plasma Se concentration increased for control vs. supplemented treatments ($P = 0.002$) and increased linearly ($P = 0.004$) as length of supplementation increased (Table 3). Muscle Se concentration increased quadratically ($P = 0.04$) as length of supra-Se supplementation increased.

Discussion

The majority of performance measures, carcass characteristics, and carcass quality of the lambs in this study were not affected by the length of supra-selenium supplementation. These results are similar to results in steers (Hintze et al., 2002; Lawler et al., 2004). However, we observed a linear decrease in dry matter intake and a quadratic affect on hot carcass weight as length of supra-selenium supplementation increased. The apparent cause of the decrease in intake is not readily available, as this response is not consistent with other research (Hintze et al., 2002; Lawler et al., 2004).

Muscle Se concentration in our trial linearly increased as length of supra-selenium supplementation increased. These results are similar to results of other researchers. Van Ryssen et al. (1989) reports that mature ewes fed high-Se wheat at 1 mg of Se/kg diet had increased liver, wool, and muscle Se concentrations compared with sheep supplemented with a similar quantity of sodium selenite. Additionally, Ehlig et al. (1967) reported that lambs supplemented with 0.4 mg Se/day had higher muscle Se concentrations for supplementation with selenomethionine compared to selenite. Lawler et al. (2004) reported similar muscle Se concentrations (4.41 ppm DM) in beef cattle finished on high selenium diets, specifically with high Se wheat.

North Americans acquire their daily Se requirement primarily from wheat grain and beef (Schubert et al., 1987; Holden et al., 1991; Hintze et al., 2001). A ¼ lb portion of lamb from lambs fed a supra-selenium supplemented diet would provide approximately 155, 112, 95, and 76 μg Se/day (wet basis; 56, 28, 14, and 0 day supra-selenium supplementation, respectively).

While the non-selenium supplemented treatment in this trial provided adequate selenium to meet the recommended dietary allowance for selenium in humans (RDA = 55 μg Se/day for females and 70 μg Se/day for males), the selenium concentration in lamb skeletal muscle tissue for the 56 day selenium supplemented treatment would provide approximately 281% of the RDA for selenium. This level falls within the range indicated by Clark et al. (1996; 2 to 4 fold the RDA) for humans to reduce their chance of developing lung, colorectal, and prostate cancer.

Implications

Development of a feeding protocol for achieving high selenium lamb will aid current lamb cooperatives and individual producers in developing a niche market for the sale of lamb as an organic selenium supplement, as well as adding value to locally grown forages through the finishing of lambs. The determination of selenium status and the feeding of both high and low selenium status lambs will allow for the application of results across the entire four state region. Due to declining lamb consumption, the sheep industry may be poised and ready to develop rapid marketing strategies for the niche marketing of lamb as a health food. Additionally, the beef industry will derive benefit from this research as a model of feeding beef cattle to achieve high selenium status for the purpose of niche marketing. Our results indicate the supplementing selenium during the finishing phase can result in a lamb product that is naturally high in selenium.

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Table 1. Dietary ingredient and nutrient composition of lamb finishing diets

Ingredient	Feedstuff Se concentration, ppm	Diets[a]	
		Control	Selenium Diet
		%, DM basis	
Corn	0.42	84.25	84.25
Supplement[b]	0.92	15.00	15.00
Selenoyeast	666	---	0.21
Vitamin E	---	0.25	0.25
Ammonium Chloride	---	0.50	0.50
Nutrient Composition of Diet			
CP, %		16.9	16.9
TDN, %		87.6	87.6
ADF, %		4.56	4.56
Ca:P		2.57	2.57
Vitamin E, IU/kg diet		27.83	27.83
Selenium, ppm		0.49	1.89
Selenium intake, $\mu g \cdot kg^{-1}$ BW•d^{-1}		19.47	74.83

[a]Control = no supra-selenium supplementation with selenoyeast; 14 days = supplementation with selenoyeast for the final 14 days of finishing; 28 days = supplementation with selenoyeast for the final 28 days of finishing; 56 days = supplementation with selenoyeast for the final 56 days of supplementation.

[b]Supplement: Decoquinate = 130 g/ton; CP = 43%; Ca = 4.8%; P = 0.65%; Na = 1.45%; S = 0.7%; K = 1.5%; Mg = 0.35%; Fe = 258 ppm; Mn = 671 ppm; Cu = 20 ppm; Zn = 701 ppm; Vit A; 36,000 IU/lb; Vit D = 3,600 IU/lb; Vit E = 75 IU/lb.

Table 2. The influence of supra-selenium supplementation on feedlot lamb performance and carcass characteristics

	Treatment[a]					P-value[c]		
Item	Control	14 days	28 days	56 days	SEM[b]	Control vs Supp.	Linear	Quadratic
Dry Matter Intake (lbs/day)	4.12	4.29	3.95	3.94	0.07	0.47	0.02	0.24
Final Weight (lbs)	132	137	132	130	2.3	0.75	0.26	0.15
Gain (lbs)	59	63	57	56	2.4	0.98	0.27	0.34
Average Daily Gain (lbs/day)	0.70	0.75	0.68	0.68	0.03	0.92	0.33	0.38
F:G	5.95	5.78	5.85	5.93	0.21	0.69	1.0	0.56
Hot Carcass Weight	72	75	72	70	0.9	0.70	0.09	0.04
Fat Depth (in)	0.28	0.28	0.27	0.25	0.02	0.44	0.13	0.38
Ribeye Area (in^2)	2.75	2.69	2.56	2.67	0.06	0.14	0.20	0.18
Quality Grade[d]	3.1	3.1	3.1	3.0	0.04	1.0	0.75	0.48
Yield Grade	3.1	3.2	3.1	2.9	0.08	0.72	0.11	0.13

[a]Control = no supra-selenium supplementation with selenoyeast; 14 days = supplementation with selenoyeast for the final 14 days of finishing; 28 days = supplementation with selenoyeast for the final 28 days of finishing; 56 days = supplementation with selenoyeast for the final 56 days of supplementation.
[b]Standard Error of Mean; n = 4 .
[c]*P*-value for Control vs supra-selenium supplemented treatments and linear and quadratic affect of supra-selenium supplementation.
[d]1 = utility; 2 = good; 3 = choice; 4 = prime.

Table 3. The influence of supra-selenium supplementation on feedlot lamb muscle and plasma selenium concentration

	Treatment[a]					P-value[c]		
Item	Control	14 days	28 days	56 days	SEM[b]	Control vs Supp.	Linear	Quadratic
Initial plasma Se concentration (ppm)	0.18	0.18	0.18	0.18	0.004	0.84	0.69	0.95
Final plasma Se concentration (ppm)	0.20	0.31	0.30	0.35	0.03	0.003	0.005	0.20
Muscle Se concentration (ppm; DM)	2.87	3.64	4.33	6.10	0.20	< 0.001	< 0.001	0.04
Muscle Se concentration (ppm; wet)	0.76	0.95	1.12	1.55	0.05	< 0.001	< 0.001	0.02

[a]Control = no supra-selenium supplementation with selenoyeast; 14 days = supplementation with selenoyeast for the final 14 days of finishing; 28 days = supplementation with selenoyeast for the final 28 days of finishing; 56 days = supplementation with selenoyeast for the final 56 days of supplementation.
[b]Standard Error of Mean; n = 4 .
[c]*P*-value for Control vs supra-selenium supplemented treatments and linear and quadratic affect of supra-selenium supplementation.