Effect of Feeding 2,500, 50,000 or 100,000 IU of Vitamin D_3 Daily on Feedlot Performance, Carcass Merit, and Plasma and Tissue Metabolite Concentrations

H.A. DePra, J.D. Duggin, D.R. Gill, C.R. Krehbiel, J.B. Morgan, D.C. Bietz, A.H. Trenkle, R.L. Horst, F.N. Owens

Story in Brief

One hundred eighty yearling steers (initial BW = 357 $\pm$ 28 kg) were used in a randomized complete block design to determine the effects of supplementing vitamin D_3 throughout the finishing phase on feedlot performance, carcass merit, and plasma and tissue metabolite concentrations. Vitamin D_3 was supplemented at 2,500 (control), 50,000 or 100,000 IU·steer^{-1}·day^{-1} over the entire 175-d (avg) finishing phase. Dry matter intake did not differ among treatments; calculated vitamin D_3 intakes based on lab assay were 3,607, 27,506 and 70,075 IU·steer^{-1}·d^{-1}. Final BW and ADG did not differ among treatments. Vitamin D_3 supplementation did not affect hot carcass weight, carcass characteristics or lean and skeletal maturity. Plasma D_3 (5.3, 17.3, 30.9 $\pm$ 0.8 ng/mL) and 25-hydroxyvitamin D_3 (68.1, 97.0, and 117.0 $\pm$ 3.5 ng/mL) concentrations increased ($P<0.001$) as level of vitamin D_3 supplementation increased, whereas plasma 1,25-dihydroxyvitamin D_3 level numerically ($P=.13$) increased. Liver and muscle levels of vitamin D_3 and metabolites did not differ among treatments. Vitamin D_3 can be supplemented over the entire finishing period without negatively affecting feedlot performance and carcass characteristics. In addition, numerical increases in metabolite concentrations of tissue and plasma samples indicate that calcium concentrations within the body can be safely increased with low levels of vitamin D_3 supplementation over extended periods of time.

Key Words: Beef, Calcium, Tenderness, Vitamin D

Introduction

Supplementing vitamin D_3 to beef cattle with the intent of increasing beef tenderness has been debated within the literature despite considerable investigation. The hypothesis has been that increased dietary vitamin D_3 increases the amount of calcium within the body. Upon harvest, the increased calcium is then available to more fully activate the calpain proteolytic system, increasing beef tenderness. Some data has suggested that high doses of vitamin D_3 (5 to 8 million IU·animal^{-1}·d^{-1}) fed for short periods of time (5 to 10 d) before slaughter improved Warner-Bratzler shear force of specific cooked beef cuts (Swanek et al., 1999; Montgomery et al., 2000, 2002). However, vitamin D_3 supplementation at high levels results in lower DMI, which may subsequently cause lower final live BW and hot carcass weight (HCW) (Karges et al., 1999 and 2001; Scanga et al., 2001). Additionally, high levels of vitamin D_3 supplementation increase the concentration of vitamin D_3 (or its metabolites) within the meat to potentially toxic levels (Montgomery et al., 2000, 2002; Foote et al., 2004). We hypothesized that vitamin D_3 continuously fed at lower levels (50,000 and 100,000 IU animal^{-1}·d^{-1}) would improve tenderness without negative effects on intake, BW and HCW.

Materials and Methods

Animals. A total of 180 yearling steers (initial BW = 357 $\pm$ 28 kg) were received in three loads at the Willard Sparks Beef Research Center in May, 2003. On arrival (d 0), steers were individually weighed and identified with an individual ear tag. Based on initial BW, steers were stratified into three groups (60 animals per group) by weight and randomly assigned within weight block to 6 pens of 10 steers each. One third of the pens in each block (n=2) were randomly assigned to one of three treatments: 2,500 IU (control), 50,000 IU, or 100,000 IU vitamin $D_3 \cdot steer^{-1} \cdot d^{-1}$. To decrease bias of cattle origin, cattle originating from a different source were equally distributed among pens and treatment groups.

Processing. Steers were processed (d 1) the day after arrival. Individual weights were recorded and each steer received the following: vaccination with Titanium 5 L5[TM1] and Vision 7 with SPUR[TM2] (2 mL each, sub-Q; Intervet Inc., Millsboro, DE); treatment with anthelmintics for internal and external parasites (7 mL sub-Q; Ivomec-Plus[TM3], Merial Limited, Iselin, NJ); and implantation with Revalor-S [TM4] (20 mg trenbolone acetate, 4 mg estradiol; Intervet, Inc.). Steers were reimplanted with Revalor-S on d 70. Subsequent BW (unshrunk) were taken on d 35, 70, 105, 141, and 176. Additionally, steers in the heavy block (n = 60) had blood samples drawn on d 176 by venous puncture from the jugular into sterile 10 mL BD Vacutainer® [Beckton Dickinson & Co., Franklin Lakes, NJ] tubes containing sodium heparin. Plasma was then collected and frozen at –20°C for later analyses by USDA-ARS National Animal Disease Center.

Diet. All steers were stepped up with 4 adaptation diets (55, 70, 80, and 87% DM of concentrate for 8, 6, 7, and 6 d, respectively) to a final finishing diet consisting of (DM basis) 80.7% rolled corn, 8.0% ground alfalfa hay, 3.0% fat, and 8.3% pelleted vitamin D_3 supplement (Table 1). The OSU vitamin premix consisted of 19 parts fine ground corn to 1 part vitamin D_3-500 [Roche Vitamins, Nutley, NJ] to dilute the pure vitamin D_3 to levels that would allow for the mixing of supplemental vitamin D_3 directly into the pelleted supplement.

Table 1. Vitamin D_3 supplement ingredients (% DM)[a] by treatment level

Supplement	2,500 IU	50,000 IU	100,000 IU
Soybean meal	23.45	23.45	23.45
Cottonseed meal	23.71	23.71	23.71
Wheat midds	23.05	22.83	22.61
Limestone 38%	16.22	16.22	16.22
Salt	3.79	3.79	3.79
Vitamin A – 30,000 IU	.13	.13	.13
Vitamin E – 50%	.08	.08	.08
Rumensin – 80b	.21	.21	.21
Zinc Sulfate	.05	.05	.05

Manganous oxide	.05	.05	.05
Copper sulfate	.01	.01	.01
Selenium – 600	.09	.09	.09
Urea	9.03	9.03	9.03
Tylan –40b	.12	.12	.12
OSU vitamin premix	.01	.23	.46

[a]Rumensin provided at the rate to supply 0.37 g/kg and Tylan provided at the rate to supply 0.11 g/kg

[b]Elanco Animal Health, Greenfield, IN

The listed treatment levels of 2,500 (control); 50,000 and 100,000 IU vitamin D_3 were established target levels of intake. Samples were taken from each batch of supplement and composited by month. Assay of the supplements (Dr. Jonathan Wilson, Nutritional Products, Inc., Parsippany, NJ) showed lower than expected levels of vitamin D_3. Calculated average intake of vitamin D_3, based on assay results, are shown in Table 2.

Table 2. Calculated average daily intake of assayed vitamin D3 by target treatment

Treatment	Assayed D_3 level, IU/kg	Total D_3 intake, IU/d
2,500 IU	4,748	3,607
50,000 IU	37,397	27,506
100,000 IU	88,998	70,075

Slaughter. Steers were determined to be at optimum finish by visual appraisal and were harvested based on weight block. The heavy and intermediate blocks were harvested together on d 146, while the light block was harvested on day 181. All groups were harvested at Tyson Fresh Meats in Emporia, Kansas. Oklahoma State University personnel accompanied cattle to the plant to collect HCW, REA, marbling score, fat thickness, KPH estimates, lean and skeletal maturity, and USDA quality and yield grade on all harvest groups. Longissimus steak samples, as well as kidney and liver tissue samples, were collected from the heavy block of steers (n = 60) and frozen for later analysis. Analyses of steak, kidney, liver, and plasma samples were conducted by USDA-ARS National Animal Disease Center.

Statistical Analysis. Performance and carcass data were analyzed as a randomized complete block design with pen serving as the experimental unit. The PROC MIXED procedure of SAS was used to determine means and standard errors of means, with treatment level of vitamin D_3 and block as fixed effects. For tissue and plasma samples, individual animal was considered the experimental unit. The PROC MIXED procedure of SAS was used, but with load and treatment considered as main effects, and pen and the load*pen interaction considered as random effects.

Results and Discussion

Feedlot Performance. Beginning and interim BW, average daily gain (ADG), feed efficiency, and DMI are reported in Table 3. At the initiation of the experiment BW did not differ among treatments. Final BW for steers fed 100,000 IU of vitamin D_3 was 11 kg greater compared with control steers. However, final BW did not differ among treatments. By decreasing the level of vitamin D_3 supplementation from previously reported levels, we were able to eliminate decreases in final body weight observed by Karges et al. (2001), Scanga et al. (2001), and Montgomery et al. (2002).

Table 3. Effect of vitamin D3 supplementation on feedlot performance

Item	2,500 IU	50,000 IU	100,000 IU	SEM
Pens	6	6	6	-
Inwt, kg	356	357	356	.47
Final BW, kg	593	589	602	4.28
Carcass adj. BW, kg[a]	610	618	616	3.49
DMI d 0 – finish, kg/d	9.41	9.50	9.63	.18
ADG d 0 – finish, kg/d	1.49	1.53	1.56	.03
Gain:Feed d 0 – finish, kg/kg	.158	.162	.162	.002
Carcass adj. ADG, kg/d	1.56	1.60	1.60	.02
Carcass adj. gain:feed, kg/kg	.174	.181	.180	.003

[a]Carcass adj. BW calculated by dividing HCW by average dressing percent of each block

Average daily gain was calculated by weigh period and by overall time on feed, based on a 4% pencil shrink applied to interim and final BW. In contrast to Scanga et al. (2001) and Montgomery et al (2002), no difference in ADG among treatments was observed. Scanga et al. (2001) reported cattle that received greater than 10×10^6 IU of vitamin D_3 over an 8-d period had lower ($P<.05$) ADG than negative control cattle, and cattle that received 10×10^6 IU of vitamin D_3 or less over the same 8-d period had intermediate ADG that did not differ from control cattle or cattle receiving the higher dose of supplementation. Montgomery et al. (2002) observed similar findings and reported vitamin D_3 treatment linearly decreased ($P<.01$) ADG across the last 21 d of feeding with supplementation rates of 5 and 7.5×10^6 IU vitamin $D_3 \cdot steer^{-1} \cdot d^{-1}$, resulting in negative ADG that differed ($P=.02$) from those of steers treated with 1×10^6 IU vitamin $D_3 \cdot steer^{-1} \cdot d^{-1}$.

No difference in DMI was observed among treatments during any period. This agrees with Montgomery et al. (2002) who reported no difference in daily feed intake with vitamin D_3

supplementation. However, Montgomery et al. (2002) did report a vitamin D_3 supplementation x day interaction (P<.002) when feed intake was measured during a 9-d supplementation period; supplementing steers with 2.5, 5, or 7.5 x10^6 vitamin D_3·steer^{-1}·d^{-1} decreased feed intake during d 7 and 8 compared with that of control steers (P<.05). Similarly, Scanga et al. (2001) reported that following d 2 of supplementation with vitamin D_3, the appetite of cattle receiving more than 1 x 10^6 IU vitamin D_3/d declined. Karges et al. (2001) also reported numerically lower DMI for steers supplemented with vitamin D_3. In the present study, no differences in efficiency (ADG:DMI) were observed when vitamin D_3 levels of 2,500, 50,000, and 100,000 IU/hd/d were fed over the entire finishing period.

Carcass Merit. Effects of vitamin D_3 supplementation on carcass characteristics are shown in Table 4. Supplementation did not affect carcass yield, quality, or maturity traits as expected since no difference in feedlot performance was observed. Montgomery et al. (2002) reported that hot carcass weight and dressing percentage were not affected by vitamin D_3 supplementation for 9 d despite supplementation effects on ADG and feed intake.

Table 4. Effect of vitamin D_3 supplementation on carcass characteristics

Item	2,500 IU	50,000 IU	100,000 IU	SEM
Hot carcass weight, kg	384	389	388	2.19
12th rib fat thickness, cm	1.14	1.17	1.17	.04
Longissimus muscle area, cm^2	87.92	86.18	87.40	1.33
Kidney, pelvic, and heart fat, %	2.2	2.2	2.3	.10
Marbling[a]	380	376	380	7.04
Lean maturity[b]	172	180	174	3.08
Skeletal maturity[b]	159	158	156	3.69
USDA yield grade	2.3	2.4	2.2	.08
USDA quality grade[c]	2.7	2.6	2.7	.05

[a]Marbling score: 300 = slight00, 400 = small^{00}
[b]Maturity score: 100 = A, 200 = B
[c]USDA quality grade: 3 = select, 2 = choice

Plasma and Tissue Concentrations. As shown in Table 5, vitamin D_3 supplementation at 50,000 and 100,000 IU vitamin D_3·steer^{-1}·d^{-1} significantly increased (P<.05) plasma vitamin D_3 and 25-hydroxyvitamin D_3 concentrations. Plasma concentrations of vitamin D_3 and 25-hydroxyvitamin D_3 were 5.8– and 1.7– fold greater in cattle fed 100,000 IU vitamin D_3·steer^{-1}·d^{-1} compared with steers fed the control diet (2,500 IU vitamin D_3·steer^{-1}·d^{-1}). Additionally, vitamin D_3 and 25-hydroxyvitamin D_3 concentrations in kidney tissue increased (P<.05) with increasing

level of supplementation. Concentrations of the biologically active form of vitamin D_3, 1,25dihydroxyvitamin D_3, were numerically greatest in plasma, liver tissue, and muscle tissue.

Table 5. Effect of treatment on vitamin D_3 and metabolite concentrations in plasma and tissue

	2,500 IU	50,000 IU	100,000 IU	SEM	P>F
Plasma	60	60	60		
[a]D_3 (ng/g)	5.32[a]	17.25[b]	30.19[c]	.82	<.0001
[b]$25D_3$ (ng/g)	68.08[a]	96.96[b]	116.86[c]	3.54	<.0001
[c]$1,25D_3$ (pg/g)	53.81	46.63	60.15	4.68	.13
Ca (mg%)	8.92	9.06	9.24	.15	.30
Mg (mg%)	1.69	1.68	1.73	.07	89
Liver	44	44	41		
[a]D_3 (ng/g)	38.11	45.93	47.11	3.79	.12
[b]$25D_3$ (ng/g)	6.95	8.52	13.58	2.87	.35
[c]$1,25D_3$ (pg/g)	138.20	97.28	134.05	18.29	.22
Muscle	60	59	60		
[a]D_3 (ng/g)	15.70	16.41	15.90	.89	.85
[b]$25D_3$ (ng/g)	1.44[a]	1.80[ab]	2.27[b]	.18	.10
[c]$1,25D_3$ (pg/g)	51.07	61.02	69.33	6.71	.19
Kidney	57	57	41		
[a]D_3 (ng/g)	5.51[a]	25.05[b]	39.71[c]	3.75	<.0001
[b]$25D_3$ (ng/g)	6.50[a]	9.28[b]	11.07[b]	0.54	<.0001
[c]$1,25D_3$ (pg/g)	126.95	156.17	131.82	37.28	.83

[a]Vitamin D_3.
[b]25-hydroxyvitamin D_3.
[c]1,25-dihydroxyvitamin D_3.
[abc]Means with different subscripts differ, $P<0.05$

Calcium concentrations in plasma numerically increased as level of vitamin D_3 supplementation increased. This supports previous work by Karges et al. (1999), Montgomery et al (1999), and Swanek et al (1999) who reported increased plasma calcium concentrations with increased vitamin D_3 supplementation. Karges et al. (2001) reported blood plasma calcium concentrations were significantly greater ($P<.03$) for animals supplemented with 6×10^6 IU of vitamin D_3 daily for 4 or 6 d before harvest, with cattle supplemented for 6 d having greater plasma calcium concentrations than those supplemented for 4 d.

Implications

Low levels (50,000 to 100,000 IU·steer^{-1}·d^{-}1) of vitamin D_3 can be supplemented throughout the finishing period to increase plasma calcium concentrations, as well as concentrations of vitamin D_3 and 25-hydroxyvitamin D_3 in plasma and kidney, without affecting feedlot performance or carcass merit. Based on the numerical increase of vitamin D_3 and its metabolites in other tissue samples with increasing level of supplementation, more data are needed to determine at what level, if any, vitamin D_3 can have a positive effect on beef tenderness when fed over the entire finishing period.

Literature Cited

Foote, M.R., et al. 2004. J. Anim. Sci. 82:242-249.

Karges, K., et al. 1999. Oklahoma Agric. Exp. Sta. Res. Rep. P-973:134-142.

Karges, K., et al. 2001. J. Anim. Sci. 79:2844-2850.

Montgomery, J.L., et al. 2002. J. Anim. Sci. 80:971-981.

Montgomery, J.L., et al. 2000. J. Anim. Sci. 78:2615-2621.

Montgomery, J.L., et al. 1999. J. Anim. Sci. 77 (Suppl. 1):173 (Abstr.).

Scanga, J.A., et al. 2001. J. Anim. Sci. 79:912-918.

Swanek, S.S., et al. 1999. J. Anim. Sci. 77:874-881.

Authors

DePra, H.A. – Graduate Student

Duggin, J.D. – Graduate Student

Gill, D.R. – Professor Emeritus

Krehbiel, C.R. – Assistant Professor

Morgan, J.B. – Associate Professor

Bietz, D.C. – Distinguished Professor, Iowa State University

Trenkle, A.H. – Professor, Iowa State University

Horst, R.L. – National Animal Disease Center, USDA-ARS, Ames, IA

Owens, F.N. – Pioneer Hi-Bred International