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Short Communication

# Seasonal variation in vitamin D status of beef cattle reared in the central United States

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ABSTRACT

The objective was to retrospectively measure seasonal sunlight-associated variation in serum concentrations of 25-hydroxyvitamin D (25OHD) in beef cattle. The concentration of 25OHD was measured in crossbred animals born from March to May in 2011 and 2012. Vitamin D status 2 to 3 mo after birth (period 1) was only available for 2012 calves and was measured in June 2012. Period 1 animals had serum 25OHD concentrations of 26.3 ± 1.5 ng/mL. The 25OHD concentrations for late summer (period 2) were 46.6 ± 1.4 and 51.0 ± 1.5 ng/mL for 2011 and 2012, respectively. Serum concentration of 25OHD in early fall (period 3) were 63.8 ± 1.4 and 55.2 ± 1.5 ng/mL for calves in 2011 and 2012, respectively. Values observed for both late summer and early fall indicated vitamin D sufficiency ($P <$ 0.001) compared with period 1. With diminishing exposure to ultraviolet B and consuming ~800 IU or 1800 IU (2011 and 2012, respectively) of supplemental vitamin D, the calves' midwinter (period 4) 25OHD concentrations fell to 15.2 ± 1.6 and 16.7 ± 1.5 ng/mL for 2011 and 2012, respectively, after 4 to 5 mo on a finishing diet ($P <$ 0.0001). This is considered vitamin D insufficiency in most species. Results indicate that calves are marginally sufficient to insufficient for vitamin D based on serum 25OHD concentrations soon after birth and during winter. Some individual animals would be classified vitamin D deficient. In the absence of sufficient UVB exposure, the dietary vitamin D requirements for rapidly growing beef cattle may need to be increased.

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## 1. Introduction

Vitamin D is key to both calcium homeostasis and for modulating innate and adaptive immunity [1–3]. Dietary vitamin D can be obtained as ergocalciferol from plants or cholecalciferol from animal sources. Vitamin D can be produced in the skin by exposure to ultraviolet B (UVB) (defined as wavelengths between 290 and 320 nm) containing sunlight, which catalyzes the conversion of 7-dehydrocholesterol in the skin. Conversion of vitamin D to its active form (1,25-dihydroxyvitamin D) occurs in 2 steps: the first step is the conversion of vitamin D to 25-hydroxyvitamin D (25OHD) in the liver. The second step is conversion of 25OHD to the active steroid hormone, 1,25-dihydroxyvitamin D, in the kidney to allow systemic calcium homeostasis and the local production of 1,25-dihydroxyvitamin D in immune cells for control of immune functions [4]. Circulating 25OHD reflects adequacy of intake of vitamin D and indicates vitamin D status [4,5].

Exposure to sunlight is the principal natural mechanism through which 25OHD is produced in mammals [5]. Season, latitude, and skin pigmentation, impact UVB exposure and thus concentrations of 25OHD in humans [6–8]; however, there are limited reports in cattle [9–11]. The objective of this study was to measure seasonal variation in concentration of circulating 25OHD in beef cattle reared in the Central United States and fed commonly used dietary vitamin D supplements.

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## 2. Materials and methods

Animal experimental procedures were approved and performed in accordance with U.S. Meat Animal Research Center Animal Care Guidelines and the Guide for Care and Use of Agricultural Animals Research and Teachings [12].

### 2.1. Animals

Measurement of 25OHD was performed in serum collected from cattle at the U. S. Meat Animal Research Center Germplasm Evaluation Project, in Clay Center, Nebraska, Latitude: 40.5416798; Longitude: −98.2508865. This particular Germplasm Evaluation Project subset consisted of calves produced from multiple-sire matings of crossbred cows to F1 bulls of varying breed composition. Offspring used consisted of fractions of Angus, Hereford, Red Angus, Brahman, Charolais, Gelbvieh, Limousine, Simmental, and MARC III (¼ Hereford, ¼ Angus, ¼ Red Poll, and ¼ Pinzgauer).

Calves were born from March to May in 2011 ($n = 99$, steers = 46 and heifers = 53) and in 2012 ($n = 96$, steers = 65 and heifers = 31). Male calves were castrated after ~1 mo after birth. Blood samples for 25OHD measurements were collected at 4 periods. This was a retrospective study; therefore, period 1 included only the calves born in 2012 because samples for 2011 calves were unavailable. For period 1 (June 2012), 2- to 3-mo-old calves were brought in from pasture, and blood samples collected for collection and storage of serum. For period 2 (first week of August 2011 or September 2012), blood samples were obtained from 5- to 6-mo-old calves at the time of vaccination for bovine viral diarrhea types 1 and 2, parainfluenza 3, infectious bovine rhinotracheitis, and bovine respiratory syncytial virus. During period 3 (September 2011 or October 2012), blood samples were obtained 3 wk after period 2 when calves received vaccination boosts. Calves were weaned and placed in the feedlot. For period 4 (February 2012 or March 2013), blood samples were collected from feedlot animals aged 10 to 12 mo.

### 2.2. Diets

Calves with their cows were maintained on pasture with access to trace mineral salts and had access to free choice hay as required by season. Animals were fed according to guidelines [13]. Feedlot diets are outlined in Table 1. Dietary vitamin supplements provided 36 IU and 86 IU of vitamin D per pound of dry matter for years 2011 and 2012, respectively. The composition of these supplements is in Table 1. Vitamin D content of the feed components is unknown.

### 2.3. Vitamin D status measurements

Blood samples were obtained via jugular puncture, maintained on ice and allowed to clot for 1 h. Serum was separated by centrifugation at 1,500g for 15 min at 4°C and frozen at −20°C until used. The 25OHD concentration was determined using a radioimmunoassay with the intra-assay and interassay coefficients of variation averaging 6% and 16%, respectively [14].

**Table 1**
Composition of finishing diet.

| Ingredient | Dry matter %, 2011 calves | Dry matter %, 2012 calves (September to January 2013) | Dry matter %, 2012 calves (January 2013 to March 2013) |
|---|---|---|---|
| Ground corn | 25.00 | 20.0 | 59.5 |
| Silage | 13.75 | 26.5 | 5.0 |
| Earlage | 40.00 | — | — |
| Wet distillers grains | 20.00 | 25.0 | 32.0 |
| Soybean straw | — | 25.0 | — |
| Supplement[a] | 1.25 | — | — |
| Steakmaker[b] | — | 3.5 | 3.5 |

[a] Supplement: 94.45% limestone; 2.07% thiamine; 0.73% vitamin A, D, E premix; and 2.74% Rumensin80.
[b] Land O Lakes Steakmaker Co-Product Balancer.

### 2.4. Statistical analysis

Data were analyzed with the MIXED model procedure (SAS Inst Inc, Cary, NC). The model included the fixed effects of sex (steers and heifers) and season (early summer, late summer, fall, and winter) nested within year of birth. Year of birth was included as a random effect. There were 3 samples periods from each animal in 2011 and 4 samples periods from each animal in 2012. Animal was treated as a repeated measurement in the model. Least square differences and probability values were estimated for significant associations. All data are presented as means ± standard error of the mean. Data were considered different if $P < 0.05$.

## 3. Results

Figure 1 shows serum concentrations of 25OHD from period 1 at 2 to 3 mo of age to period 4 at 1 yr of age.

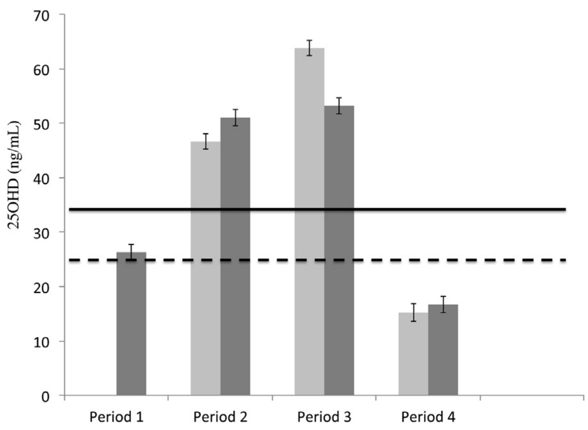


**Fig. 1.** Serum 25-hydroxyvitamin D (25OHD) measured for animals born in March or May 2011 (light gray bars) and in March or May 2012 (dark gray bars). Upper horizontal line (solid black line) corresponds to the putative serum 25OHD concentration threshold for sufficiency, based primarily on the human literature, and shown to support optimal immune function. Lower horizontal bar (dashed line) corresponds to the serum 25OHD threshold for optimal calcium homeostasis. Within a period, values for 2011 calves differed ($P < 0.05$) from those of 2012 calves. For period 1, 25OHD concentrations of calves differed ($P < 0.0001$) from those in periods 2 and 3. For period 4, 25OHD concentrations of calves differed ($P < 0.0001$) from those in all other periods.

Concentrations of 25OHD in early summer (period 1) differed ($P < 0.0001$) from 25OHD concentrations during periods 3 to 4. During winter (period 4), animals born in 2011 and 2012 had similar concentrations of 25OHD, and these concentrations were lower ($P < 0.0001$) when compared with concentrations at any other growth stage. There was no difference ($P > 0.05$) between concentrations of 25OHD in steers and heifers at any stage.

## 4. Discussion

The role of vitamin D in human and animal health has rapidly evolved in the last decade from a primary role in calcium and/or skeletal homeostasis to a more complex one that includes a role in immune function [1,3]. Serum 25OHD is the best measure of vitamin D status, with 25OHD values >20 ng/mL considered sufficient for calcium and/or skeletal homeostasis. However, values are not considered immunologically adequate until serum concentrations of 25OHD are >30 ng/mL. This is based on the threshold required for optimal immune function in immune cell function assays, both in vitro and in vivo [4,5]. Serum concentrations of 25OHD of <20 ng/mL are generally considered insufficient for calcium and/or skeletal homeostasis, with serum 25OHD <10 ng/mL resulting in frank deficiencies in animals and humans [5,15].

By this criterion, 2- to 3-mo-old calves from period 1 in this study were potentially immunologically deficient for vitamin D with 25OHD concentrations of 26.3 ± 1.5 ng/mL (Fig. 1) pending further studies confirming human immune function data described previously. These 25OHD concentrations may have been even lower in March to May when UVB is too low to support cutaneous vitamin D production [6,7]. Of greater importance was the finding that all feedlot animals in mid-late winter (period 4) had serum 25OHD concentrations that were <20 ng/mL (Fig. 1). Serum concentrations of 25OHD at this level are putatively too low for optimal immune function, and subclinical calcium disturbances are possible with associated additional calcium-mediated disturbances to immune function [16,17]. In fact, although period 4 means were 15 to16 ng/mL, 28% of the individuals in this group had serum 25OHD concentrations below 10 ng/mL, which is considered true deficiency [15].

The feedlot animals used in this study received ∼80 IU or 184 IU of supplemental vitamin D/kg dry matter (DM) in 2011 and 2012. This translates to a growth-supporting vitamin D intake of ∼1 to 2 IU/kg body weight (BW). This intake is below the conservative recommendations [18] for humans at 8 IU/kg BW and the more often sited 30 IU/kg BW for both dairy cattle and humans [5,19,20]. This low vitamin D intake is not a surprise, as a survey of beef cattle nutritionist (personal communications) shows that most do not add supplemental vitamin D. Moreover, the National Research Council Guide for Nutrient Requirements of Beef Cattle [21] and others [22] recommends only 275 IU/kg DM of vitamin D daily.

However, if the effects of dark pigmentation are combined with a potential 10-fold reduction in UVB vitamin D production [6,7] during winter, an even lower vitamin D status may be observed in black cattle such as Angus. The calves in our study were removed from summer pasture and entered the feedlot in the fall (periods 2 and 3) with excellent vitamin D status (serum 25OHD of 63.8 ± 1.4 and 55.2 ± 1.5 ng/mL). Pickworth et al [10] reported on Angus crossbred calves reared on summer pasture and entering the feedlot with serum 25OHD of only 17 to 18 ng/mL. This is considered vitamin D insufficiency and, in the absence of supplementation, values may drop to ∼8 ng/mL, which is a deficiency. One half of the animals in this study with Angus cattle were supplemented with 1,860 IU vitamin D/kg DM, and serum concentrations of 25OHD in the winter were considered excellent at ∼ 65 ng/mL. This is similar to observations in dairy cows fed 30 IU vitamin D/kg BW [23].

Despite entry to the feedlot with excellent serum concentrations of 25OHD, values for all calves were well below 20 ng/mL during winter in both years of our study (Fig. 1). It is likely that supplementation of vitamin D needs to be re-evaluated during winter, given that animals have less exposure to sunlight (Fig. 1) at this time in North America (depending on latitude) and UVB is too low to support cutaneously produced vitamin D in light-skinned animals. This effect is exacerbated at least 10-fold in dark-skinned animals [6–8,10]. We speculate that current levels of supplementation of vitamin D fed during winter are inadequate to maintain proper immune function and calcium homeostasis and for black breeds such as Angus. Based on Pickworth et al, the supplementation of vitamin D may need to be increased, and this may include the entire year.

The vitamin D deficits noted in beef cattle in this study could lead to growth deficiencies or increased disease susceptibility. In the absence of sufficient UVB exposure from sunlight, the dietary vitamin D requirements for beef cattle need to be re-evaluated, taking into consideration season, latitude, and skin pigmentation. The 25OHD concentrations observed during the winter in calves used in this study could interfere with both the intracrine and endocrine functions of vitamin D.

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