# Does Vitamin $D_3$ Improve Beef Tenderness?

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## Introduction

"Beef, It's What's For Dinner." This catchy phrase certainly has been successful at getting the message out that beef is still the evening entrée of choice. However, with this successful campaign comes the responsibility to consistently supply beef products that deliver assurance in reference to palatability attributes such as flavor, juiciness and especially tenderness.

Consumers today consider tenderness to be the single most important determinant of beef quality. This is reflected by the positive relationship between retail price of a beef cut and its perceived tenderness (i.e., tenderloin steak). The most recent National Beef Quality Audit estimated that the inconsistencies associated with beef tenderness potentially cost the U.S. beef industry approximately $250 million annually. According to the National Beef Tenderness Survey conducted in 1998 (Brooks et al., 2000), a great deal of tenderness improvement needs to be focused on retail cuts originating from the round. With these findings in mind, research scientists have focused their attention on developing innovative nutrition, management, or product processing technologies that address this issue.

One factor which "turns-on" the tenderization process is the elevation of calcium in muscle. Many non-published, unsuccessful efforts have been attempted to elevate muscle calcium concentrations through dietary calcium supplementation. However, infusion of carcasses/cuts with a calcium containing solution, which in turn promoted enhanced postmortem tenderization and improved meat tenderness, has been clearly demonstrated. These calcium induced tenderness enhancement systems, which after tedious development, testing, and verification by scientists at the Meat Animal Research Center in Clay Center, NE proved to be a very successful tenderizing system (Wheeler et al., 1994). Even though calcium-induced tenderization clearly works, minimal industry acceptance resulted in meat scientists returning to the research drawing board trying to discover new calcium altering systems to ensure that consumers can enjoy tender steaks.

## Vitamin $D_3$ and Calcium Elevation

Early studies using lactating dairy cows showed that oral administration of vitamin D (VITD) for 2 weeks prepartum increased serum calcium (Hibbs et al., 1951; Hibbs and Pounden, 1955). Additionally, injections of vitamin D metabolites (i.e., 25-hydroxyvitamin $D_3$, 1,25-dihydroxyvitamin $D_3$) increased serum calcium concentrations of dairy cows (Bar et al., 1985; Sachs et al., 1987). These procedures posed as potential methods that could be used to elevate muscle calcium and in turn activate the postmortem tenderization process. Thus, information was gathered and summarized in order to address several valid questions with regard to the impact of VITD supplementation on live cattle performance traits, muscle calcium levels, cooked beef tenderness characteristics and potential residues in various tissues.

## Does VITD Influence Live Animal Performance?

In several studies, feed intake patterns for cattle supplemented with VITD were determined, and daily feed consumption estimates were collected prior to harvest (Figure 1). In all of these studies, VITD supplementation occurred between 6 to 12 days prior to harvest. Consumption information from these separate research investigations suggested that cattle appetite was



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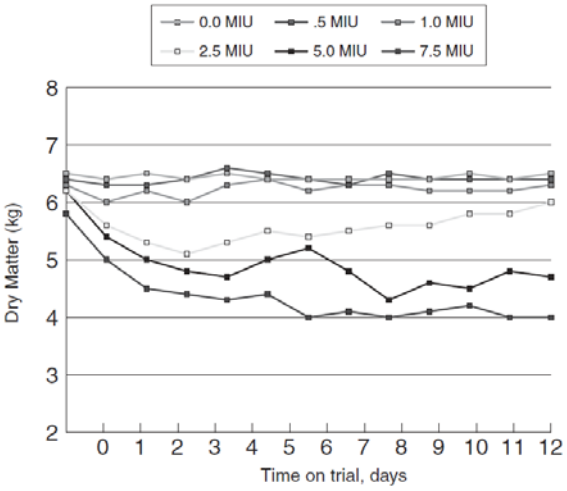


**Figure 1: Weighted means for dry matter intake of animals supplemented different levels of vitamin D**
*Source: Swanek et al. (1999), Kargas et al. (2001), Montgomery et al. (2002).*

suppressed when greater than 1.0 million IU of VITD was supplemented per animal each day. A linear decrease was observed per day for each animal. Additionally, a decline was observed in feed consumption as VITD supplementation level was increased. This pattern of reduced feed intake could be indicative of cattle that manifested acute toxicity from the VITD supplementation. This information is crucial for producers to understand. In order to incorporate supranutritional VITD supplementation into standard U.S. cattle feeding operations, care must be taken to prevent depressed consumption trends. In order to maintain a normal daily gain, animals could be fed a maximum of 1.0 million IU of VITD per animal from 2 to 10 days prior to harvest. This level does not appear to present any symptoms associated with toxicity (Montgomery et al., 2002).

## Can VITD Be Used To Elevate Muscle Calcium?

One of the most consistent findings between all of the trials investigating the impact of VITD supplementation on meat tenderness is a noticeable spike in serum calcium that peaks during the second day of supplementation (Figure 2). Pooled results suggest that supplementing beef cattle diets with at least .5 million IU of VITD per animal each day caused a 30 to 35% increase in blood calcium concentration. Maximal calcium concentration was maintained for the entire time of supplementation. Animals fed no supplemental VITD showed no change in calcium concentration throughout the entire preharvest dietary period.

## Does VITD Supplementation Improve Tenderness?

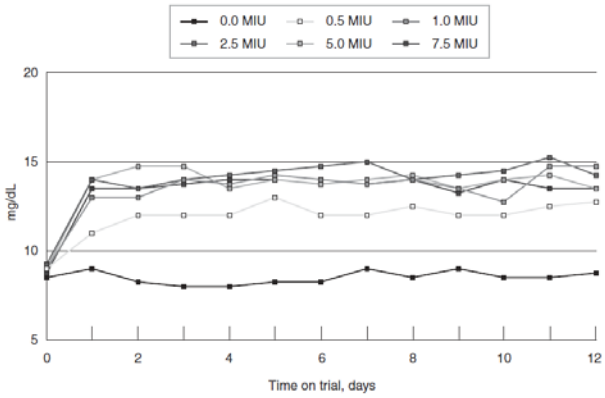


**Figure 2: Influence of Vitamin D Supplementation on Blood Calcium Concentrations**
*Source: Swanek et al. (1999), Kargas et al. (2001), Montgomery et al. (2002), Scanga et al. (2001), Elam et al. (2001).*

The first evidence that associated the involvement of calcium with the process of meat tenderization during postmortem aging was noted over 30 years ago (Davey and Gilbert, 1969). They indicated that weakening and disappearance of muscle structure during postmortem aging was inhibited by ethylene diamine tetraacetiz acid (EDTA). They also speculated that EDTA might exert its effect by chelating calcium ions. It appears that VITD supplementation accelerates the aging process by shifting calcium to inner areas within muscle cells. In normal muscle, calcium is primarily housed in compartmentalized structures. If VITD can solicit calcium from these areas and into a closer proximity to muscle cells, calcium mediated enzymes can more readily tenderize meat during postmortem aging. Initial results demonstrated that VITD supplementation primarily improves beef tenderness ratings by reducing the percentage of “tough” steaks, bringing them back into a more acceptable



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"tender" category (Swanek et al., 1999; Karges et al., 2001; Montgomery et al., 2000 and 2002). However, more recent findings (Elam et al., 2002; Scanga et al., 2001) involving VITD supplementation and its impact on cooked beef tenderness conflict these findings and certainly raise questions about the commercial application of VITD. These research findings are summarized in the following statements and in Table 1.

| Investigator(s)[1] | Postmortem Aging, d | Supplementation Level/Time | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 5 million IU for 7 d | | 7.5 million IU for10 d | | |
| Swanek | 7 | 4.70[a] | 4.12[b] | | --- | | |
| | 14 | 4.30 | 3.87 | | --- | | |
| | 21 | 3.58 | 3.60 | | --- | | |
| | 7 | 5.13[a] | --- | | 4.21[b] | | |
| | 14 | 4.40[a] | --- | | 3.80[b] | | |
| | 21 | 4.04 | --- | | 3.44 | | |
| | | 0 | 6.0 million IU for 4 d | | 6.0 million IU for 6 d | | |
| Karges | 7 | 4.19[a] | 4.15[a] | | 3.75[b] | | |
| | 14 | 4.12[a] | 3.79[b] | | 3.58[b] | | |
| | 21 | 4.30 | 4.00 | | 4.02 | | |
| | | 0 | 5 million IU for 5 d | | --- | | |
| Elam | 7 | 4.17 | 4.08 | | --- | | |
| | 14 | 3.67 | 3.87 | | --- | | |
| | | 0 | 1.0 million | 2.0 million | 3.0 million | 4.0 million | 5.0 million |
| Scanga | 2 | 6.27 | 5.86 | 6.11 | 5.85 | 6.25 | 6.08 |
| | 7 | 4.91 | 4.62 | 5.13 | 5.13 | 5.26 | 4.95 |
| | 14 | 4.64 | 4.26 | 4.48 | 4.53 | 4.68 | 5.14 |
| | 21 | 3.80 | 3.81 | 4.14 | 3.94 | 4.10 | 4.45 |
| | | 0 | 5.0 million IU for 9 d | | 7.5 million IU for 9 d | | |
| Montgomery | 3 | 3.58 | 3.11 | | 3.17 | | |
| | 7 | 3.32 | 3.20 | | 2.89 | | |
| | 14 | 3.25[a] | 2.80[b] | | 2.78[b] | | |
| | 21 | 3.38 | 2.90 | | 3.02 | | |

**Table 1: Summary of Findings Associated With Vitamin $D_3$ Supplementation on Longissimus Beef Tenderness (i.e., Warner-Bratzler Shear Force, kg)**

- In 1999, Swanek and coworkers at Oklahoma State University found that elevated blood serum and muscle calcium concentration as a result of VITD supplementation resulted in improved strip loin steak tenderness. This improvement accounted for an approximate 12% improvement in tenderness compared to non-supplemented samples. However, these noted improvements lessened as postmortem aging time increased.

- Texas Tech University meat scientists showed that supplementing steers with 0.5 million IU of VITD per day for 9 days prior to harvest improved tenderness ratings of strip loin and round steaks from cattle that tended to produce tougher beef when compared to steaks from non-supplemented animals (Montgomery et al., 2002). This same dose had no impact on cattle that produced tender beef.

- Iowa State University scientists noted that feeding 5.0 million IU of VITD per day for 9 days before harvest could be implemented in a commercial feedlot system to improve tenderness of strip loin and round steaks (Montgomery et al., 2000).

- Recent findings demonstrate that feeding a single dose of 125 mg of 25-hydroxy VITD (a VITD derivative) for four days immediately prior to harvest could be implemented in



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a commercial feedlot system more easily than daily VITD supplementations (Foote et al., 2001). Besides being easier, hydroxy VITD produced significantly more tender strip loin and round steaks compared to VITD steaks.

- Conflicting studies do exist. A recent published report from Colorado State University, (Scanga et al., 2001) concluded that even though a marked increase in blood calcium level was observed, supplementation with VITD for up to 8 days prior to harvest did not improve measured tenderness ratings at 2, 7, 14 or 21 days of postmortem aging compared with control steaks cooked to final internal temperatures corresponding to either medium or medium well degree of doneness.

## A Balancing Act: Tenderness Improvement Versus VITD Tissue Residues

Tenderness has been long identified as the single most important palatability factor affecting consumer satisfaction of beef. As discussed, it appears that feeding supplemental VITD to beef cattle can improve tenderness in cattle that are prone to produce tougher meat. It is hypothesized that this effect occurs because of the increase in calcium concentrations found in blood and muscle when fed VITD. This increase in calcium may activate muscle proteases (i.e., calpains), which are active during postmortem tenderization or aging. Unfortunately, prior to implementation, an important safety question regarding feeding supplemental VITD had to be answered, "As a result of this feeding practice, will a substantial amount of VITD or its intermediates reside in tissue(s) consumed by humans?" Information in Table 2 summarizes the effects of supplementation on concentrations of VITD in strip loin, round and sirloin steaks as well as in raw and cooked beef liver samples. In all of these studies, animals were supplemented with VITD between 6 to 9 days prior to harvest. Supplementing animals with levels of 1.0 million IU/animal/day of VITD and greater, increased VITD concentrations in raw beef and raw liver samples. Supplementing a high dose (i.e., 7.5 million IU/day) resulted in VITD concentrations 5 to 6 times higher than control muscle and liver samples. Cooking appears to decrease the amount of VITD (i.e., between 12% and 20%) accumulated in the liver during supplementation.

| | Vitamin D Treatment, Million IU/Animal Daily | | | | | |
|---|---|---|---|---|---|---|
| Item | Control | 0.5 | 1.0 | 2.5 | 5.0 | 7.5 |
| Raw Strip Loin Steaks | 1.5 | 7.8 | 21.4 | 33.3 | 53.2 | 62.5 |
| Raw Round Steaks | 1.1 | 9.0 | 23.2 | 36.0 | 43.2 | 58.6 |
| Raw Sirloin Steaks | 1.3 | 6.7 | 20.1 | 39.2 | 52.3 | 65.3 |
| Raw Liver | 98.7 | 211.5 | 304.7 | 345.6 | 503.1 | 489.2 |
| Cooked Liver | 78.9 | 178.4 | 267.6 | 298.5 | 444.2 | 423.7 |

**Table 2: Concentration of Vitamin $D_3$ (ng/g) in Various Beef Tissues of Cattle Given Supplemental Doses of Vitamin $D_3$**
*Source: Swanek et al. (1999), Karges et al. (2001), Montgomery et al. (2002), Foote et al. (2001).*

The recommended dietary allowances of VITD for an adult human is 200 IU/day or 400 IU/day for young adults (NRC, 1989). At this rate, an adult would need to eat approximately 3 ounces of steak from animals treated with 5.0 million IU of VITD to meet their daily needs for this nutrient. Currently, all livers from animals supplemented with VITD are required to be removed from the food chain. However, two important research findings may allow this potential safety concern to be overcome. First, only 0.5 million IU/day of VITD is needed to elicit increased tenderness while preventing a significant increase in tissue residues (Montgomery et al., 2002). Second, it appears that some VITD intermediates may be candidates to improve tenderness while significantly reducing the concerns associated with elevated VITD tissue residues (Foote et al., 2001). Iowa State University researchers hypothesized that since VITD is initially hydroxylated to 25-hydroxy VITD and eventually to the hormonally active form of 1,25-dihydroxy VITD, these intermediates could be supplemented to animals and would enhance cooked beef tenderness without generating a large concentration of VITD residue in beef. Findings suggested that feeding a single dosage



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of 25-hydroxy VITD four days prior to harvest produced significantly more tender strip loin and round steaks without generating a large concentration of VITD in beef (Foote et al., 2001).

## Summary

Elevation of muscle calcium concentration as a result of VITD supplementation seems to be a practice that promotes meat tenderness. It appears that supplementing beef cattle diets with 0.5 million IU/day for the week immediately prior to harvest can improve beef tenderness ratings while not creating any safety concerns associated with VITD residues in meat products. However, since there does not appear to be a consistent response to VITD supplementation and its impact on cooked beef tenderness, commercial application at this time is premature. It must be understood that VITD supplementation is just one of the tools which can be used to insure a satisfactory beef eating experience. Pre- and post-harvest factors which promote beef palatability still must be in place to capture the enjoyable eating experience associated with grain-fed U.S. beef.

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