Use of 25-hydroxyvitamin D_3 to Improve Tenderness of Beef

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Background

Tenderness is one of the most important quality characteristics of beef to both consumers and producers. To date, no practical method of producing consistently tender beef has been adopted by the beef industry. Researchers have demonstrated that feeding a supernatural dosage (0.5 to 7.5 million IU) of vitamin D_3 to beef cattle for 7 to 10 days before slaughter will result in more tender carcasses (Swanek et al., 1999; Montgomery et al., 2000; Montgomery et al., 2002; Karges et al., 2001). Feeding this amount of vitamin D_3 results in elevated plasma and muscle calcium concentrations (Swanek et al., 1999; Montgomery et al., 2000; Montgomery et al., 2002; Karges et al., 2001). The assumed mechanism for this tenderization effect is that the elevated muscle calcium concentration enhances the action of the calcium-dependent protease system of myofibrillar (troponin-T) protein degradation postmortem. Enhanced myofibrillar protein degradation results in more tender beef that is more desirable to consumers. For producers, being able to produce a "guaranteed tender" product even may warrant a price premium.

The disadvantage of feeding a high dosage of vitamin D_3 close to time of harvest, however, is that the excess vitamin D_3 results in a relatively high concentration of vitamin D_3, and its metabolite, 25-hydroxyvitamin D_3 (25-OH D_3) in muscle (Montgomery et al., 2002 and Foote, 2004). Hypervitaminosis D is undesirable because increased concentrations of vitamin D can cause more calcium to be absorbed from the small intestine, leading to increased calcium concentrations in blood and tissues. This effect is undesirable in humans if the high plasma calcium concentrations leads to soft tissue calcification. In effect, the same mechanism that works to improve tenderness of beef from cattle treated with vitamin D_3 can cause ill effects in humans if high amounts of vitamin D are consumed regularly. Feeding large doses of vitamin D_3 to cattle a few days before harvest, however, is considered safe for cattle because the cattle are not fed this high dosage of vitamin D_3 long enough to cause calcification of soft tissues.

Some research already has been conducted to observe the effectiveness of feeding 25-hydoxyvitamin D_3 (25-OH D_3), a metabolite of vitamin D_3, to elicit the desired increase in plasma calcium concentrations (Foote et al. 2004; Wertz et al. 2004). In these studies, minimal increases in plasma calcium and tenderness were observed. Results indicate that the necessary dosage and time of 25-OH D_3 administration was not obtained; therefore, additional research to determine the optimal dosage and time of administration was conducted.

Experiment 1

A preliminary experiment was designed to determine the dosage of 25-OH D_3 that would be necessary to increase plasma calcium concentrations. Twelve crossbred steers were allotted randomly to four dietary treatments [0, 125, 250, or 500 mg of 25-OH D_3 (DSM, Ames, IA)]. Dosages were administered via gelatin capsules. The 0 mg 25-OH D_3 group received cornstarch in their capsules because starch was a carrier for the 25-OH D_3. Plasma samples were obtained by jugular venipuncture on the day of bolusing and every 48 hours thereafter for 14 days.

Results from the preliminary experiment are shown in Figure 1. An oral bolus of 500 mg of 25-OH D_3 increased blood calcium concentration ($P<0.0003$), whereas plasma calcium in those animals that received 0, 125, or 250 mg of 25-OH D_3 did not change ($P> 0.05$). The largest difference in plasma calcium, an increase of 17%, occurred eight days after 25-OH D_3 administration. The smaller dosages of 25-OH D_3 increased plasma calcium concentration but not significantly ($P>0.05$). Results indicate that a 500-mg dose of 25-OH D_3 seven days before harvest is required to increase plasma calcium concentrations in beef steers.

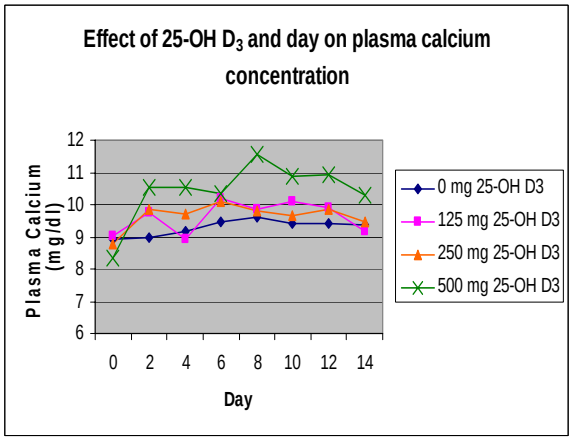

Figure 1.

Experiment 2

By using information gathered from the previous experiments and recent data that suggests that the antioxidative characteristics of vitamin E (α-tocopherol) fed at 1000 IU/day for 125 days prior to harvest may protect the calpains, enzymes that participate in meat tenderization, from oxidation (Harris et al., 2001) another experiment was designed. We hypothesized that orally administering 500 mg of 25-OH D_3 seven days before harvest in conjunction with feeding vitamin E for 104 days would improve tenderness by increasing calcium available to activate calpains to degrade muscle fibers and by decreasing loss of activity of the calpains. Forty-eight crossbred heifers were assigned to one of four dietary treatments: 1) no supplemental vitamin E or 25-OH D_3, 2) 1000 IU vitamin E for 104 days before slaughter, 3) 25-OH D_3 administered orally as a single bolus seven days before harvest, and 4) both vitamin E and 25-OH D_3. Blood samples were obtained by jugular venipuncture at the start of the study, on the day of 25-OH D_3 bolusing, and one day before harvest. Upon harvest, rib sections were collected from each carcass and sliced into six one-inch steaks. Two steaks from each carcass were aged for 72 hours, 7 days, or 14 days. Analysis already completed show that plasma calcium concentrations were increased on the day before harvest in steers treated with 25-OH D_3 ($P < 0.05$) (Figure 2). Concentrations of 25-OH D_3 in plasma and meat samples were higher in steers treated with 25-OH D_3 than in control steers or in those that received only the vitamin E treatment (Figures 3 and 4). 1,25-Dihydroxyvitmin D_3 concentrations were increased in plasma of steers treated with 25-OH (D_3) (Figure 5) but were unchanged in meat samples ($P > 0.05$) (Figure 6). Analysis will be completed to determine the Warner-Bratzler shear force, troponin-T degradation, vitamin E concentration, calcium concentration, and extent of oxidation in the steak samples. We expect to see that the tenderizing effect 25-OH D_3 has on beef will be increased by the supplemented vitamin E.

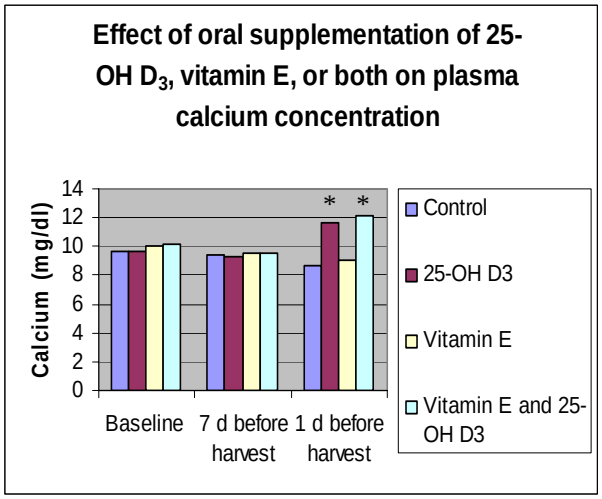

Figure 2.
* Indicates $p<0.05$

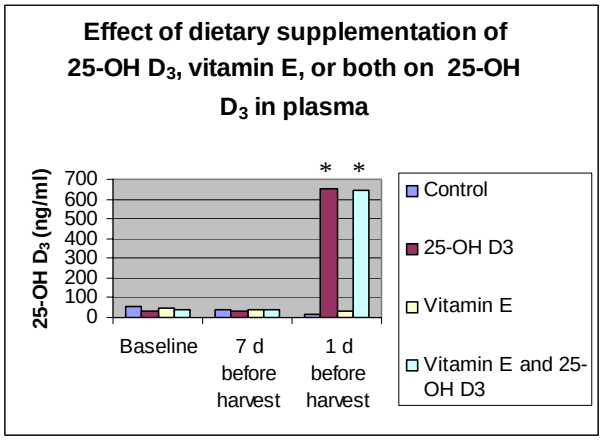

Figure 3.
* Indicates $p<0.05$

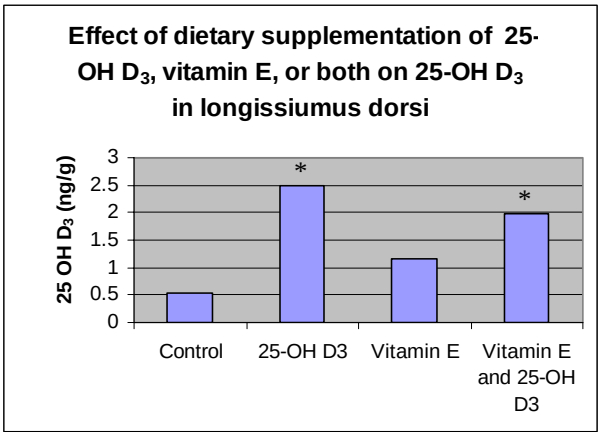

Figure 4.
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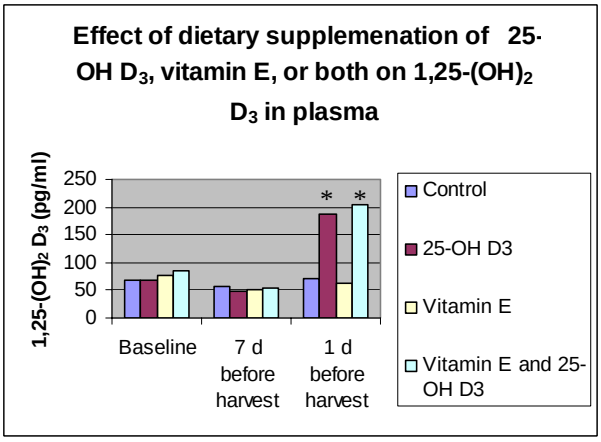

Figure 5.
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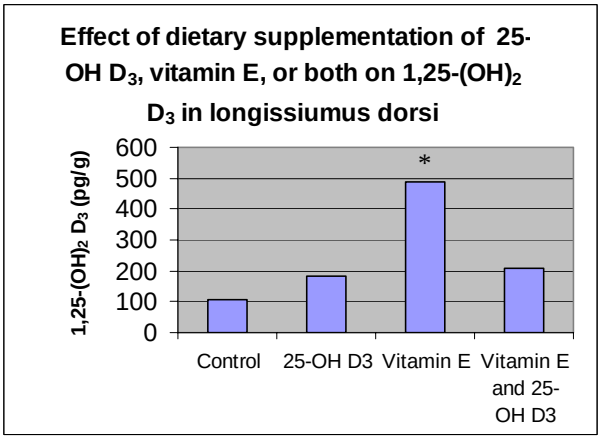

Figure 6.
* Indicates $p<0.05$

Implications

Results from data generated thus far have been promising. Most likely, the dosages used in the initial trials were too low to elicit the desired effects. We now know that increasing the dosage of 25-OH D_3 increases plasma calcium without raising concentrations of 25-OH D_3 or 1,25-$(OH)_2$ D_3 in the meat to values higher than those observed when lower dosages were administered. We believe that the higher dosages used in our more recent experiments (500 mg of 25-OH D_3) will improve tenderness of beef to an extent similar to that when vitamin D_3 (e.g., 5×10^6 IU per day for 8 days) is supplemented. Developing a practical method for improving tenderness of beef could lead to greater profits for beef producers because consumers would likely pay a premium for beef that could be guaranteed tender. These feeding strategies of supplemental 25-OH D_3 and varying dietary calcium could allow producers the option of making their beef more tender and, possibly, gaining profit in a niche market. Research still needs to be conducted to evaluate the effectiveness of these feeding strategies in a pasture setting because grass-fed beef is widely known to be less tender than corn-fed beef. Improving tenderness of grass-fed beef while retaining some of the perceived health benefits, such as increased conjugated linoleic acid, could be possible with feeding strategies similar to those described within this article. Even with the current studies, the use of 25-OH D_3 as an "on the farm" method for improving the tenderness of beef is still a new concept, and much research remains before the practice should be employed by beef producers.

References

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