Report

How to Incorporate Dietary Vitamin D_3 into an Animate® Program for Prepartum Dairy Cows

Kristen Glosson, Ph.D

Introduction

Vitamin D_3 (Vit D_3) is routinely supplemented to dairy cows to support a variety of physiological functions, such as mineral homeostasis and immune activity. Once absorbed, Vit D_3 is converted to 25-hydroxyvitamin D [25(OH) D] (calcidiol) in the liver and enters the circulating pool. The Vit D_3 status of a dairy cow is based on serum concentrations of 25(OH) D and can range from 40-100 ng/mL (Nelson et al., 2016). This inactive form is converted to the biologically active form, 1,25-dihydroxyvitamin D [1,25$(OH)_2$D], by the kidneys and is tightly controlled. The active form works with parathyroid hormone (PTH) in the PTH pathway that regulates the cow's circulating calcium (Ca) concentrations.

Additional supplementation of dietary Vit D has been investigated in dairy cows to support Ca homeostasis during the transition period. In this report, the different forms of dietary Vit D, feeding rates, and the recommendations for supplementation in a prepartum Animate program will be discussed.

Vitamin D_2 vs D_3

Forages can be a source of Vitamin D, in the form of Vit D_2 (ergocalciferol). This form is highly variable in common forage types, with levels highest at the time of harvest in leafy forages and degradation occurring over time in stored forages. Since Vit D_3 (cholecalciferol) is more metabolically efficient than Vit D_2, it is the primary form found in blood circulation. Vitamin D_3 occurs naturally as a chemical reaction in the skin when a form of cholesterol reacts to ultraviolet light (sunlight). However, this is an unreliable and insufficient source of Vit D_3 unless the cow is exposed to consistent sunlight. Commercially, Vit D_3, either created synthetically or extracted from sheep cholesterol, is the main form of supplemented Vit D_3 sources.

Vitamin D_3 supplementation is expressed as mg or International Units (IU), while circulating concentrations are expressed as ng/ml. This converts to, approximately, 1 mg of Vit D_3 equal to 40,000 IU. The National Research Council: Nutrient Requirements of Dairy Cattle, 2001, (NRC, 2001), recommendation for Vit D_3 supplementation is 21,000 IU/d for a mature lactating dairy cow. Nelson et al. (2016) surveyed 12 commercial dairy herds and reported that cows supplemented with Vit D_3 between 30,000 and 50,000 IU/d had average serum 25(OH) D concentrations of approximately 70 ng/ml. One herd in the study was supplementing 20,000 IU of Vit D_3/d resulting in cows averaging 42 ng/ml of serum 25(OH) D concentrations, with 22% of the herd falling below 30 ng/ml. In determining the new adequate intake requirement for Vit D_3 supplementation for heifers and dry cows (30 IU/kg BW) and for lactating cows (40 IU/kg BW) the NASEM, 2021 Nutrient Requirements of Dairy Cattle committee used a response variable based on minimum serum concentration of 30 ng/ml for 25(OH) D.

Nelson et al. (2016) also reported that across the 12 surveyed herds supplementing 30,000 to 50,000 IU/d of Vit D_3, fresh cows had lower serum 25(OH) D (< 60 ng/ml) compared to late lactation cows (> 70 ng/ml). The increased conversion of 25(OH) D to 1,25$(OH)_2$ D to be used in immune system functions and within the PTH pathway for Ca mobilization in fresh cows is likely the cause of decreased circulating concentrations (Holcombe et al., 2018). Combined with lower intakes, the increase in metabolic demand for 25(OH) D may be a limiting factor in transition cow health.

Wisnieski et al. (2020), used samples collected from 5 commercial dairy herds to test the association of serum 25(OH) D during the transition period with metabolic disorders. They found that lower serum 25(OH) D concentrations (less than 71 ng/ml) at 2 to10 days post calving were associated with uterine disease. This has led to investigations of additional supplementation of Vit D_3 and/or supplementation of the 25(OH) D form around the time of calving to better support this increased need.

25-hydroxyvitamin D_3

Supplementing 25(OH) D is an alternative to Vit D_3 supplementation and may be seen as a more effective method to increase the circulating concentrations of 25(OH) D. The 25(OH) D bypasses conversion from Vit D_3 by the liver and can directly enter the circulating pool. This intermediate metabolite remains in circulation longer than Vit D_3, extending the efficacy (half-life) from 1 to 3 days to up to 2 weeks (Martinez et al., 2018a). Another advantage in supplementing the inactive form, 25(OH) D, instead of the active form, 1,25$(OH)_2$ D, is that the 25(OH) D does not become the target of enzymes designed to maintain 1,25$(OH)_2$ D within a tight margin.

Wilkens et al. (2012) used a 2x2 factorial design study to investigate the effects of DCAD (+14.4 mEq/100 g of

DM or -16.8 mEq/100 g of DM, using commodity anionic salts prepartum) and 25(OH) D supplementation (0 or 3 mg/d oral dose) using 60 transition dairy cows. Plasma Ca concentrations were significantly increased in cows fed the combination of 3 mg of 25(OH) D with a negative DCAD prepartum diet. This is thought to be related to the effects of compensated metabolic acidosis and kidney PTH receptors. Compensated metabolic acidosis is a direct result of feeding a negative DCAD prepartum diet and increases the responsiveness of the kidney to PTH. The kidneys control the activation of circulating 25(OH) D to the active $1,25(OH)_2$ D. Wilkens et al. (2012) explained that the direct impact of a negative DCAD diet on the kidneys was essential for the success of supplementing 25(OH) D in prepartum cows.

Rodney et al. (2018) used a 2x2 factorial arrangement of treatments to determine the direct effects and interactions of DCAD and Vit D_3 source (n = 79). Cows were fed a positive DCAD (+13.0 mEq/100 g of DM) or a negative DCAD (-13.0 mEq/100 g of DM; using a commercial anion supplement) supplemented with either 3 mg (120,000 IU vitamin D) of Vit D_3 or 25(OH) D. Cows fed a negative DCAD prepartum diet had improved ionized and total Ca concentrations directly after calving regardless of additional supplementation. Supplementing the prepartum diet with 3 mg of 25(OH) D improved prepartum ionized and total Ca. Feeding both a negative DCAD and supplementing 25(OH) D, regardless of DCAD, increased prepartum urinary Ca excretion. Urinary Ca excretion reflects Ca flux, or the movement of Ca in and out of the circulating Ca pool. When 25(OH) D was supplemented with a negative DCAD prepartum diet, urinary Ca excretion increased from 8.5 g/d to 15.4 g/d, indicating greater Ca flux prepartum. Ionized calcium excreted in the urine is diverted to the mammary gland at calving to help meet increased calcium needs for colostrum and milk production (Megahed et al., 2018)

Companion papers to Rodney et al. (2018), followed the same cows through early lactation (Martinez et al., 2018a and 2018b). Feeding a negative DCAD diet eliminated clinical hypocalcemia, reduced subclinical hypocalcemia, and improved neutrophil activity. Neutrophil oxidative burst and phagocytosis activity, as a measure of immune function, was increased. Supplementation of 25(OH) D improved milk and colostrum production (first milking) and tended to increase milk fat and protein yield, regardless of the prepartum DCAD strategy (Martinez et al., 2018b). Colostrum production was increased from an average of 6.0 kg to 7.8 kg and milk production during the first 49 DIM increased from 31.5 kg/d to 35.2 kg/d when cows were supplemented with 3 mg of 25(OH) D compared to 3 mg of Vit D_3.

Combining the prepartum and postpartum results from Rodney et al. (2018), Martinez et al. (2018a) and Martinez et al. (2018b), a prepartum program supplementing 3 mg of 25(OH) D_3 with a negative DCAD diet improved Ca status and promoted greater milk production and improved health in transition cows.

Summary

Vitamin D_3 is important in many physiological functions of a dairy cow and circulating 25(OH) D concentrations are a way to measure the Vit D_3 status of the animal. At the time of calving, serum 25(OH) D decreases and may become a limiting factor in Ca recovery mechanisms and health of postpartum cows. Supplementing 25(OH) D to transition cows in combination with a prepartum acidogenic Animate program may help improve the cow's Vit D_3 and further improve Ca status which leads to better performance.

References

Holcombe, S. J., L. Wisnieski, J. Gandy, B. Norby, and L. M. Sordillo. 2018. Reduced serum vitamin D concentration in healthy early-lactation dairy cattle. J Dairy Sci. 101:1488-1494.

Martinez, N., R. M. Rodney, E. Block, L. L. Hernandez, C. D. Nelson, I. J. Lean, and J. E. P. Santos. 2018. Effects of prepartum dietary cation-anion difference and source of vitamin D in dairy cows: Health and reproductive responses. J. Dairy Sci. 101:2544-2562.

Megahed, A. A., M. W. Hiew, and P. D. Constable. 2018. Plasma calcium concentrations are decreased at least 9 hours before parturition in multiparous Holstein-Friesian cattle in a herd fed an acidogenic diet during late gestation. J. Dairy Sci. 101:1365–1378.

Nelson, C. D., J. D. Lippolis, T. A. Reinhardt, R. E. Sacco, J. L. Powell, M. E. Drewnoski, M. O'Neil, D. C. Beitz, and W. P. Weiss. 2016. Vitamin D status of dairy cattle: Outcomes of current practices in the dairy industry. J. Dairy Sci. 99:10150-10160.

National Academy of Sciences, Engineering, and Medicine. 2021. Nutrient Requirements of Dairy Cattle: Eighth Revised Edition. Washington, DC. The National Academies Press

National Research Council. 2001. Nutrient Requirements of Dairy Cattle: Seventh Revised Edition, 2001. Washington, DC. The National Academies Press.

Rodney, R. M., N. Martinez, E. Block, L. L. Hernandez, P. Celi, C. D. Nelson, J. E. P. Santos, I. J. Lean. 2018. Effects of prepartum dietary cation-anion difference and source of vitamin D in dairy cows: Vitamin D, mineral, and bone metabolism. J Dairy Sci. 101:1-25.

Wilkens, M. R., I. Oberheide, B. Schroder, E. Azem, W. Steinberg, and G. Breves. 2012. Influence of the combination of 25-hydroxyvitamin D3 and a diet negative in cation-anion difference on peripartal calcium homeostasis of dairy cows. J. Dairy. Sci. 95:151-164.

Wisnieski, I., J. L. Brown, S. J. Holcombe, J. C. Gandy, and L. M. Sordillo. 2020. Serum vitamin D concentrations at dry-off and close-up predict increased postpartum urine ketone concentrations in dairy cattle. J. Dairy Sci. 103:1795-1806.