FEEDING BEEF CATTLE III:

VITAMIN A EFFECTS ON BEEF QUALITY AND NEONATAL SUPPLEMENTATION

Abstract

Vitamin A supplementation is an essential part of beef cattle diets. Cattle performance, health, and beef quality are all impacted by vitamin A content in the diet. Vitamin A deficiency can cause several health issues in cattle that reduce performance and welfare. Supplementation to meet requirements prevents deficiency, while supplementation exceeding requirements can impact beef quality in a variety of ways. Most research on vitamin A supplementation has focused on the backgrounding and finishing periods, where supplementing over minimum requirements can negatively impact intramuscular fat (IMF) or marbling. New studies focusing on neonatal vitamin A supplementation have shown improved IMF in supplemented calves at harvest. Supplementing calves with 150,000 IU injectable vitamin A source (retinol palmitate) increased calf performance, IMF development, marbling scores, and muscle fiber size. Initial results show increased performance without significantly increased inputs in neonatally injected vitamin A calves, which could benefit producers economically.

Introduction

Vitamin A is an essential vitamin in the diets of beef cattle during their life and production stages. Throughout this publication, deficiency will be defined as feeding below the National Research Council (NRC) recommendation for beef cattle, and supplementation will refer to adding vitamin A to the diet to meet or exceed NRC requirements. Vitamin A supplementation should be monitored and adjusted, as requirements vary across production stages (Church 1988). Feeding cattle too little dietary vitamin A can lead to deficiency, disease, and loss of production. Supplementation can result in decreases in production as well, depending on the stage of production and the rate of supplementation (Church 1988). Researchers have examined the effects of vitamin A during several important stages in cattle production with varying results on beef quality. Studies focusing on the 100 days prior to slaughter have typically shown that increased vitamin A supplementation is not advantageous for production or beef quality. Neonatal vitamin A supplementation has shown promise as an affordable strategy to improve cattle performance and beef quality, while ensuring cattle are meeting vitamin A requirements from birth to slaughter.

Vitamin A

Vitamin A is a fat-soluble vitamin that is necessary for many physiological functions in beef cattle. Vitamin A, or retinol, does not occur naturally, but its precursors are found in green plants as carotenoids and carotenes, with β-carotene, α-carotene, γ-carotene, and cryptoxanthin (found in corn) having the highest vitamin A activity (NRC 2016). Vitamin A can be synthetically produced as well. Many feeds can contain vitamin A precursors; however, over time they will degrade, especially with exposure to sunlight. In the body, the liver stores about 90% of the body's vitamin A, though it cannot be continuously synthesized in the body without the ingestion of precursors (McDowell 2000). This means vitamin A, as precursors or synthetic forms, must be consumed through the diet in order to build up or maintain adequate bioavailable levels in the body. Most cattle entering the feedlot after grazing fresh pasture, especially those with high vitamin A precursor contents such as fescue, have enough reserved vitamin A to sustain up to 120 days without vitamin A supplementation (Jin et al. 2015). Table 1 lists the current NRC vitamin A recommendations for beef cattle and demonstrates how they vary across production stages.

WASHINGTON STATE UNIVERSITY
EXTENSION

Table 1. NRC recommendations for vitamin A for beef cattle.

Production Stage	Vitamin A (IU/kg dry feed)[1]
Feedlot Cattle	2,200
Pregnant Cows	2,800
Pregnant Heifers	2,800
Lactating Beef Cows	3,900

[1] Values from NRC (2016).

Vitamin A has important effects on cattle physiology. When vitamin A is deficient it can cause health issues, declines in cattle performance, and impacts on carcass characteristics. Animals deficient in vitamin A are more susceptible to diseases, parasites, and infections (Spears 2000). Eye issues, such as blindness, are also commonly seen in cases of vitamin A deficiency, along with muscular edema (Kawachi 2006). Some studies have found positive health impacts from the supplementation of vitamin A. Pickworth et al. (2012) found the percentage of steers that received antibiotics for respiratory diseases tended to decrease in groups that received 2,700 IU vitamin A/kg dry matter (DM) from weaning to slaughter, compared to groups that received no supplementation after weaning. Intermediate levels of vitamin A supplementation may help to improve levels of available vitamin A in the blood serum, while supplementing higher doses of vitamin A may increase liver storage of vitamin A (Harris et al. 2018). For cattle to be able to fully utilize the vitamin A that is consumed, more intermediate, consistent levels of supplementation is necessary to maintain serum retinol levels.

It is important to know the vitamin A content of the feed a diet consists of before supplementing so that the desired rate of supplementation can be accurate. Different rates of supplementation can impact cattle performance, such as changing IMF deposition or marbling. This is important to cattle producers as marbling plays a role in USDA quality grading, with increased IMF typically increasing the USDA Quality Grade of beef and presumably carcass value.

Feeding Period Supplementation

When considering vitamin A supplementation and its effects on backgrounding and finishing cattle, it is important to identify the rate of supplementation and keep in mind its relationship to the NRC requirement. For example, feedlot steers had improved gains when receiving 2,134 IU of supplemental vitamin A/kg DM compared to steers receiving 6,274 IU/kg DM (Hill et al. 1995). Additionally, crossbred cattle consuming 2,200 IU/kg DM versus 11,000 IU/kg DM were found to have greater ADG and feed efficiency (Zinn et al. 1996). In both cases, supplementing vitamin A to levels near or at the NRC recommendation resulted in improved performance over cattle that received well over the NRC recommendation.

More recent studies have examined carcass data and shown that heavy supplementation during the feeding period often reduces IMF deposition. Arnett et al. (2008) fed a concentrate finishing diet with either zero supplemented vitamin A above the NRC (2016) recommendation or seven times the NRC recommendation for vitamin A in the diet. This resulted in 17% less IMF in the heavily supplemented cattle when compared to the controls (Arnett et al. 2008). Limiting over supplementation of vitamin A in the diet during the feeding period increases marbling, while maintaining average daily gain and feed-to-gain ratio (Arnett et al. 2008; Krone et al. 2016). Cattle fed a barley backgrounding diet containing 3,664 IU/kg DM, followed by a barley finishing diet with 555 IU/kg DM vitamin A (25% NRC requirement) had no deficiency symptoms, and blood serum concentrations at the end of the finishing period were sufficient to maintain homeostasis (Krone et al. 2016). Lower serum vitamin A levels typically increase IMF in beef, and monitoring vitamin A levels in blood serum is a tool producers can use to fine-tune levels of vitamin A their cattle are receiving (Jin et al. 2015). Monitoring serum vitamin A levels can also help producers determine if cattle are deficient before health issues occur. Jin et al. (2015) noted decreased IMF as supplementation of vitamin A increased during a 150 day finishing period. Siebert et al. (2006) examined the effects of vitamin A supplementation on twelve-month-old angus steers bred for marbling propensity. Control steers were fed for ten months on a diet comprised of 95% triticale, 5% wheat, canola meal, triticale straw, and a vitamin premix not containing supplementary vitamin A (Siebert et al. 2006). Vitamin A supplemented steers received retinol palmitate fed as a capsule at a rate of 60,000 IU/100 kg live weight (LW)/day (Siebert et al. 2006). The control steers in this study had higher levels of IMF deposition and monosaturated fatty acids, which both are desirable attributes in high-quality beef (Siebert et al. 2016).

Pickworth et al. (2012) found that early weaned steers provided with vitamin A supplementation of less than 300 IU/kg DM for the first 56 days of backgrounding and then at or slightly above NRC requirements of less than 2,300 IU/kg DM (target 2,250 IU/kg DM) for the finishing period had improved USDA quality grades compared to traditionally weaned steers supplemented with vitamin A. This improvement among the early weaned steers could be attributed to receiving more vitamin A supplementation at a younger age while only receiving the minimum NRC recommendation throughout the finishing period. In the same study, steers supplemented with vitamin A in the first 56 days after weaning had improved ADG over those that did not receive supplementation (Pickworth et al. 2012). Finishing cattle in this study that did not receive vitamin A supplementation had an average marbling score of 591.6, with 33.8% grading choice and above, compared to supplemented cattle which had an average marbling score of 559.8, with 23.8% grading choice and above (Pickworth et al. 2012).

Overall, feeding vitamin A to backgrounding and finishing cattle can have a variety of results depending on the timing, duration, and amount of vitamin A being supplemented. These studies suggest that greatly exceeding the NRC requirement for vitamin A in backgrounding and finishing diets causes some negative impacts on cattle performance and beef quality, such as reduced IMF and marbling.

Neonatal Supplementation

Harris et al. (2018) examined the effects of providing neonatal high dose retinol palmitate (vitamin A) injections by administering either a control null injection, 150,000 IU, or 300,000 IU to calves at birth and at one month of age. Vitamin A content in the diet met NRC (2016) recommendations throughout the backgrounding and finishing phases (2,200 IU/kg diet DM). Cow-calf pairs were managed together on native and improved pasture in Washington, and all calves used were weaned at 206 (±6) days old (Harris et al. 2018). The calves were first fed a backgrounding diet, then three step-ups, and a final finisher concentrate diet. This method is consistent with current industry practices for feedlot beef cattle production. Both the backgrounding and finishing diets were comprised of 5% dry supplement which contained 90,200 IU/kg vitamin A, and steers were harvested at an average age of 483 days (Harris et al. 2018). Cattle ADG was increased within the 150,000 IU and 300,000 IU vitamin A treated groups compared to controls, with calves injected with 150,000 IU vitamin A having increased marbling scores (Harris et al. 2018). Supplemented calves had greater growth rates, resulting in heavier, more developed calves at weaning, which for cow-calf producers could mean increased economic gains from supplementing calves with vitamin A. Two genes, ZFP423 and PPARG, had increased expressions that were consistent with the increased marbling in cattle supplemented with the 150,000 IU of vitamin A (Harris et al. 2018).

Samples from the same neonatally supplemented cattle used in Harris et al. (2018) were examined for gene activity and muscle composition characteristics in a subsequent study from Wang et al. (2018). Wang et al. (2018) found that neonatal vitamin A supplementation increased muscle fiber size and quantity at the time of harvest (Figure 1). Muscle biopsies taken from the calves at two months of age showed increases in activity for transcription factors that regulate myogenic genes, indicating that myogenesis (muscle synthesis) was stimulated in supplemented calves (Wang et al. 2018). Calves that received 150,000 IU vitamin A had increased muscle cell sizes in the latissimus dorsi (LD) muscle, shown in Figure 1 (Wang et al. 2018).

Increased muscle mass per animal could increase their value at weaning and slaughter by improving the overall ability to produce more beef per animal without increasing cattle size or significantly increasing feed inputs. Under these conditions, calf growth and beef marbling were improved with neonatal vitamin A supplementation, introducing a new perspective on how vitamin A impacts beef quality.

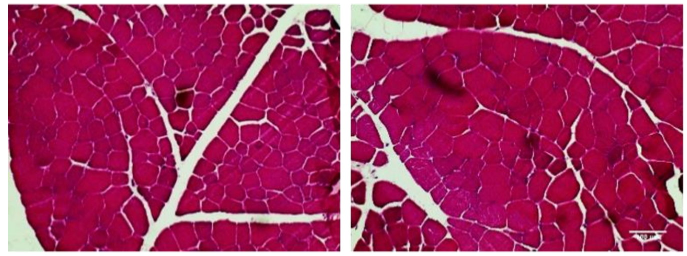

Figure 1. Latissimus dorsi muscle sample from calves supplemented with 150,000 IU vitamin A (right) showing larger muscle cell size compared to samples from a control calf that did not receive a vitamin A injection (left). Photo by Wang et al. (2018).

Economics

Using the data of Harris et al. (2018), calf average daily gain from birth to weaning at 210 days increased linearly ($p < 0.05$) from 0.88 kg/day to an average of 0.98 kg/day for the 150,000 IU vitamin A injected calves. This 28.2 kg (62.2 lb) increase seen in weaned calves, if worth $140/cwt (USDA AMS 2020 a,b), would yield an additional $87/head for an investment of about $4/calf. Similarly, 24.3 kg (53.5 lb) of this additional body weight was retained through backgrounding which would be worth about $75/head. However, the weight advantage was not retained through slaughter, but marbling score increased linearly ($p < 0.05$), which averaged 583, 671, and 610 ± 20 for 0 IU, 150,000 IU, and 300,000 IU vitamin A injected calves, respectively. In other words, vitamin A injection increased marbling from small to modest. No other carcass characteristics were affected by the amount of injected vitamin A. The Certified Angus Beef premium for modest marbling is $5.10/cwt (AAA 2020), and, with an average carcass weight of 349 kg (768 lb), would yield $39/carcass more for about a $4 investment for the injection. Therefore, there are good economic incentives gained from neonatal vitamin A supplementation, especially for producers who sell cattle at weaning as yearling or fat cattle.

Conclusions

Vitamin A supplementation has both positive and negative impacts on cattle performance and beef quality, which should be considered when making decisions on how to raise and feed beef cattle. Vitamin A in cattle diets should meet NRC requirements to avoid deficiency, but additional vitamin A supplementation is not necessary for backgrounding and finishing cattle. Studies suggest that vitamin A is vitally important for the growth and development of young cattle. Neonatal supplementation using moderate levels of vitamin A has been shown to improve calf growth and increase myogenesis, while being cost effective for cattle producers. Neonatal vitamin A supplementation can therefore be a strategy for improving calf growth, performance, and beef quality as they progress through production phases, without significantly increasing feed inputs later in production.

Further Reading

Rhinehart, J. 2008. Interpreting Carcass Data. Mississippi State University Extension Service. https://extension.msstate.edu/sites/default/files/topic-files/cattle-business-mississippi-articles/cattle-business-mississippi-articles-landing-page/stocker_aug2008.pdf.

References

AAA (American Angus Association). 2020. Yearly Value Indexes.

Arnett, A.M., M.J. Daniel, and M.E. Dikeman. 2008. Restricting Vitamin A in Cattle Diets Improves Beef Carcass Marbling and USDA Quality and Yield Grades. *Kansas Agricultural Experiment Station Research Reports* 1: 24–27. https://doi.org/10.4148/2378-5977.1508.

Church, D.C. 1988. Vitamins in Ruminant Nutrition—Vitamin A. In *The Ruminant Animal: Digestive Physiology and Nutrition*, 313–316. Englewood Cliffs, NJ: Prentice-Hall.

Harris, C.L., B. Wang, J.M. Deavila, J.R. Busboom, M. Maquivar, S.M. Parish, B. McCann, M.L. Nelson, and M. Du. 2018. Vitamin A Administration at Birth Promotes Calf Growth and Intramuscular Fat Development in Angus Beef Cattle. *Journal of Animal Science and Biotechnology* 9(1): 55. https://doi.org/10.1186/s40104-018-0268-7.

Hill, G.M., S.E. Williams, S.N. Williams, L.R. McDowell, N. Wilkinson, and B.G. Mullinix. 1995. Vitamin A and Vitamin E Effects on Performance and Tissue α-Tocopherol Concentrations of Feedlot Steers. *Journal of Animal Science* 73(suppl. 1): 95.

Jin, Q., H. Cheng, F. Wan, Y. Bi, G. Liu, X. Liu, H. Zhao, W. You, Y. Liu, and X. Tan. 2015. Effects of Feeding β-Carotene on Levels of β-Carotene and Vitamin A in Blood and Tissues of Beef Cattle and the Effects on Beef Quality. *Meat Science* 110(December): 293–301. https://doi.org/10.1016/j.meatsci.2015.07.019.

Kawachi, H. 2006. Micronutrients Affecting Adipogenesis in Beef Cattle. *Animal Science Journal* 77(5): 463–71. https://doi.org/10.1111/j.1740-0929.2006.00373.x.

Krone, K., A. Ward, K. Madder, S. Hendrick, J. McKinnon, and F. Buchanan. 2016. Interaction of Vitamin A Supplementation Level with *ADH1C* Genotype on Intramuscular Fat in Beef Steers. *Animal* 10(3): 403–409. doi: 10.1017/S1751731115002153.

McDowell, L.R. 2000. Vitamin A. In *Vitamins in Animal Nutrition: Comparative Aspects to Human Nutrition*, 2nd edition, 10–54. Iowa State University Press.

NRC (National Research Council). 2016. Vitamin A. Nutrient Requirements of Beef Cattle, 8th Edition, 140–142. National Academies of Sciences, Engineering, and Medicine. Washington, DC: The National Academies Press. doi: 10.17226/19014.

Pickworth, C.L., S.C. Loerch, and F.L. Fluarty. 2012. Effects of Timing and Duration of Dietary Vitamin A Reduction on Carcass Quality of Finishing Beef Cattle. *Journal of Animal Science* 90: 2677–2699. doi: 10.2527/jas.2011-4756.

Siebert, B.D., Z.A. Kruk, J. Davis, W.S. Pitchford, G.S. Harper, and C.D.K. Bottema. 2006. Effect of Low Vitamin A Status on Fat Deposition and Fatty Acid Desaturation in Beef Cattle. *Lipids* 41(4): 365–70. https://doi.org/10.1007/s11745-006-5107-5.

Spears, J. 2000. Micronutrients and Immune Function in Cattle. *Proceedings of the Nutrition Society* 59(4): 587–594. doi: 10.1017/S0029665100000835.

USDA AMS (Agricultural Marketing Service). 2020a. Daily Value Indexes. Livestock, Poultry, and Grain Market News.

USDA AMS (Agricultural Marketing Service). 2020b. Daily Value Indexes. Livestock, Poultry, and Grain Market News.

Wang, B., Nie, W., Fu, X., DeAvila, J. M., Ma, Y., Zhu, M., Maquivar, M., et al. 2018. Neonatal Vitamin A Injection Promotes Cattle Muscle Growth and Increases Oxidative Muscle Fibers. *Journal of Animal Science and Biotechnology* 9(1): 82. https://doi.org/10.1186/s40104-018-0296-3.

Zinn, R.A., E. Alvarez, and R.L. Stuart. 1996. Interaction of Supplemental Vitamin A and E on Health and Performance of Crossbred and Holstein Calves during the Receiving Period. *The Professional Animal Scientists* 1: 17–23.

By
Ashley Norberg, Graduate Student, Department of Animal Sciences, Washington State University
Mark Nelson, Professor Emeritus, Department of Animal Sciences, Washington State University
Don Llewellyn, Associate Professor/Livestock Extension Specialist, Washington State University Extension

WSU PEER REVIEWED

FS381E

WASHINGTON STATE UNIVERSITY
EXTENSION

Copyright © Washington State University

WSU Extension publications contain material written and produced for public distribution. Alternate formats of our educational materials are available upon request for persons with disabilities. Please contact Washington State University Extension for more information.

Issued by Washington State University Extension and the US Department of Agriculture in furtherance of the Acts of May 8 and June 30, 1914. Extension programs and policies are consistent with federal and state laws and regulations on nondiscrimination regarding race, sex, religion, age, color, creed, and national or ethnic origin; physical, mental, or sensory disability; marital status or sexual orientation; and status as a Vietnam-era or disabled veteran. Evidence of noncompliance may be reported through your local WSU Extension office. Trade names have been used to simplify information; no endorsement is intended. Published July 2023.