How Much Supplemental Vitamins do Cows Really Need?

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Summary

Because of major production problems, vitamin A and to a lesser extent vitamin E are in very limited supply and prices have increased markedly. Because of price and scarcity, many nutritionists are re-evaluating vitamin supplementation strategies. Based on current information, the NRC (2001) requirements for vitamin A (approximately 75,000 IU/day for all cows) and vitamin E (500 IU/day for lactating cows and 1000 IU/day for dry cows) are adequate. However, feeding an additional 1000 IU of vitamin E per day during the prefresh period (2 or 3 weeks prepartum) can improve cow health post partum. More data are needed but limited information suggest that for lactating cows, supplementation rates for vitamin D should be increased to about 1.5 X NRC (about 30,000 IU/day). Because vitamin A is in very limited supply, supplementation may need to be prioritized. Because of low expected intakes of basal β-carotene and the high requirement of vitamin A for colostrum synthesis, prefresh cows should be fed at NRC rates at the expense of other cows. Next highest priority is far-off dry cows, followed by lactating cows. Some supplemental vitamin A should be provided to all types of cows if possible; however, if necessary, the liver can supply adequate vitamin for several weeks, and perhaps up to a few months, without adversely affecting lactating cow health or productivity.

Introduction

Historically, most nutritionists have given little consideration to the cost of vitamins A, D, and E. Cows needed them and even at high supplementation rates, cost per cow per day was reasonable. However because of a fire at a chemical factory in late 2017, worldwide production of feed grade vitamin A has been reduced by more than 40%. Production of vitamin E has also been reduced because an intermediate that was produced at the factory with the fire cannot be produced right now. Because of other productions issues, vitamin D supply is also tighter than normal. These production problems have led to major increases in vitamin prices. Compared to historic norms, vitamin A price at wholesale level has increased about 10 times (local and spot markets may differ markedly), vitamin E price has increased 3 to 4 times, and vitamin D price has increased less than 2X. Approximate cost of supplementing vitamins A, D, and E at NRC recommended levels would cost about 10 to 12 cents per day (there will be a very wide range on this value because of margins and local markets). Using historically typical prices, it costs 3 or 4 cents per day to provide supplemental vitamins A, D, and E. Although this is a very substantial increase in cost, it is still a very small portion of the total feed bill (about 3% of total feed costs). A bigger problem than increased cost is limited supply. In some markets, vitamin A simply is

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not available at any price or supplies are being rationed. This paper will review current research and recommendations regarding vitamins A, D, and E and strategies to use when supplies are inadequate.

Vitamin A

The common form of supplemental vitamin A is all-trans retinyl palmitate with some retinyl acetate also being used. Based on current standards, 1000 IU of vitamin A is equal to 0.55 mg of retinyl palmitate or 0.35 mg of retinyl acetate. Based on a survey of nutritionists we conducted about 20 years ago (Weiss, 1998), average supplementation rates ranged from 100,000 to 150,000 IU/day depending on the type of cow. On a mass basis, that is only about 80 mg/day of supplemental vitamin. The current NRC recommendation for supplemental vitamin A (all NRC 2001 vitamin recommendations are for supplemental, not total vitamins) is 50 IU/lb of body weight (**BW**) or about 75,000 IU/day for an average Holstein cow (Table 1). That recommendation is for all classes of dairy cattle. Although vitamin A is not an active area of research, there is little data indicating that the NRC (2001) recommendation is inadequate for lactating cows fed a typical diet. A recent study evaluated feeding 2X NRC (95 IU/lb BW) and reported some small increases in various measures of immune function, but no effects on production and clinical responses (e.g., mastitis) were measured (Jin et al., 2014).

The NRC recommendation is based on several assumptions:

1. The diet is approximately 60% forage,
2. The cow is consuming little or no fresh forage,
3. Milk yield is approximately 75 lb/day, and
4. Basal diet provides typical amounts of β-carotene.

The conditions stated above either effect vitamin A supply or vitamin A requirements. Based on in vitro rumen studies (Rode et al., 1990; Weiss et al., 1995), a substantial amount of vitamin A is destroyed in the rumen and destruction rate increases with the amount of concentrate in the diet (in those studies the concentrate was predominantly starch-based). In vitro ruminal destruction of vitamin A was 20 to 25% when the substrate was 90 to 100% forage and 70 to 75% was destroyed with diets containing 50 or 30% forage, respectively. In studies evaluating responses to vitamin A, diets were around 60% forage; ruminal destruction was assumed to be about 50% via extrapolation. Therefore, a diet with 50% forage may need about 17% more vitamin A (~84,000 IU/day) than recommended by NRC (2001); however, a cow fed an 80% forage diet may need only 0.65 X NRC requirements (~47,000 IU/day).

Higher forage diets are also typically higher in β-carotene which can be converted into vitamin A by the cow. Once a forage plant is cut, β-carotene starts being oxidized (destroyed). Losses during silage making can be greater than 50%, and for hay, losses can exceed 80% as compared to fresh forage (Noziere et al., 2006). Corn silage is a poor source of β-carotene and usually has about 50% of the concentration found in haycrop silages. However since most of the experiments evaluating responses to vitamin A consited of corn silage, this effect is already incorporated into requirements. Most concentrates are poor sources of β-carotene. Straw, a common ingredient for dry cows, has virtually no β-carotene. The take home from this is:

- Cows that are grazing fresh, green forage with pasture providing at least 40% of diet DM probably need very little, if any, supplemental vitamin A because pasture is probably providing 70,000 to 100,000 more

IU/day of vitamin A equivalents than a cow consuming silage.

- Hay-based diets will need more supplemental vitamin A than silage based diets. If you change from a diet in which the forage was 50% hay and 50% silage (similar to many of the studies) to a diet with all the forage as hay, intake of basal vitamin A equivalents would be reduced by 15,000 IU/day. Most diets in the Midwest do not have that much hay so the adjustment will be smaller.

- Straw-based dry cow diets will require more supplemental vitamin A than hay or silage based diets. Replacing 8 lb of haycrop silage DM with straw will reduce intake of basal vitamin A equivalents by about 45,000 IU/day. You probably do not need to increase supplementation that much because efficiency of conversion of β-carotene to vitamin A is likely lower than anticipated, but a substantial increase in supplementation is likely necessary with straw based diets

Milk contains about 7 mg of retinol/kg of fat or about 0.11 mg/lb of milk (assumed 3.7% fat). The average milk yield by cows in studies evaluating responses to vitamin A was about 75 lbs/day. Therefore, the current NRC recommendation should be adequate for cows producing 75 lb of milk. For every additional pound of milk above 75 lb, vitamin A supplementation should be increased by about 450 IU to cover losses in milk (for a Jersey cow it would be about 580 IU/lb of milk). In a pen situation, if the average cow is milking 75 lb and needs 75,000 IU of vitamin A, the diet needs to contain about 1400 IU/lb of DM. If a cow was milking 100 lb, she would need an additional 11,000 IU of vitamin A to cover milk losses but because she would be expected to eat about 10 lb more DM, her intake of A would be adequate. In other words, the concentration of vitamin A (IU/lb of DM) does not have to be increased for high producing cows).

Substantial amounts of feed grade vitamin A (retinyl palmitate) can be destroyed during storage and this potential loss should be considered when developing formulating strategies. If vitamin A is blended in a premix with inorganic zinc and copper, vitamin A activity decreased by about 9% per month (compared to about 3% for other vitamins) (Shurson et al., 2011). Pelleting and excess heat, humidity and sun exposure during storage will greatly increase losses in activity. If feed mixes are stored for long periods of time, especially if it contains inorganic trace metal or is stored under poor conditions, supplementation should be increased to cover losses in activity.

How Low Can You Go

Cows are efficient storers of retinol when fed in excess or when large amounts are injected. Excess retinol is stored in the liver and liver retinol concentrations are a good indicator of status. It changes rapidly (days to weeks) in response to changes in supply. Hepatic retinol concentrations less than 30 mg/kg (dry basis; all liver concentrations in this paper are on a mg/kg dry weight basis) is considered indicative of a vitamin A deficiency and values less than about 100 mg/kg are considered suboptimal. Beef cattle fed a high concentrate diet (so ruminal destruction of vitamin A was likely high) and approximately 40 or 80 IU of vitamin A/lb of BW for 140 days (Figure 1) had liver concentrations ranging from about 500 mg/kg dry weight to more than 800 mg/kg (Bryant et al., 2010). It is very likely that dairy cows fed ~100,000 IU/day of vitamin A probably have liver concentrations in excess of 400 mg/kg. Liver retinol concentrations in beef heifers and steers fed no supplemental vitamin A and a basal diet void of β-carotene diet (Figure 2) dropped from about 474 mg/kg (dry basis) to 210 mg/kg over 84 days (Alosilla et al., 2007). If fed the same diet, depletion will occur more rapidly in a dairy cow than a beef animal because of secretion of retinol in milk; however, typical dairy cow diets contain more β-carotene than feedlot diets. Liver depletions rates have not been determined in lactating cows fed typical diets, but based on beef data, liver retinol will remain in the adequate range for several weeks to a few months when all supplemental vitamin A is removed from the diet. I am not advocating removing all supplemental vitamin A from lactating cow diets; however, feeding no supplemental vitamin A for a month or so likely will have no negative impacts.

Dry cows and Prefresh Cows

The 2001 NRC has the same supplemental vitamin A requirements for all dairy cattle (50 IU/lb BW) and data generally support that. However, with the widespread application of straw-based dry cows diets (i.e., low β-carotene diets), increased supplemental vitamin A may be warranted (discussed above). Independent of basal diet, the prefresh cow may need increased vitamin A supplementation. As with vitamin E, plasma concentrations of retinol and β-carotene drop markedly starting about 2 weeks prepartum, even when cows are fed diets adequate in supplemental vitamin A (Goff and Stabel, 1990; Weiss et al., 1994). What is unusual is that plasma retinol concentration is a very poor indicator of vitamin A status or vitamin A intake. When fed deficient diets, animals mobilize retinol from the liver and plasma levels are maintained until liver concentration drops below about 30 mg/kg (clinical deficient state). But in the prepartum dairy cow, plasma concentrations decrease even though the liver likely has more than adequate stores. The decrease in plasma retinol is caused entirely by secretion of retinol into colostrum starting about 7 days before calving because mastectomized cows experienced no decrease in serum retinol at calving (Goff et al., 2002). It is not known whether additional vitamin A during the prefresh period will prevent the decrease in plasma vitamin A or whether the decrease is even a problem. However, when supplemental vitamin E is added and the decrease in plasma tocopherol is prevented, improved mammary gland health is observed.

Prioritizing When Vitamin A Supplies are Limited

If vitamin A supplies are limited or price is a major factor, the first step is to feed supplemental vitamin A at NRC recommendations. Based on survey data, this will reduce supplementation by about 50% on average. If additional cuts are needed, the dry cow and prefresh cow should be fed at NRC levels if possible. They have low intakes of basal β-carotene, several studies have shown increased retained placenta and mastitis when dry cows are not fed adequate vitamin A, and the newborn calf will need retinol-rich colostrum since calves are born with almost no circulating retinol. The last priority is lactating cows. Intakes are very high and the basal diet generally has substantial β-carotene (all hay diets are an exception). In addition, most cows are probably in excellent vitamin A status (large liver stores of retinol), and it is acceptable for the cow to mobilize that as long as liver concentrations of retinol stay above 30 mg/kg and ideally above about 100 mg/kg.

Vitamin E

The standard form of supplemental vitamin E used in the feed industry is all-rac α-tocopheryl acetate. By definition, 1 IU of vitamin E equals 1 mg of all-rac α-tocopheryl acetate. Based largely on reduction in incidence of mastitis and retained placenta, the 2001 NRC set the supplemental vitamin E requirement at 0.36 IU/lb BW for lactating cows and 0.73 IU/lb BW for dry cows. This equates to about 500 IU/day for lactating cows and 1000 IU/day for dry cows (Table 1). Basal diets can provide substantial amounts of tocopherol, but the same factors that affect β-carotene concentrations (discussed above) affect tocopherol concentrations. Diets used in the studies evaluating supplemental vitamin E were largely hay-based for dry cows and silage based for lactating cows. The only major adjustment to vitamin E supplementation needed because of basal diet is for grazing cows. Fresh pasture can have 2 to 10 times more tocopherol than silage or hay (respectively), and plasma concentration of tocopherol in grazing cattle (with no vitamin E supplementation) is usually much higher than what we observe in confinement cattle fed supplemental vitamin E per NRC. If the diet is composed of 50% or more of pasture DM, no supplemental vitamin E is needed. Based on average tocopherol concentrations in fresh pasture and corn silage and alfalfa silage and assuming pasture replaces silages, a diet with about 30% fresh pasture (DM basis) will need about 50% of NRC supplementation. Another type of basal diet that needs to be considered with respect to vitamin E supplementation is straw-based dry cow diets. Straw is essentially void of tocopherol, but it often replaces hay which is low in tocopherol. If 8 lb of straw replaced 8 lb of hay, basal intake of tocopherol likely did not decrease very much. However, if the straw replaced hay silage, intake of basal tocopherol could decrease by 100 to 150 IU/day.

Current data support the 2001 NRC requirement for dry and lactating cows. One study suggested that excess vitamin E during the dry period (3X NRC) may actually be detrimental to cow health (Bouwstra et al., 2010). Since 2001, several studies have evaluated the effect of additional vitamin E during the prefresh period, and in general, positive response on immune function or clinical measures have been reported (Politis et al., 2001; Politis et al., 2004; Chandra et al., 2014). Supplementation rates during the last 2 to 3 weeks of gestation ranged from 2000 to 4000 IU/day. Because of cost, providing prefresh cows (not grazing) with about 2000 IU/day will likely improve immune function and cow health.

Vitamin E supplies have been reduced and prices have increased 3 to 4 times over historic prices, but true shortages have not been reported. Considering the benefits of adequate vitamin E relative to its cost, NRC supplementation rates should be maintained, and if a prefresh diet is fed, consider increasing vitamin E to 2000 IU/day.

Vitamin D

The primary form of supplemental vitamin D fed to livestock is vitamin D3. Vitamin D2 may be available, but it is vastly inferior to D3 and probably should not be fed. If it is used, supplementation rates should be about double those for vitamin D3. For this paper, recommendations are appropriate for vitamin D3. Cows and other animals can synthesize vitamin D when the skin obtains adequate UV irradiation from the sun. The amount of vitamin D synthesized depends on intensity of the sunlight which depends on season (summer >> winter) and time of day (noon > morning or evening), cloud cover, and duration of exposure. Cows exposed to 90 minutes of intense sun (centered around noon) maintained serum concentrations of 25-OH vitamin D in the adequate range (Hymoller and Jensen, 2012). Based on human synthesis rates, cows in winter in the tristate area cannot synthesize adequate vitamin D, regardless of how long they are outside, and during spring and fall may need more than 5 hours of sun exposure to synthesize adequate vitamin D.

After decades of almost no research on vitamin D for dairy cows, it is starting to receive substantial interest. This is probably caused by the data showing relationships between low vitamin D status and increased risk for numerous diseases in humans. Previously, vitamin D was considered only with respect to calcium metabolism and current requirements (14 IU/lb of BW or about 20,000 IU/day; Table 1) are adequate to maintain normal calcium metabolism. New data suggests a role of vitamin D in immune function and more general health responses (Lippolis, 2011) and supplementation rates may need to be higher to see this responses. Based more on data from human subjects than cattle, blood concentrations of 25-OH vitamin D (an excellent status indicator of vitamin D) below 30 ng/ml are associated with increased health problems. Concentrations of 8 to 10 ng/ml are probably adequate for Ca metabolism. From a survey of commercial and university dairy herds, feeding 30,000 to 50,000 IU/day (1.5 to 2.5 X current NRC recommendation) maintained serum 25-OH vitamin D well above 30 ng/ml. However, one herd was fed 20,000 IU/day (i.e., NRC requirement) and although the blood average was above 30 ng/ml, several individual cows had concentrations less than 30 ng/ml. This suggests that feeding 20,000 IU/day may not be adequate; however, data showing improved clinical or production responses with additional vitamin D supplementation are lacking. Based on the limited data available, supplementation rates of 1.5 X NRC are justified (i.e., about 30,000 IU/day for lactating cows). Because calcium metabolism is so important to transition cows, at this time, feeding at NRC (2001) rate is recommended.

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Table 1. Recommended daily intakes (IU/day) of supplemental vitamins A, D, and E for a Holstein cow (multiply values by 0.75 for Jersey cows).

	Type of Cow			
Vitamin	Far-off Dry	Prefresh	Lactating	Adjustments
A	75,000	75,000	75,000	• Increase when feeding straw-based diets and consider increasing when feeding hay-based diets. • For grazing cattle, these should be reduced substantially (sometimes to 0). • Prefresh cows may benefit from higher intakes because of colostrum synthesis • For lactating cows producing more than 75 lb of milk, increase by 450 IU/day per pound of milk greater than 75 lb
D	20,000	20,000	30,000	• Cows grazing at least 2 hours per day in the summer probably do not need supplemental D. • Increase substantially if using vitamin D2.
E	1,000	2,000	500	• Increase by about 100 IU/day with straw based diets. • Hay based diets may need slightly more vitamin E. • For grazing cows, reduce supplementation substantially (sometimes to 0)

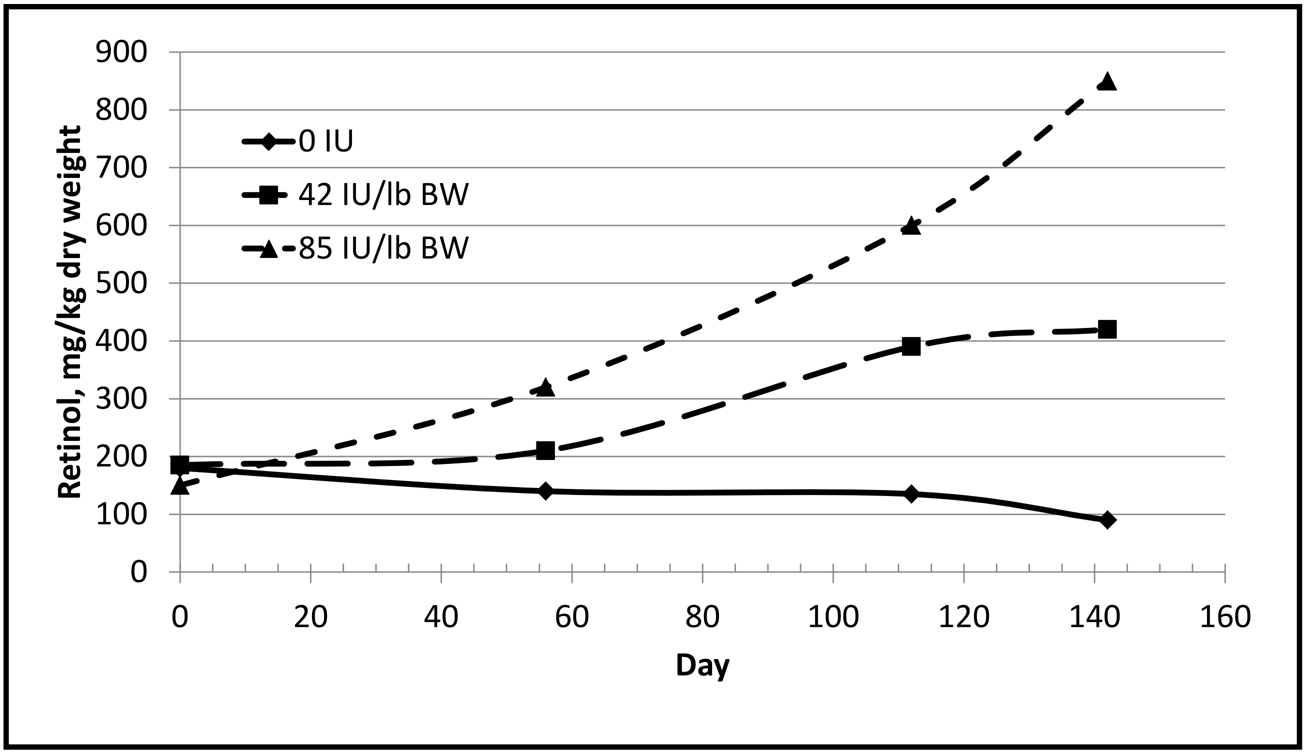

Figure 1. Concentrations of retinol (vitamin A) in liver of beef steers that were fed no supplemental vitamin A or approximately 40 or 80 IU/lb of BW (the NRC requirement for dairy cattle is 50 IU/lb BW). The basal diet likely provided some β-carotene (not measured). The black arrow marks the clinical deficient concentration and the grey arrow indicates marginal deficiency (Bryant et al., 2010).

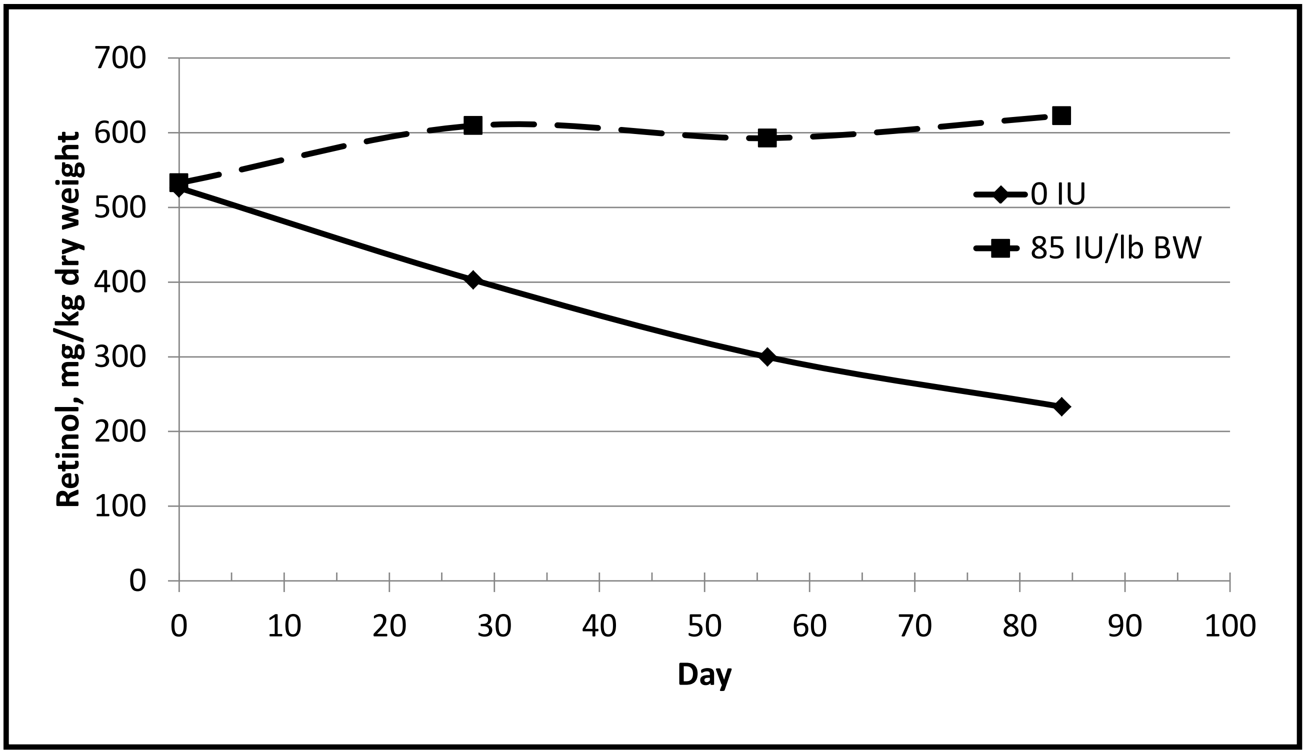

Figure 2. Concentrations of retinol (vitamin A) in liver of growing beef steers and heifers fed no supplemental vitamin A or approximately 85 IU/lb of BW (1.7 X NRC requirement for dairy cows). The basal diet likely provided no β-carotene. The black arrow marks the clinical deficient concentration and the grey arrow indicates marginal deficiency (Alosilla et al., 2007).