The Technical Edge

Natural Versus Synthetic Vitamin E for Dairy Cows

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The risk of mastitis and retained fetal membranes (also known as retained placenta) is higher for dairy cows with low vitamin E status compared to cows receiving an adequate amount of dietary vitamin E. Unfortunately, many common feedstuffs used in dairy diets do not contain sufficient amounts of vitamin E (the major exception is fresh, green pasture) to support optimum immune function. Consequently, feeding supplemental vitamin E is usually recommended and has become a standard industry practice.

Vitamin E and Neutrophil Function

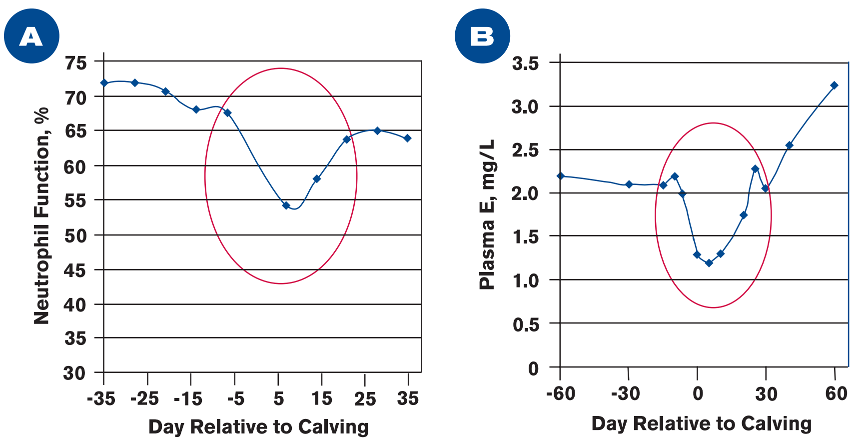
Arguably, the most critical period in terms of dairy cow health is between about two weeks before calving until about two weeks after calving ("the transition period"). Calving can predispose the cow to several orders including retained placenta, milk fever, and ketosis. Also during this crucial period, the dairy cow is at the highest risk of developing mastitis. Vitamin E status has no direct relationship with milk fever and ketosis, but it can have a direct influence on the incidence of retained placenta and mastitis. A link between these two apparently very different health problems is the neutrophil, a type of white blood cell that is part of the immune system. Neutrophils primary function is to kill bacteria that enter the body. Unlike antibodies, neutrophils are non-specific; if the body identifies something as "foreign," neutrophils from the blood are drawn to the infection site and once there, they engulf the invading pathogen and via a complex series of reactions, produce toxic chemicals that kill the pathogen.

The link between neutrophil function and retained placenta is less clear, but research conducted at the USDA animal disease lab found that cows with retained placenta had suppressed neutrophil function. What was most interesting was that the difference in neutrophil function between cows with and without retained placenta was found a few weeks before the cow calved. Numerous studies have shown that vitamin E and other antioxidants are absolutely critical for neutrophils to function properly. When neutrophils are functioning properly, cows are less likely to succumb to mastitis and retained placenta.

Unfortunately during the critical transition period, the immune system, including neutrophils, may become compromised. This phenomenon is called immunosuppression. When neutrophils are not functioning properly, bacterial infections in the mammary gland are more likely to become established resulting in more occurrences of mastitis.

The National Research Council (NRC) recommends that non-grazing dairy cows be fed 1000 international units (IU) of supplemental vitamin E daily during the dry period and 500 IU daily during lactation. That recommendation is based largely on studies showing that supplemental vitamin E reduced the prevalence of retained placenta and mastitis. One mode of action for those clinical responses is via the positive effects vitamin E has on neutrophil function. Indeed, one, but certainly not the only reason neutrophil function is suppressed around calving is because cows typically have low vitamin E status during this time (see Figure 1).

Figure 1



Change in neutrophil function (Figure 1A) and plasma vitamin E (Figure 1B) in dairy cows during the transition period. Note that both neutrophil function and plasma vitamin E decrease shortly before calving and remain low until several days after calving. Figure 1A from Kehrli (*Proc. Natl. Mastitis Council,* 2002). Figure 1B from Weiss et al. (*J. Dairy Sci.* 1989).

Vitamin E status of cows decrease during the transition period due to reduced dry matter intake which results in reduced intake of vitamin E, transfer of vitamin E to colostrum, and increased utilization of vitamin E because of events associated with parturition. It has been shown that feeding 1000 IU daily of supplemental all-rac-alpha-tocopheryl acetate (most common form of synthetic supplemental vitamin E) to transition cows will not maintain plasma concentrations of vitamin E. Studies from Ohio State and elsewhere has shown that feeding 2000 to 5000 IU (different studies used different supplementation rates) of synthetic vitamin E daily reduced or eliminated the drop in plasma vitamin E and improved mammary gland health in fresh cows compared with those fed 1000 IU daily.

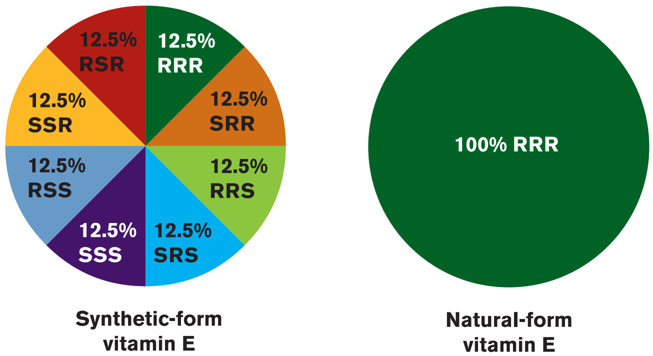
Impact of Vitamin E on Vitamin E Status

In addition to supplementation rate, form of vitamin E can influence vitamin E status. While there are numerous chemical forms of vitamin E, the dairy industry uses two main types of supplemental vitamin E:

- All-rac-alpha-tocopheryl acetate (synthetic form; commonly referred to as dl-alpha-tocopheryl acetate)
- RRR-alpha-tocopheryl acetate (natural form; commonly referred to as d-alpha-tocopheryl acetate)

The chemical form of vitamin E in both synthetic and natural-form vitamin E is alpha-tocopherol (an acetate unit is attached to both forms to increase stability). When tocopherol is chemically synthesized, eight different isomers are produced, each equal to 12.5% of the total (see Figure 2). When a living plant makes vitamin E (natural) only one isomer is produced – the one called RRR (synthetic vitamin E contains 12.5% RRR and 87.5% other isomers – see Figure 2). Decades ago, it was realized that different forms of vitamin E have different potencies with respect to biological function. This led to the development of the international unit (IU) system. In theory, one IU of vitamin E has the same biopotency regardless of the type of vitamin E. Based on studies with rats (incidentally results from those studies were extremely variable), a cow would need to consume one gram of synthetic-form vitamin E or 0.73 grams of natural-form vitamin E to obtain 1000 IU of vitamin E. However, numerous studies have questioned the accuracy of the IU equivalency factors when applied to dairy cows.

Figure 2



Research Comparing Synthetic Versus Natural Vitamin E

A study at Ohio State compared vitamin E status of transition cows fed synthetic versus natural-form vitamin E. Starting about 60 days before calving, all cows were fed a silage and hay-based dry cow diet that provided 1000 IU daily of synthetic-form vitamin E. Two weeks before expected calving, cows were changed to a prefresh diet that did not provide supplemental vitamin E (control), 2500 IU daily of supplemental synthetic-form vitamin E (equal to 2.5 grams), or 2500 IU daily of natural-form vitamin E (equal to 1.8 grams). If the IU system was correct, measures of vitamin E status would be similar between the two groups of supplemented cows and both would be higher than the control. It was observed that supplementing either form of vitamin E enhanced vitamin E status of the cows during the transition period; however, cows fed natural-form vitamin E were in better vitamin E status than cows fed an "equivalent" amount of synthetic-form vitamin E. Concentrations of vitamin E in plasma, colostrum, and milk were higher when cows were fed natural-form vitamin E compared with synthetic-form (see Figure 3 on the next page). Furthermore, the higher concentrations of vitamin E in colostrum increased the concentration of vitamin E in the plasma of calves fed the colostrum and milk.

In addition to measuring concentrations of total vitamin E in plasma and milk, concentrations of specific vitamin E isomers were also measured. This was done in an attempt to develop more accurate equivalency factors. In the Ohio State study, essentially no 2-S type of isomers in plasma and very little in colostrum and milk were found. Of the eight isomers in synthetic-form vitamin E, four (50%) are 2S type and four are 2R type (RRR is a 2R type). Researchers did not expect to find very much 2S in samples from cows fed natural-form vitamin E because those cows were not consuming any 2S. However, about 50% of the vitamin E consumed by cows fed the synthetic form of vitamin E was 2S. The almost complete lack of 2S isomers in plasma samples from those cows means that either cows do not absorb that isomer from the intestine or it is not distributed throughout the body after it is absorbed (if this is the reason, it most likely occurs in the liver). If 50% of the vitamin E in the synthetic form is not absorbed or distributed within the body, then the natural form should be twice as potent as the synthetic form, rather than 1.36 times as potent as estimated using the IU system. Therefore, if one wants to provide cows with the equivalent of 1000 IU daily of synthetic-form vitamin E (i.e., one gram daily) one needs to only feed 0.5 grams of natural-form vitamin E.

Conclusion

Vitamin E is clearly an integral component of immune function and is especially critical during the transition period when cows are more susceptible to retained placenta and mastitis. Cows in transition exhibited better vitamin E status when fed natural-form vitamin E compared to cows consuming synthetic-form vitamin E. The calf also benefits from the dam receiving natural-form vitamin E. Enhancing the vitamin E status of transition cows enables them and their calves to better withstand immunosuppression. Only half as much natural-form vitamin E is needed compared to synthetic-form vitamin E based on an Ohio State potency study.

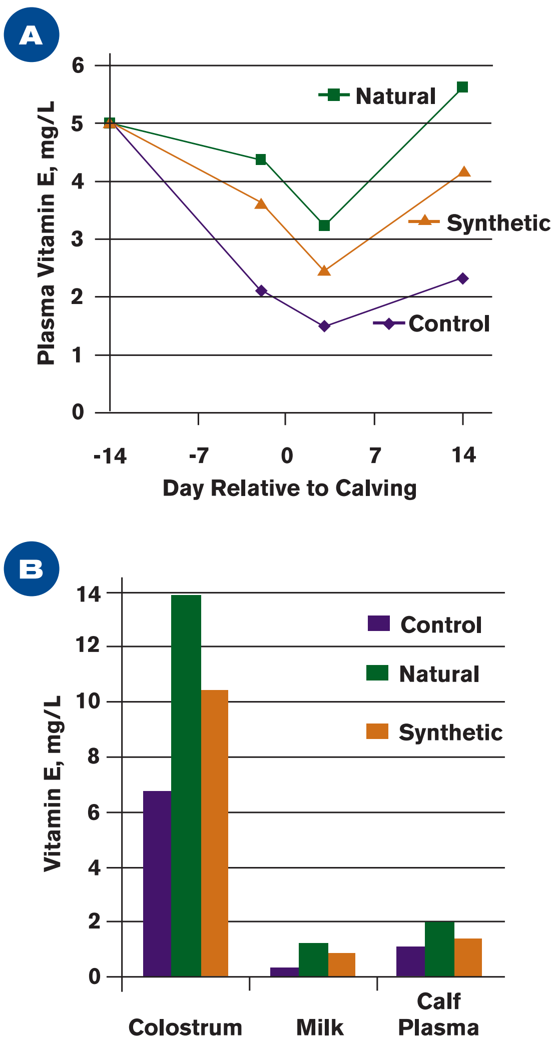
References:

Kehrli, M. E. 2002. Importance of functional mammary gland immunity during periods of stress. *Proc. Natl. Mast. Council.*:11-21.

Weiss, W. P., J. S. Hogan, K. L. Smith, and K. H. Hoblet. 1990. Relationships among selenium, vitamin E, and mammary gland health in commercial dairy herds. *J. Dairy Sci.* 73:381-390.

Weiss, W. P., J. S. Hogan, and D. J. Wyatt. 2009. Relative bioavailability of all-rac and RRR vitamin E based on neutrophil function and total a-tocopherol and isomer concentrations in periparturient dairy cows and their calves. *J. Dairy Sci.* 92:720-731.

Figure 3



Concentrations of vitamin E in plasma (Figure 3A) and milk (Figure 3B) when cows were fed no supplemental vitamin E, or 2500 IU daily of either synthetic-form or natural-form vitamin E. Concentrations were significantly greater when cows were fed natural-form vitamin E even though the intakes of vitamin E (IU/day) were equal for cows fed synthetic or natural vitamin E. Calves were fed only their dam's colostrum and milk for six feedings before plasma was sampled. Data from Weiss et al. (*J. Dairy Sci.* 2009).

The Difference: Natural Versus Synthetic Vitamin E

Most manufactured vitamins produced as synthetics are made with the same molecular configuration as the natural forms. The synthetic molecules look and behave exactly the same as the natural molecules. Therefore, there is no difference in the effectiveness of the vitamins. This is not so for vitamin E. There are differences in the molecular structures of the two forms, which affect how well the vitamin is retained in the body and, in turn, its biological availability.[1]

The Chemical Difference

Natural-source vitamin E is derived from vegetable oils, primarily soybean, canola, and sunflower oils. The vitamin E found in nature is known as d-alpha-tocopherol or more correctly, RRR-alpha-tocopherol. For maximum stability, RRR-alpha-tocopherol is converted to RRR-alpha-tocopheryl acetate for animal diets.

Synthetic vitamin E, commonly referred to as dl-alpha-tocopherol or all-rac-alpha-tocopherol, is a mixture of eight alpha-tocopherol stereoisomers in equal amounts. Only one of these stereoisomers, 12.5% of the total mixture, is RRR- or d-alpha-tocopherol, the natural form. The remaining seven stereoisomers have different molecular configurations due to the chemical randomization in the manufacturing process.

The Biological Difference

Both natural-source vitamin E and synthetic vitamin E are absorbed in the body. However, after absorption, a specific transport protein in the liver known as RRR-alpha-Tocopherol Transport Protein (α-TTP) recognizes the natural d-alpha-tocopheryl acetate and gives it priority over the synthetic forms.[1-2] The unrecognized forms of synthetic vitamin E are preferentially excreted.[3]

Owing to this discriminatory process, d-alpha-tocopherol, the natural form, is retained better and for longer time in the body when compared to the synthetic form. The bioavailability (availability for use by the body) is approximately 2:1 for natural-source vitamin E over synthetic vitamin E.[3-4] To compensate for the lower retention of synthetic vitamin E, a person or animal would have to ingest twice the amount of synthetic vitamin E (by weight) to match the bioavailability of the natural form.

The Advantage

A number of studies have shown significant differences between natural-source and synthetic vitamin E. They have also shown that natural-source vitamin E is more efficiently used by the body than its synthetic counterpart. Simply put, the body has a preference for natural-source vitamin E over synthetic vitamin E.[1]

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1. Human plasma and tissue alpha-tocopherol concentrations in response to supplementation with deuterated natural and synthetic vitamin E. *Am J Clin Nutr* 1998; 67:669-683.
2. Biokinetics of and discrimination between dietary RRR- and SRR-alpha-tocopherols in the male rat. *Lipids* 1987;22:163-172.
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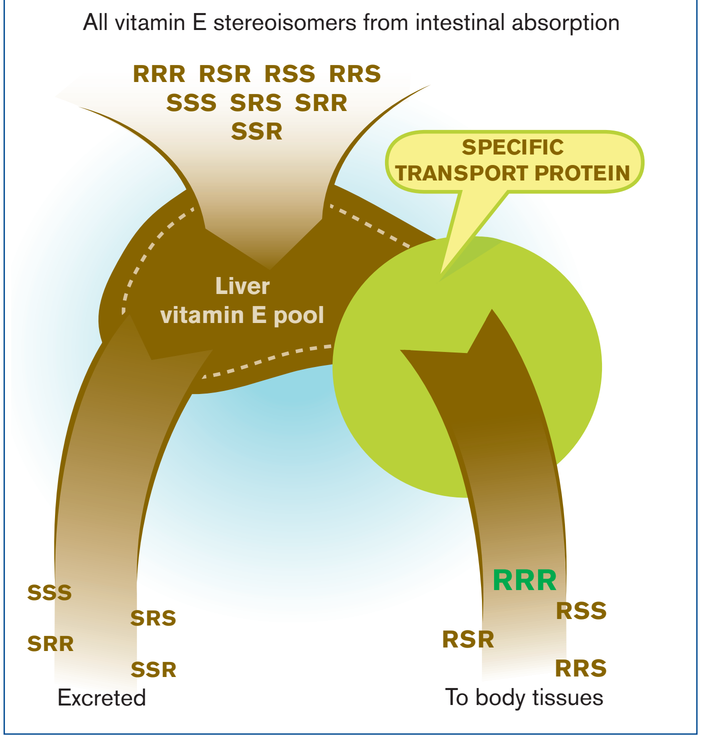
4. Relative biological values of d-alpha-tocopheryl acetate and all-rac-alpha tocopheryl acetate in man. *Am J Clin Nutr* 1980;33:1856-1860.

Natural-Source Vitamin E is Biologically Superior



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