

# The Effects of Supplemental Beta-Carotene for Dairy Cows

D. Hubby

DSM Nutritional Products LLC, Parsippany, NJ

---

## Introduction

Dietary beta-carotene (BC) is recognized as the major precursor of vitamin A with an activity of 400 IU per milligram. The activity of vitamin A is measured in retinol equivalents (1 IU of vitamin A equals 0.3  $\mu\text{g}$  of all-*trans* retinol). The NRC (2001) recommends 110 IU of vitamin A per kg of body weight for mature dairy cows. Signs of vitamin A deficiency include: abortion, retained placenta, reduced immune function, and calf morbidity and mortality (NRC, 2001). Dietary BC is absorbed and stored directly, and can be converted to retinol by intestinal enzymes.

BC can directly function as an antioxidant, which can enhance immunity with possible reproductive and mammary benefits (Chew, 1993). Although the National Research Council (NRC, 2001) concluded that the data was insufficient to establish a BC requirement for dairy cattle, they recommended additional dietary vitamin A with low forage diets, high corn silage diets, diets with low quality forages, high pathogen loads, or reduced immunocompetence.

Because of the wide variation in serum BC status, responses to BC supplementation can be inconsistent (Weiss, 1998). Dietary sources include vegetative plants and concentrations decrease with plant maturity. Most grains and fermented feeds contain minimal levels of BC because of heat damage and breakdown during storage. Although serum BC levels of 3.0  $\mu\text{g}/\text{ml}$  have been suggested as the level in which supplementation is beneficial (Frye et al., 1991), a large proportion of serum samples from the 1996 NAHMS study of U.S. dairy herds (NAHMS, 1996) contained less than 3.0  $\mu\text{g}/\text{ml}$  BC (Herdt and Seymour, 2006). LeBlanc et al. (2004) found mean serum BC concentration of 1828 samples from peripartum ( $\pm$  1 wk) Holstein cows from 20 Canadian herds to be 1.12  $\mu\text{g}/\text{ml}$  (SD=0.78).

## Immunity

Because BC is an antioxidant in addition to being a vitamin A precursor, it may enhance immune response in dairy cattle. Chew et al. (1982) reported low plasma vitamin A and/or BC had higher California Mastitis Test Scores. Chew (1983) supplemented 300 mg BC and 53 K.I.U. vitamin A, or 80 K.I.U. vitamin A, or 53 K.I.U. vitamin A, or no supplemental A or BC from 30 days before calving to 70 DIM. The percentages of cows with a SCC > 500,000 were 13, 27, 54, and 67%, respectively, indicating that BC had a positive effect on immune response. Wang et al. (1988) required fewer clinical mastitis treatments in cows supplemented with 300 mg BC.

Other researchers have not found indications that BC improved immune function. Oldham et al. (1991) did not reduce the incidence of mastitis with supplemental BC. Bindas et al. (1984) found that supplementing 600 mg of BC per day had no effect on SCC. Although LeBlanc et al. (2004) found no relationship between serum BC and retained placenta or mastitis, but found that when serum retinol concentrations increased 100 ng/ml or more during the last week prior to calving, there was a 60% reduction in clinical mastitis in early lactation.

## Production Responses

Supplemental BC has improved milk and butterfat yield in some studies (Arechiga et al, 1998; Oldham et al. 1991; deOndarza et al 2009), but not in all (Bindas et al., 1984, Rakes et al., 1985, Wang et al., 1988). This may be due to observed wide variations in BC status in dairy herds and also stage of lactation, but more research is needed to characterize production responses.

## Reproduction

Dietary BC levels may be linked to fertility as evidenced by higher concentrations of BC in the ovary and corpus luteum (Chew et al., 1984). Benefits of supplemental BC for the dairy cow may be related to the conversion of circulating BC to vitamin A in the uterus and ovaries (Schweigert, 2003). Graves-Hoagland et al. (1988) found plasma BC to be positively related to progesterone production by corpus luteum cells. Cows that ovulated during the first follicular wave postpartum had a higher mean plasma BC concentration than anovulatory cows (2.97 +/- 0.24 µg/ml vs. 1.53 +/- 0.14 µg/ml) three weeks prepartum (Kawashima et al., 2009a). This same research group supplemented BC during the close-up dry period (500 mg/d or 2000 mg/d in two different experiments) and increased the number of ovulating cows at the first follicular wave postpartum (Kawashima et al., 2009b). Pregnancy rate at 120 d postpartum in heat-stressed cows supplemented with 400 mg BC/d for  $\geq 90$  d was increased (35.4% vs. 21.1%)(Arechiga et al., 1998). Rakes et al. (1985) found that supplementing 300 mg of BC for the first 100 DIM reduced days to first estrus ( $P < 0.05$ ). Lotthammer (1978, 1979) found that supplemental BC improved conception rates, uterine involution, and ovulation and reduced incidence of cystic ovaries and early embryonic death.

Inaba et al. (1986) reported that cows with ovarian cysts had significantly lower plasma concentrations of BC (11 +/- 2 µg/dl) than cows without ovarian cysts (33 +/- 4 µg/dl) ( $P < 0.001$ ). In superovulated Japanese Black cattle, plasma BC concentration was related to embryo quality (Goto et al., 1989). Plasma BC concentrations above 200 µg/dl tended to improve numbers of corpus lutea and total recovered embryos and significantly improved the numbers of normal transferable embryos. In a Quebec study, low serum BC was associated with lower conception rates and longer days open (Chorfi, 2010).

In a recent study, deOndarza and others (2009) observed increases in 3.5% FCM and milk fat yield in early lactation and mature cows, improvements in reproduction (21d pregnancy rates) after 110 d, and reduced early embryonic mortality. The test herd used pedometers for heat detection, and heat signs were stronger in the BC pens.

There are reports of improved reproduction with supplemental BC in other species. Schweigert (2001) found that supplemental vitamin A (4000 IU) and BC (100 ppm) increased BC levels in the adrenals and corpus lutea of gilts. Besenfelder et al. (1996) supplemented 40 mg BC to rabbits that were assumed to have sufficient vitamin A status (20,000 IU vitamin A per kg of feed).

## Conclusions

Because of positive responses in colostrum quality, milk production, immunity, and reproduction, current BC supplementation has centered on 300-400 mg BC/hd/d for 100 days, starting during the early dry period or 500-800 mg/hd/d for several weeks around calving. Feeding BC to the lactating herd at 100-200 mg/hd/d can be used to help maintain year round

BC status. Variation in responses may be due to individual or herd BC status, diet sources, wide variation in breeding protocols and objectives, and other factors, and status monitoring is encouraged.

## References

- Arechiga, C.F., C.R. Staples, L.R. McDowell, and P.J. Hansen. 1998. Effects of timed insemination and supplemental  $\beta$ -carotene on reproduction and milk yield of dairy cows under heat stress. *J. Dairy Sci.* 81:390-402.
- Besenfelder, U., L. Solti, J. Seregi, M. Muller, and G. Brem. 1996. Different roles for  $\beta$ -carotene and vitamin A in the reproduction on rabbits. *Theriogenology.* 45:1583-1591.
- Bindas, E.M., F.C. Gwazdauskas, R.J. Aiello, J.H. Herbein, M.L. McGilliard, and C.E. Polan. 1984. Reproductive and metabolic characteristics of dairy cattle supplemented with  $\beta$ -carotene. *J. Dairy Sci.* 67:1249-1255.
- Chew, B.P., L.L. Hollen, J.K. Hillers, and M.L. Herlugson. 1982. Relationship between vitamin A and  $\beta$ -carotene in blood plasma and milk and mastitis in Holsteins. *J. Dairy Sci.* 65:2111-2118.
- Chew, B.P. 1983. Vitamin A and beta carotene influence on bovine mastitis. *Proc 18<sup>th</sup> Pacific Northwest Nutr Conf.* 77.
- Chew, B.P., D.M. Holpuch, and J.V. O'Fallon. 1984. Vitamin A and  $\beta$ -carotene in bovine and porcine plasma, liver, corpora lutea, and follicular fluid. *J. Dairy Sci.* 67:1316-1322.
- Chew, B.P. 1993. Role of carotenoids in the immune response. *J. Dairy Sci.* 76:2804-2811.
- Chorfi, Y., 2010. Personal communication.
- de Ondarza, M.B., J.W. Wilson, and M. Engstrom. 2009. Case Study: Effect of supplemental beta-carotene on yield of milk and milk components and reproduction of dairy cows. *The Professional Animal Scientist.* 25:510-516.
- Frye, T.M., S.N. Williams, and T.W. Graham. 1991. Vitamin deficiencies in cattle. *Vet. Clinic N. America: Food Anim. Prac.* 7:217-275
- Goto, K., O. Kajisa, K. Ezoe, Y. Nakanishi, K. Ogawa, M. Tasaki, H. Ohta, S. Inohae, S. Tateyama, and T. Kawabata. 1989. Relationship between plasma  $\beta$ -carotene concentration and embryo quality in superovulated Japanese black cattle. *Mem. Fac. Agr. Kagoshima Univ.* 25:113-117.
- Graves-Hoagland, R.L., T.A. Hoagland, and C.O. Woody. 1988. Effect of  $\beta$ -carotene and vitamin A on progesterone production by bovine luteal cells. *J. Dairy Sci.* 71:1058-1062.
- Herdt, T.H. and W. Seymour, 2006. Serum beta-carotene concentrations and variability factors in US dairy herds. *DSM Technical Report.* 10318/0706.
- Inaba, T., M. Mezan, R. Shimizu, Y. Nakano, and J. Mori. 1986. Plasma concentration of  $\beta$ -carotene and vitamin A in cows with ovarian cysts. *Jpn. J. Vet. Sci.* 48:1275-1278.
- Kawashima, C., K. Kida, F.J. Schweigert, and A. Miyamoto. 2009a. Relationship between plasma  $\beta$ -carotene concentrations during the peripartum period and ovulation in the first follicular wave postpartum in dairy cows. *Animal Repro. Sci.* 111:105-111.

- Kawashima, C., S. Nagashima, Y. Fujihara, F.J. Schweigert, K. Sawada, A. Miyamoto, and K. Kida. 2009b. Effect of  $\beta$ -carotene supply during the close-up dry period on ovulation at the first follicular wave postpartum in dairy cows. *J. Dairy Sci.* 92 E-Suppl 1.: 106.
- LeBlanc, S.J., T.H. Herdt, W.M. Seymour, T.F. Duffield, and K.E. Leslie. 2004. Peripartum serum vitamin E, retinal, and beta-carotene in dairy cattle and their associations with disease. *J. Dairy Sci.* 87:609-619.
- Lotthammer, K.H. 1978. Importance and role of beta-carotene for bovine fertility. *Roche Symp.* London. pp. 5-44.
- Lotthammer, K.H. 1979. Importance of beta-carotene for the fertility of dairy cattle. *Feedstuffs.* 51(43):16
- National Animal Health Monitoring System (NAHMS). 1996. Part III Reference of 1996 Dairy Health and Health Management. USDA, Animal and Plant Health Inspection Service.
- NRC. 2001. Nutrient Requirements of Dairy Cattle. 7<sup>th</sup> rev. ed. Natl. Acad. Press, Washington, DC.
- Oldham, E.R., R.J. Eberhart, and L.D. Muller. 1991. Effects of supplemental vitamin A or  $\beta$ -carotene during the dry period and early lactation on udder health. *J. Dairy Sci.* 74:3775-3781.
- Rakes, A.H., M.P. Owens, J.H. Britt, and L.W. Whitlow. 1985. Effects of adding beta-carotene to rations of lactating cows consuming different forages. *J. Dairy Sci.* 68:1732-1737.
- Schweigert, F.J. 2003. Changes in the concentration of  $\beta$ -carotene, alpha-tocopherol and retinal in the bovine corpus luteum during the ovarian cycle. *Archives of Animal Nutrition* 57:307-310.
- Schweigert, F.J., I. Buchholz, A. Schuhmacher, and J. Gropp. 2001. Effect of dietary  $\beta$ -carotene on the accumulation of  $\beta$ -carotene and vitamin A in plasma and tissues of gilts. *Reprod. Nutr. Dev.* 41:47-55.
- Schweigert, F.J., F. Engalbert, R. Mothes, A. Hurtienne, and I. Immig. 2007. Cooperative European study for the validation of a novel cow-side  $\beta$ -carotene assay in serum and blood. In: Program of 13<sup>th</sup> International Conference on Production Disease in Farm Animals, Leipzig, Germany (abstract 162).
- Schweigert, F.J. and I. Immig. 2007. Rapid assessment of  $\beta$ -carotene status. *International Dairy Topics.* Vol. 6, No. 4.
- Wang, J.Y., F.G. Owen, and L.L. Larson. 1988. Effect of beta-carotene supplementation on reproductive performance of lactating Holstein cows. *J. Dairy Sci.* 71:181-186.
- Weiss, W.P. 1998. Requirements of fat-soluble vitamins for dairy cows: A review. *J. Dairy Sci.* 81:2493-2501.