Improving breeding by vitamin nutrition

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Throughout the Asian region, dairy production systems are intensifying with the use of cattle of improved genetic merit coupled with high levels of concentrate feeding to achieve production goals. However, with few exceptions the primary factor limiting cow performance in the region is the lack of quality forages.

After calving the feed intake capacity of the cow is physiologically restricted concurrent with limitations imposed on the extent to which fermentable energy sources can be safely included in the diet.

During transition and early lactation (which of course coincides with the rebreeding period) nutritional management strategies which markedly affect breeding and fertility are designed to reduce the risk of metabolic disorders associated with the stress of high milk production.

Biotin and hoof health

Throughout Asia the combination of high concentrate intakes by dairy cows coupled with concrete floors and management systems which restrict animal movements results in widespread problems with hoof disorders. The calving to conception interval as well as the number of inseminations per conception are increased in lame cows. Recently, Sogstad et al, (2006) observed that sole haemorrhages in first lactation cows were associated with a significantly longer inter calving interval and white line fissures in older cows were also associated with an increased return rate following insemination.

In general, lame cows lose more body weight and spend less time eating than non lame cows and Melendez et al, (2002) found that subclinical laminitis was associated with poorer conception rates, more ovarian cysts and poorer pregnancy rates. These authors also pointed out that the expression of oestrus was more difficult if cows had sore feet.

A recent review of the nutritional influences on functional claw integrity in dairy cows highlighted the role of the water soluble vitamin biotin. Biotin is important for the differentiation of epidermal cells that are required for normal production of keratin and hoof horn tissue. In this regard, biotin supplementation has been used successfully for many years to improve claw and hoof health in pigs and horses.

Higuchi and Nagahata (2001) demonstrated a highly significant relationship between increasing blood biotin concentrations and decreased moisture content of sole horn tissue.

Cows which exhibited clinical laminitis had significantly lower blood biotin concentrations.

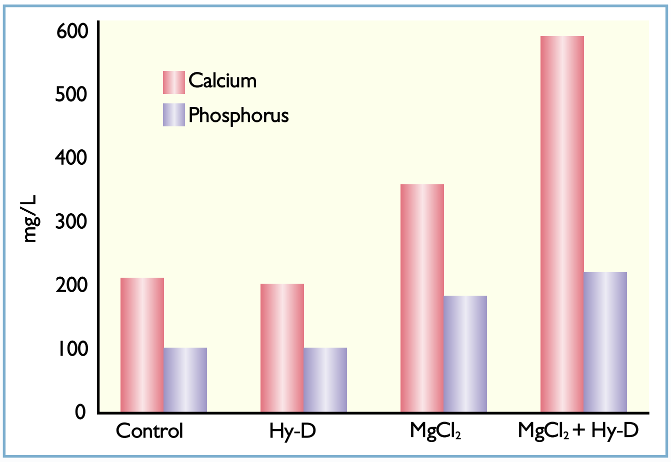

Fig. 2. The influence of supplements on the calcium and phosphorus concentrations in urine after 10 days.

Significant beneficial effects of biotin supplementation have now been reported for interdigital dermatitis, sole bruising, ulcers, interdigital dermatitis, sole haemorrhage and vertical fissures and coronary band lesions in beef cows.

However, the strongest evidence for the influence of biotin on hoof integrity in cattle comes from studies of white line disease. Midla et al, (1998) in the USA showed that supplementation with 20mg biotin/day from calving produced a significant improvement in the prevalence of white line lesions at 100 days into lactation.

In a more extensive trial involving over 1,000 cow lactations in five commercial UK dairy herds, supplementation with 20mg/day biotin significantly halved the risk of clinical lameness caused by white line lesions.

There were no differences between the biotin supplemented and control groups until after 130 days of supplementation, due to the time that it takes for the entire white line to be replaced with improved horn material. In addition, only 17.5% of biotin supplemented animals required a repeat treatment in the same digit, compared with 30% of unsupplemented controls and this may further indicate increased speed of lesion healing.

The interaction of wet conditions and biotin supplementation on the incidence of hoof disorders was clearly demonstrated by the large field trial of Fitzgerald et al, (2000).

In this double-blind study involving over 2,700 cows, the influence of 20mg/day supplementary biotin was investigated over a 13 month period.

Ten herds were supplemented with biotin, the other 10 herds being kept as controls. The biotin supplemented herds exhibited better locomotion scores than the unsupplemented herds.

In the wet summer period of

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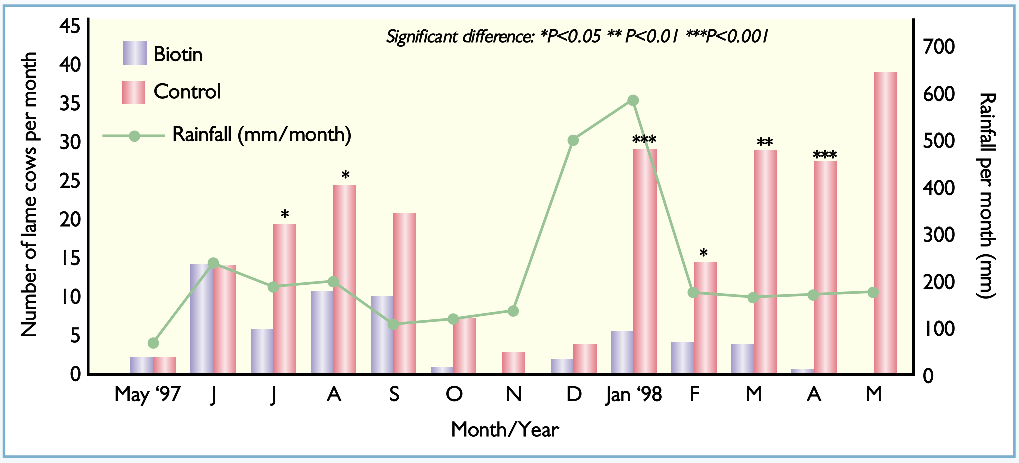
Fig. 1. Reported monthly incidence of lameness in cattle with or without biotin supplementation.



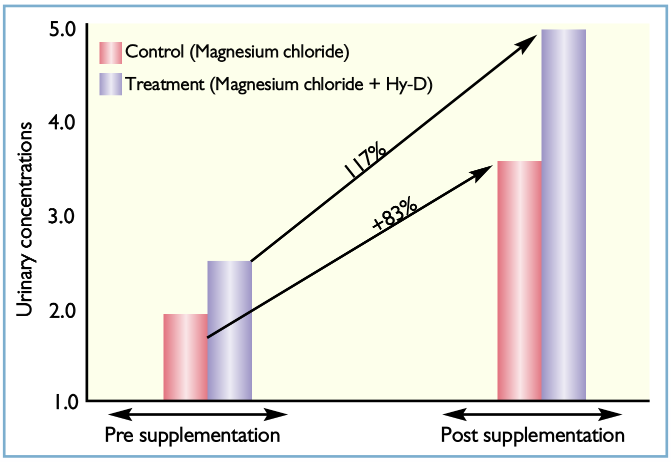


Fig. 3. Calcium concentrations in urine immediately prior to calving.

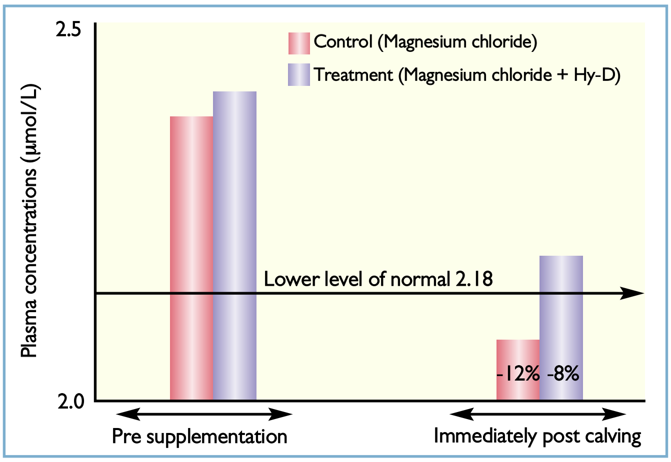


Fig. 4. Blood calcium concentrations in cows at enrolment and after calving.

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tropical Australia, the number of lame cows were significantly fewer for the biotin supplemented herds.

Vitamin D metabolites

After calving and before the next pregnancy is likely to be successfully established, the uterus has to return to its non pregnant size (involution). The endometrium also has to be regenerated and bacterial contamination from the uterus eliminated, not withstanding the need to regain ovarian cyclic activity.

Adequate plasma levels of calcium are required for both muscle fibre activity and general immunity which, in turn, are responsive to vitamin D metabolism.

On average 5-10% of dairy cows succumb to milk fever, although the incidence rate in individual herds can be as high as 30%. Even at low rates of clinical milk fever there exists a huge potential for subclinical hypocalcaemia.

After calving both clinical and subclinical hypocalcaemia reduce the ability of the cow to effect smooth and skeletal muscle contraction. In older cows this can also lead to dystocia and uterine prolapse.

Meldendez et al, (2004) reported that low plasma calcium concentrations were associated with increased incidence of retained foetal membranes. It now appears that retention of foetal membranes is indicative of a poor immunological status in the cow at calving and, therefore, there is also a strong link between low blood calcium at calving and the cow's susceptibility to endometritis.

Whiteford and Sheldon (2005) observed a significantly higher incidence of endometritis in cows which also suffered from hypocalcaemia in comparison to normal cows.

In a recent study from New Zealand, McDougall (2007) evaluated over 2,500 cows for endometritis after calving. Approximately 20% of cows examined had severe infection but were not treated and were then entered into a normal breeding programme.

Some 30% of the cows which were heavily infected failed to conceive compared to only 7% of 'clean' cows.

Of those animals which did eventually fall pregnant in this heavily infected group, the time taken to conception was 45 days from the start of the breeding programme compared to only 20 days for the group of 'clean' cows.

Similarly, an American study revealed that the mean calving to conception interval was greater (151 vs 119 days) in animals which presented with endometritis.

Uterine disorders such as retained placenta and infections are also risk factors for the development of abnormal hormone (progesterone) profiles which are a reflection of delayed ovulation and cystic ovary disease.

Kamgarpour et al, (1999) previously reported that cows with subclinical hypocalcaemia have fewer ovulatory size follicles on day 15, 30 and 45 post partum as well as significantly lower plasma progesterone concentrations.

	β-carotene concentration (ug/dl)		
	<50	50-100	100<
Head	39	43	36
No. collected ova	8.5 ± 8.0	11.3 ± 9.7	14.6 ± 10.3
No. normal ova	3.6 ± 5.0	6.1 ± 6.6	7.2 ± 7.0
Vitamin A (IU/dl)	76.6 ± 21.7	73.3 ± 16.1	84.6 ± 17.1
Vitamin E (µg/dl)	65.8 ± 10.8	71.6 ± 30.1	64.3 ± 10.0
β-carotene (µg/dl)	30.6 ± 6.4	72.3 ± 14.6	171.0 ± 64.6

Table 1. Plasma vitamin concentrations and results of ovum collection.

Reduced plasma calcium concentrations also have a dramatic impact on gastro intestinal motility, affecting the frequency and amplitude of movements in the rumen and abomasum. After calving it is important to maintain as high a feed intake as possible.

As stated previously a negative energy balance after calving could lead to an increasing incidence of ketosis resulting in a reduction in successful rebreeding.

The use of vitamin D and its metabolites in calcium homeostasis and their use in preventing hypocalcaemia has been reviewed by Horst et al (2003).These authors concluded that while the metabolites encourage greater calcium absorption in normal animals it is also important to increase bone resorption in anticipation of calving.

This combination of factors unfortunately does not take place in normal animals. It has been suggested that combination of vitamin D metabolites in conjunction with dietary manipulation precalving could be more effective.

The dietary manipulation was intended to reduce the dietary cation/anion difference (DCAD) by the use of chlorides and sulphates pre calving. In this regard we have recently conducted a series of large scale experiments into the use of 25 OH vitamin D (Rovimix Hy-D) in conjunction with the use of anionic salt, magnesium chloride.

Experimental evidence

● Experiment 1. (Elliott et al, 2006). A study was conducted into the

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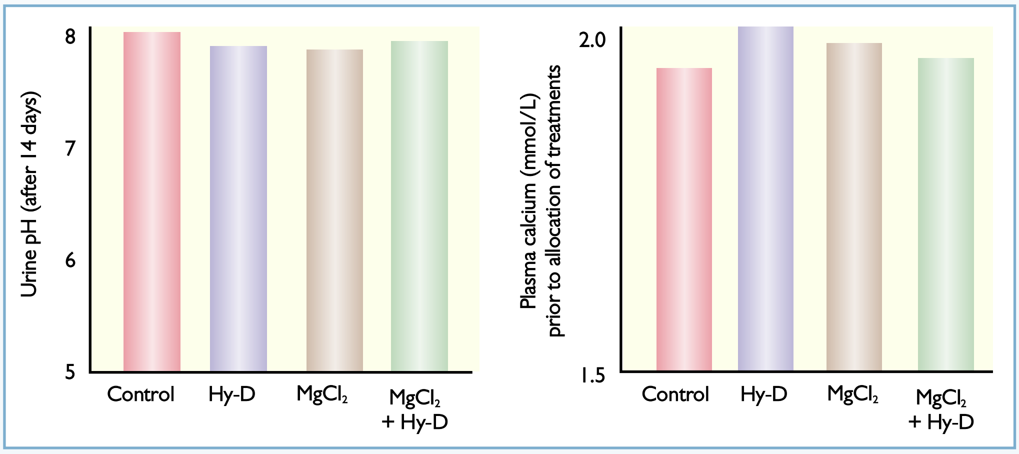
Fig. 5. Urine pH after 14 days and plasma calcium at calving.



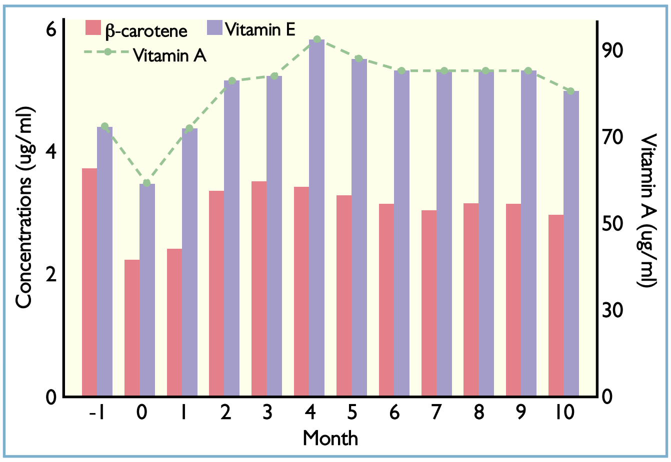


Fig. 6. Serum β-carotene, vitamin A and E concentrations (ug/ml) from cows 30 days before expected parturition (-1), at parturition (0) and subsequently at monthly intervals during lactation and up to the start of the next dry period (1-10).

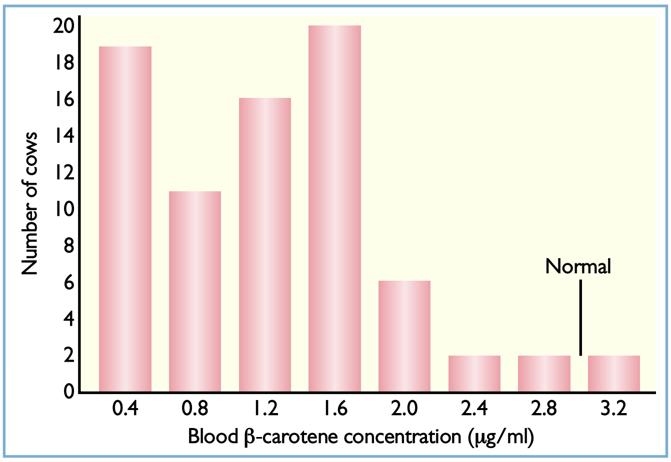


Fig. 7. Variations in plasma β-carotene concentrations in dry cows.

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extent to which the dietary cation/anion balance affected blood macro mineral profiles and urinary outputs of macro minerals from non lactating animals, supplemented with or without 5mg/day of Rovimix Hy-D. Magnesium chloride supplements significantly reduced urine pH from 7.1 to 6.2.

Calcium concentrations in urine were unaffected by Rovimix Hy-D supplementation alone. Magnesium chloride significantly increased urine calcium concentration (75% increase over control) and phosphorus concentration (60% increase).

The combination of magnesium chloride plus Rovimix Hy-D effected significant increases of 162% in calcium and 105% in phosphorus concentrations in urine above control values.

Experiment 2. (Bryant et al, unpublished data).
Evaluated the effect of magnesium chloride with and without supplements of Rovimix Hy-D via water medication to cows for 10 days prior to calving.

The addition of magnesium chloride in the water supply reduced urine pH to approximately six from pre supplementary levels of 7.8. After calving there was a reduction in blood calcium concentrations in both groups of cows, however, cows which received the water medication containing both magnesium chloride and Rovimix Hy-D prior to calving maintained blood calcium concentrations well above the level of normality.

Calcium concentrations in urine immediately prior to calving was increased by 83% with magnesium chloride and 117% with the combination or magnesium chloride and Rovimix Hy-D compared to pre-treatment levels.

Experiment 3. (McDougall et al, unpublished).
Cows on two commercial farms were drenched for two weeks before calving using the same combination of treatments employed by Elliott et al.

The urine pH from cows prior to allocation of treatments was well above eight and although the addition of magnesium chloride and magnesium chloride plus Rovimix Hy-D significantly reduced urine pH, the depressions were very small and did not approach the required range of 6-6.5.

As a consequence, there was no beneficial effect of either the magnesium chloride nor the combination of magnesium chloride and Rovimix Hy-D on maintaining plasma calcium concentrations at calving and in all treatments plasma concentrations of calcium were below the lower level of normality (2.18 mmol/L) after calving.

In many 'all grass' production systems the potassium loading is very high before calving and it is difficult to create a metabolic acidosis in the animal.

Feedstuffs such as maize silage, high fibre hays/straws, brewers grain, cereal meals and palm kernel meal all help to reduce the potassium loading allowing the best opportunity for supplementary anionic salts to effect changes in the cow's metabolism.

The lack of high protein green forages in dairy rations throughout the Asian region would ensure that the DCAD prior to calving would not be highly positive and therefore the combination of anionic salts plus Rovimix Hy-D supplementation for a very short period (10-14 days) would have a very beneficial effect on maintaining blood calcium concentrations after calving.

Influence of β-carotene

Until the advent of vitamin A synthesis on a commercial scale for use in stock feed, ruminants (along with other animals) were dependant on the carotenoids for their vitamin A requirements.

The biosynthesis of vitamin A from β-carotene takes place principally in the intestinal mucosa during absorption. It is now generally accepted that 1mg dietary β-carotene is equivalent to 400iu of vitamin A in practical dairy cow rations.

Peripartum fluctuations in the plasma concentrations of the fat soluble vitamins A and E have been extensively studied in well managed dairy cows.

Consistently, reports of decreases in mean serum concentrations have been related to the production of colostrum and the onset of lactation. In this regard β-carotene is no different.

Recently Katsoulos et al, (2005) provided data on serum β-carotene levels throughout lactation (Fig. 6).

For many years there was speculation that β-carotene could play a role in improving the fertility of cattle and this role was independent of the fact that it is an essential vitamin A precursor. β-carotene together with vitamin E accumulates in the bovine corpus luteum as the ovarian cycle progresses.

Graves-Hoagland et al, (1988) observed that the production of progesterone by corpus luteum cells in vitro was reduced in cows that had been subjected to diets deficient in β-carotene.

This observation confirmed previous work by Ahlswede and Lotthammer, who also showed that the depression in progesterone secretion could be overcome by β-carotene supplementation but not by vitamin A. All biological functions are multi-factorial and bovine fertility is certainly no exception. There are many ways by which low β-carotene intakes affect cow fertility.

Hormone balances may be affected and in this regard both Schams (1977) and Tekpetey et al, (1987) observed significant increases to the interval between peak production of luteinising hormone and the day of ovulation in animals deficient in β-carotene.

It has also been proposed that adequate β-carotene intakes are needed to increase the longevity of the hormone producing cells thus prolonging their period of activity.

The antioxidant characteristics of β-carotene may also be crucial in the maintenance of optimal animal health at and around the time of calving.

Michal et al (1990) found a significant reduction in the incidence of retained placenta in β-carotene supplemented cows and Lotthammer (1979) also reported a very high incidence of cystic ovaries in β-carotene deficient cows in several experiments. It has also been demonstrated that β-carotene can enhance the immune response by potentiating lymphocyte and phagocyte function and thus decreases the incidence of periparturient disorders in both cows.

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Table 2. The effect of differing levels of β-carotene supplementation on post partum disease and reproduction.

Experiment 1	Days to first heat	Retained foetal membrane (%)
Control	80^{a}	40.9
300mg	84^{a}	25.0
500mg	72^{b}	34.8

Values with different superscripts are significantly different p>0.05.

Experiment 2	Days to first heat	Retained foetal membrane (%)
Control	79^{a}	27^{a}
300mg/day	76^{a}	19^{b}
500mg/day	71^{b}	18^{b}

Values with different superscripts are significantly different p>0.05.

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The antioxidant characteristics of both β-carotene and vitamin E may also play an important role in maintaining ovum quality. In Japanese black cattle Sekizawa et al (2006) observed that the number and quality of collected ova was higher in cattle which exhibited high levels of plasma β-carotene and vitamin E (Table 1).

The 'high' concentrations of β-carotene in their report however (more than 100ug/100ml but less than 200ug/100ml), are still significantly less than levels regarded as normal.

Experiments in China

Recently in a series of experiments we examined the responses to β-carotene supplementation on the reproductive health and fertility of cows in China, where forage quality is very poor and consists mainly of maize stover, maize stover silage, rice straw together with small amounts of locally produced hays or imported lucerne. There is very limited use of fresh grass in production rations.

Four experiments were conducted using high yielding Holstein Friesian cows (7-9,000 litres/lactation).

Despite the fact that all the cows had received similar diets for considerable periods in the dairy there was still a large range in plasma β-carotene concentrations after drying off (Fig. 7).

However, of the 78 cows sampled only four had plasma β-carotene concentrations exceeding 2.5µg/ml and above. None of the cows exhibited plasma β-carotene concentrations above the level considered optimum (3.5µg/ml).

A clear response to β-carotene supplementation was the improvement in the reproductive health of the cows. Specifically there was a significant reduction in the incidence of retained foetal membranes in all experiments.

A reduction in retained foetal membranes due to β-carotene supplementation has been reported previously by Michal et al (1994).

It has been stated previously that retention of foetal membranes is a result of the poor immunological status of the cow at calving and this can also be translated into a colostrum production with a significantly lower immunoglobulin content.

Interestingly, early reports by Lotthammer (1979) also revealed that calves born from β-carotene deficient cows exhibited a higher incidence of diarrhoea and morbidity due to lower immunoglobulin levels. Improved immunological status of the cow due to β-carotene supplementation was also suggested by a significant decrease in clinical mastitis.

There is substantial evidence that circulating β-carotene improves the health and fertility of cattle through its conversion to vitamin A in specific target organs such as the uterus, mammary gland and ovary.

Although there are reports of the failure of β-carotene supplementation to improve reproductive efficiency it is significant that these experimenters commenced supplementation at different times after calving. In order to achieve the maximum beneficial effect of β-carotene it is necessary to supplement the cow with β-carotene 21 days prior to calving.

Based on early observations β-carotene supplementation programmes involving 300mg/head/day during the three weeks prior to calving and continuing until the subsequent pregnancy is confirmed have been widely adopted. More recently research in Europe, the USA and Thailand, have also reported positive results in terms of improved reproductive performance using this programme of supplementation. ■

Rovimix A	75,000-100,000iu daily three weeks prepartum 100,000-150,000iu daily during lactation
Rovimix E	3,000iu daily for three weeks prepartum 1,000 iu per day during lactation
Rovimix D	25,000-35,000 iu daily for three weeks prepartum 30,000-50,000 iu per day during lactation
Rovimix Hy-D	5mg/head/day for 10 days prepartum in conjunction with a dietary cation anion difference to reduce urine pH below seven prior to calving
Rovimix Biotin	20mg/head/day as heifers and throughout the life of the cow
Rovimix β-carotene	300mg/head/day for three weeks precalving and daily until the subsequent pregnancy is confirmed

Table 3. Current dietary recommendations for optimum vitamin nutrition of dairy cows to promote rebreeding.