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Review on transition period management of dairy animals through micronutrient supplementation

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Abstract
The purpose of this study was to look at the existing literature on the effect of micronutrient supplementation on colostrum and milk quality, production and health of dairy cows, as well as the effect on their calves. The dairy cow's hormonal level and nutrient demand fluctuate dramatically during late gestation, requiring multiple digestive, metabolic, and reproductive adjustments to fulfil the increased demand of calves, as well as the initiation of lactation. Supplementation of micronutrients (vitamins and minerals) is equally important in animal feed as energy and protein. They control enzymes and hormones that have a role in metabolism, production, and health. Various studies on the effects of vitamins A, E and zinc on the transition phase have been conducted, and the results have been summarised here. Vitamins A and E are fat-soluble antioxidants that protect periparturient cows from oxidative stress induced by lipid peroxidation produced by free radicals. Zinc helps in hormone regulation and immune system integrity, as well as energy generation, protein synthesis, and membrane stability against bacterial endotoxins, as well as the development of antioxidant enzymes. Besides this zinc also helps in vitamin A utilization both have synergistic action. The effects of vitamins A, E, and zinc on dairy cow production and reproduction throughout the periparturient period, as well as the impacts on their calves, have been summarized here.

Keywords: Calves, dairy, micronutrient, periparturient, vitamin

1. Introduction

The Transition Period is a stage in which numerous digestive, metabolic, and reproductive activities occurs to determine the general health status of the animal at the time of calving and immediately after calving which is characterised by significant changes in the hormonal level and nutrient demand (Deniz *et al.*, 2020) [14]. In mature dairy cows, approximately 75% of illness occurs within the first month following calving (LeBlanc *et al.*, 2006) [31], with the highest incidence within the first 10 days post-calving of total disease (mastitis, ketosis, digestive disorders, and lameness (Goff *et al.*, 1998; Ingvartsen *et al.*, 2008). In order to combat all these diseases immediately after calving, the period before calving that is dry period is equally relevant. The majority of these disorders are caused by the animal's inability to adjust to the changes in demand that occur as cows transition from the pregnant and non-lactating period to the beginning of lactation (Mulligan and Doherty, 2008) [32]. As a result, these abnormalities of early lactation are referred to as "transition cow" diseases. The hypermetabolic catabolic reaction in physiological homeostasis is referred to as metabolic stress (Abuelo *et al.*, 2015) which includes excess lipomobilization, immunological and inflammatory dysfunction, and oxidative stress to animals. These processes are inextricably intertwined, resulting in immunological and metabolic abnormalities that are related to a higher risk of metabolic and infectious illness during this time period.

Micronutrients (vitamins and minerals) supplementation forms an essential requirement in animal feed same as energy and protein, but this is neglected due to its requirement in a very minute quantity and hence makes them insignificant as compare to energy and protein feed resources. They are important in an animal nutrition as they regulate enzyme/hormones involved in metabolism, production and health.

2. Role of Vitamin A

Vitamin A performs four distinct biological functions; namely (a) bone formation and growth (b) vision (c) reproduction and (d) maintenance of healthy epithelial tissue. However more recent evidence points to the view that apart from these generalised functions, the vitamin also has some specific roles in various functions such as in reproduction, immune functions, and health (Chew, 1993; Kume and Toharmat, 2001) [12, 29]. β-Carotene is an antioxidant similar to vitamin E (Chew, 1987, 1993) [11, 12]. Requirement of Vitamin A is 110 IU/kg body weight (NRC, 2001) [33] under all condition but in transition cow 80000 IU/day for 680 kg cow (Van, 2018). Vitamin A requirement of different species presented in table 1.

3. Role of Vitamin E

Vitamin E serves several functions including a role as an inter and intra cellular antioxidant and in the formation of structural components of biological membranes**.** Vitamin E is a lipid-soluble antioxidant that protects against lipid peroxidation caused by free radicals. (Halliwell, 2007) [19]. Vitamin E may be found in abundance in fresh green forage and often low in concentrates and stored forages (hay, haylage, and silage) (NRC 2001) [33].

Vitamin E naturally occurs as α-tocopherol in feedstuffs. Vitamin E requirement for newborn calves is estimated to be 60 IU/kg dry matter (ICAR handbook, 2017), 1000 IU/day during the dry period, whereas herds with mastitis or other infectious disease issues may increase prepartum intake to 4000 IU/day and then 2000 IU/day during early lactation. (Van Saun, 2018) [18]. Table 2 shows the Vitamin E requirements in several species.

4. Role of Zinc

Zinc is a trace mineral that is shown to be a component of more than 300 enzymes, including alcohol dehydrogenase, carbonic anhydrase, carboxy peptidase, etc Zinc helps in regulation of hormone production (Vallee and Falchuk, 1993) [46], DNA and protein synthesis, Cell replication . Zinc contributes to immune system integrity by assisting with energy generation, protein synthesis, and membrane stability against bacterial endotoxins (Ho and Ames, 2002) [21], antioxidant enzyme production and maintainence of lymphocyte replication and antibody production. Besides this zinc also helps in vitamin A utilization both have synergistic action (Rahman *et al.*, 2002) [38].

Zinc requirement is 30-40 mg/kg DMI (ICAR handbook, 2017), generally in most situations. Zinc supplementation for lactating dairy cows should be 40 to 60 mg/kg DM, according to NRC 2001 [33]. Zinc deficiency causes more oxidative damage to cell membranes owing to free radicals (Kloubert, and Rink., 2015; Yang and L.i, 2015) [28, 49]. 500 mg/kg DMI is the maximum tolerated level. (ICAR handbook, 2017).

Table 1: Requirement of vitamin A for ruminants per unit of feed (dry basis)

Ruminant	Vitamin A	
	IU/kg	**IU/lb**
Beef cattle (NRC 2000)		
Feedlot cattle	2200	1000
Pregnant heifers and cows	2800	1273
Lactating cows and breeding bulls	3900	1773
Dairy cattle (NRC 2001)		
Lactating cows	2123-3685	965-1766
Fresh cows	3499-5540	1586-2518
Dry pregnant cows	5576-8244	2535-3749
Growing pregnant heifers	6486-7075	2948-3216
Sheep (NRC 1985)		
50 kg (110 lb) growing lambs	1567	712
70 kg (154 lb) gestating ewes (last 4 weeks)	3305	1502
80kg (176 lb) lactating ewes (suckling twins)	2667	1212
Goats (NRC 1981)		
30 kg (66 lb) growing kids	1530	695
50 kg (110 lb) late pregnancy	1532	695
The requirements of small ruminants (sheep, goats, cervids and new world camelids) are defined by NRC (2007b). The vitamin requirements are not in concentrations of feed, but as per kg of body weight or on a day basis.		

Table 2: Requirement of vitamin E for ruminants per unit of feed (dry basis)

Ruminant	Vitamin E	
	IU/kg	**IU/lb**
Dairy cattle (NRC 2001)		
Lactating cows	16-27	7.3-12.3
Fresh cows	39-35	17.7-15.9
Dry pregnant cows	81-120	36.8-54.5
Growing pregnant heifers	80-113	36.4-51.4
Sheep (NRC 1985)		
50 kg (110 lb) growing lambs	15	6.8
70 kg (154 lb) gestating ewes (last 4 weeks)	15	6.8
80kg (176 lb) lactating ewes (suckling twins)	15	6.8
The requirements of small ruminants (sheep, goats, cervids and new world camelids) are defined by NRC (2007b). The vitamin requirements are not in concentrations of feed, but as per kg of body weight or on a day basis.		

5. The impact of micronutrient supplementation on colostrums, milk production and its composition.

Several studies have been conducted to improve the quality and yield of colostrum and milk by supplementing micronutrients, which will be reviewed here. The supplementation of milk-substitute supplemented with colostral cells (MS+) results in a considerable rise in Colostral immunoglobulins, which improves the survival of calves born to these cows by delivering protective antibody and perhaps lymphocytes (Caspari and Schmidt 1991) [40]. Nicola *et al*., (1996) found that supplementing cows with Vitamin E and selenium during the dry period increased Ig synthesis in the mammary gland, resulting in higher Ig concentrations in colostrums. This is because Vitamin E enhances the ability of the mammary gland's immune cells to produce more Ig.

Kamada *et al*., (2007) [26] found that supplementing selenium with colostrum enhances immunoglobulin absorption, and the colostrum redox profile was shown to be strongly related to calves' serum immunoglobulin concentrations. (Abuelo *et al*., 2014) [2]. However, none of these investigations identified which pathways could be involved, suggesting that more study is required. Additionally, a negative relationship between colostrum immunoglobulin concentration and antioxidant capability has been documented (Kertz *et al*.,

2017) [27]. As a result, more study is needed on the long-term effects of supplementing colostrum with antioxidants on the health and productivity of animals. The concentration of vitamin E in colostrum is critical for the calf's immunological response (Van Saun *et al*., 1989) [47].

Chawla and Kaur (2004) [10], found that supplementing with Vitamin E and Beta carotene had a positive effect on milk production. The explanation for this might be because certain micronutrients fed to transition cows lower milk SCC, resulting in the animal having fewer udder infections and hence increasing milk yield on the other hand, Brozos *et al*., (2009) [6] found that daily administration of a mix containing 60 g ammonium chloride, 1000 IU Vitamin E, and 0.05 ppm Se during the dry period was safe, but had no influence on milk supply at 30 and 60 days postpartum. Cows given 2100 mg Vitamin E and 7 g sodium selenite intramuscular injections 2 weeks before calving and on the day of calving had no influence on milk output (Bourne *et al*., 2008) [36]. In Sahiwal cows, Chandra *et al*., (2015) [9] found that supplementing with vitamin E and zinc, either separately or combined, enhanced milk yield.

6. The impact of micronutrient supplementation on health of dairy cows

Several researches have been conducted to improve the health of periparturient dairy cows by supplementing them with micronutrients, which will be described here. Abortion, stillbirths, and poor newborns are all possible outcomes of trace mineral deficiency. (Hostetler *et al.*, 2003; Suttle, 2010; Davis and Myburgh, 2016) [22, 43, 13]. Homeostatic systems do not regulate nutrient-specific biological functions (i.e. Mineral-dependent metalloenzymes) of trace minerals and fat-soluble vitamins, so dietary intake of the nutrient or mobilization of tissue reserves, primarily liver and adipose (fat-soluble vitamins only) is required when dietary sources are insufficient to meet the requirements. Trace mineral needs during pregnancy have only been studied in a few cases. The loss of trace elements required for colostrum synthesis during late pregnancy, along with limited or interrupted food supplementation, may result in a nutritionally deficient dam.

Researchers discovered a decrease in maternal hepatic and serum selenium (Se) concentrations in beef and dairy cattle during the last month of pregnancy (Van *et al*., 1989) [47], which is consistent with colostrum losses. Over the advanced stage of pregnancy, the concentrations of serum retinol (vitamin A) and α-tocopherol (vitamin E) have decreased (Goff and Stabel, 1990) [17]. Mastectomy solved the problem of dropping serum retinol concentrations before to calving, implying that serum concentrations were being lost to colostrum and milk (Goff *et al*., 2002) [18] However, it had no effect on α-tocopherol concentrations in late pregnancy (Goff *et al*., 2002) [18]. In late pregnancy, serum total triglyceride and cholesterol concentrations decrease (Nazifi, *et al*., 2002; Turk *et al.*, 2005) [34, 45]. reaching a trough on or near the day of calving leading to decline in dry matter intake. So if there is inadequate supplementation of trace mineral and fat-soluble vitamin around gestation there may be amplified gestational reduction of those trace minerals and vitamins being used up for colostrums formation and that could adversely affect the cow’s immune status, which is already impaired in terms of functionality around parturition (Goff and Horst, 1997) [16].

Researchers discovered that higher concentrations of β-carotene in the ovary, particularly the corpus luteum, suggest that dietary β-carotene levels are associated to fertility (Çelik *et al.*, 2009; Kaewlamun *et al*., 2011; Sales *et al.*, 2008.) [8, 25, 41]. Zinc supplementation (0.8 gm) reduced the number of days open in cows considerably ($P<0.05$). Campbell *et al.*, (1998) [7] also found that cows and heifers fed with Zinc alone had fewer days to first estrus than cows and heifers who were not supplemented with Zinc. For cows and heifers fed Vitamin E-supplemented diets, the number of days open was decreased. Baldi *et al.*, 2000 [4] discovered that giving periparturient dairy cows 2000 IU/d of dietary vitamin E enhanced plasma and milk vitamin E levels, decreased somatic cell count in milk, and improved fertility by reducing the number of services and days to conception. The most likely explanation is that Vitamin E supplementation in cows accelerates uterine involution (Resum, *et al.*, 2018) [39].

Long term detrimental effect of low vitamin supplementation have been studied by Johansson *et al.*, 2014 [24] in which he found that the health of cow was being deteriorated on 2nd year and so supplementation of vitamins at a greater level than suggested is essential around calving to avoid such health problems in cattle.

Dairy cows suffer from immunological dysregulation during the transition phase, making them more vulnerable to viral and metabolic disorders. The onset of lactation is considered as the main contributing factor for immune dysregulation during this period along with endocrine and metabolic factors (Nonnecke *et al*., 2003) [36] like excessive lipomobilization causes high NEFA and beta-hydroxybutyrate (BHBA) concentrations, as well as hypoglycemia (glucose is essential for immune cell activity). Because glucose is the major metabolic fuel for many immunological cells, its stability throughout the dry period, with carefully managed diet, is of special relevance in minimising declines in maternal blood glucose owing to the fetus's demand for glucose.

To conclude, cows may experience metabolic stress if they are unable to adjust physiologically to the sudden rise in nutritional needs associated with foetal development, parturition, and lactogenesis at this time as 75 percent of illness in dairy cows begins in the first month of lactation (LeBlanc *et al*., 2006) [31].

7. The impact of micronutrient supplementation health and growth of calves

Only a few studies have been done to improve the health of calves through a dam-to-calf carryover effect using micronutrient supplementation, which will be reviewed here. Sikka *et al*., 2002 [42] investigated the effects of fat-soluble vitamins (Vitamin AD_3E) on dams and their calves, finding that supplemented dams' calves gained more weight monthly. In the first four days, vitamin supplementation to buffaloes during advanced pregnancy increased total Ig secretion in colostrum by 7.7%, 2.5%, 29%, and 80%, respectively. Up to 45 days after birth, calves born to supplemented mothers had higher blood serum absorbed Ig levels. On days 1 and 15, calves' born to supplemented dams Ig absorption increased by 30% and 18%, respectively. They also supplemented vitamins and minerals in combination to advanced pregnant dams in which there was suppression of total serum Igs in calves on subsequent days and this suppression was of higher order on calves of unsupplemented dams.

The impact of zinc supplementation on colostrum IgG, calves serum IgG, and total protein was investigated by Allahyari, *et al.*, 2019 [3]. They discovered that zinc supplementation resulted in a considerable rise in calves' growth rate. Torsein *et al*., (2011) [44] reported an increase in calf mortality due to inadequate serum concentrations of tocopherol and β-carotene in Swedish dairy herds. Persson *et al*., 2007 in Sweden investigated the effects of supplementing RRR—Tocopheryl Acetate to periparturient dairy cows in commercial herds with high mastitis incidence and discovered that cows fed extra vitamin supplements around calving had a lower risk of stillbirth or calf death within 24 hours after birth.

8. Conclusion

It may be inferred that vitamin A, E, and zinc play an important role in animal nutrition, particularly during the transition phase. Several studies have shown that supplementing cows with micronutrients during the transition phase enhances not only the quality of colostrum and milk, but also the health of the cows. This has an indirect beneficial influence on calves' birth weight, growth rate, and overall health.

9. Conflicts of interest

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article. The first author have conducted the research on “Effect of vitamin A, vitamin E and zinc supplementation on production performance of peri-parturient crossbred cows and their calves” under the guidance of second author. Other writers, who are researchers, also participated to the composition of the study report.

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