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The Importance of Vitamins E, A and β-Carotene for the Health and Prosperity of Dairy Calves

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Abstract

Raising healthy and viable calves is the goal of every farmer who wants healthy cows in their breeding, with excellent milk production and reproductive parameters. And it is not just infectious and metabolic diseases that are clinically visible. Even minor nutritional deficiencies and insufficient supplementation of certain important vitamins and mineral elements can affect the calf's future health and prosperity. This mini-review summarizes the latest results on the importance of vitamins E, A and β- carotene, especially for the antioxidant and immune system of calves. It also discusses briefly effects of vitamins on the hematological profile of calves. A necessary precondition for ensuring the optimal concentration of these vitamins in calves is their sufficient supply in colostrum/milk or milk replacer. Interesting results were obtained by works focused on the effect of vitamin supplementation (parenterally or per-orally) in pregnant cows before parturition on vitamin concentrations in colostrum and plasma/serum of their calves. This can also be a way to ensure a sufficient concentration of vitamins for calves.

Keywords: Antioxidants; Immunity; Neonatal Calves; Colostrum; Vitamins

Abbreviations: TP: Total Protein; IgG: Immunoglobulins; GMT: Gamma-Glutamyl Transferase; TAS: Total Antioxidant Status; TBARS: Thiobarbiturate Acid; NO: Nitrate Ions; SOD: Superoxide Dismutase; BAP: Biological Antioxidant Capacity; RBC: Erythrocytes; HGB: Hemoglobin; HMT: Hematocrit.

Introduction

Although a lot of progress has been made in recent years in knowledge about calf health, the current management and calf health at the international level are still suboptimal. In addition, the issue of calf health is considered to be a relatively minor health issue compared to the health and management of adult cows [1]. However, it is the healthy, viable calf without the history of infections at an early age, which provides the basis for a healthy adult animal, regardless of being a dairy cow or a fattening bull, which can thus fully exploit its potential in production and reproduction in the future.

The basis for breeding healthy, viable calves is, first and foremost, proper colostral nutrition and thus strong passive immunity. This is a necessary and life-determining step, neglecting or failure of which can have fatal consequences. But even in milder cases of passive immunity deficiencies, such an animal is unlikely to prosper in life, as would be the case with sufficient colostral immunity. Nowadays, colostral immunity of calves is usually controlled on farms by examining blood serum parameters such as total protein (TP), immunoglobulins (IgG) or also by the enzyme gamma-glutamyl transferase (GMT).

And although the concentration of IgG and TP in calf serum is crucial, the concentration of vitamins as an indirect parameter of colostral immunity is also very important and often escapes attention. This fact can have negative consequences for the calves' health in case of deficiency, not only at an early age, but also at a later period of their lives. Higher calf mortality was observed in herds with low levels of vitamin E and β-carotene in the serum of calves of 1-7 days of age [2]. In a recent study by the same author [3], this connection was confirmed only in case of vitamin E in relation to TP status of calves. Calves with low levels of colostral immunity (failure passive transfer) were also observed to have low serum β-carotene concentrations.

Vitamin Supplementation of Pregnant Cows and its Effect on the Concentration in Colostrum

The most natural supply of fat-soluble vitamins for calves is directly from colostrum and later from a quality milk replacer. Nowadays, on most farms, selected quality colostrum is frozen and stored to use for calves after being birth.

Here it has to be pointed out that colostrum is formed several weeks before the birth and therefore it is necessary for the pregnant cow to have a sufficient intake of vitamins already during this period. During the synthesis of colostrum, a considerable amount of vitamins are taken from the body reserves of dairy cows [4]. Vitamin supplementation of dairy cows has been shown to be necessary in difficult transition periods. The study by Johansson, et al. [5] showed that organic cows can do without supplementation with synthetic vitamins. However, the exception is the period around calving, when vitamin requirements are higher compared to other periods.

So the question is how to ensure sufficient concentration of vitamins to pregnant cows to maintain their body vitamin reserves and also affect the concentration of vitamins in the colostrum.

In the work of Ishida, et al. [6] Japanese black cows were supplemented with β-carotene on a 500 mg/day diet for 21 days before expected parturition up to 60 days after parturition. And although this supplementation significantly increased the plasma concentration of β-carotene in cows from the birth to 60 days after birth, it did not significantly affect its colostrum concentration. Similar results were observed in the work by Nishijima, et al. [7] in cows fed dried carrots enriched with β-carotene. This supplementation did not significantly increase the β-carotene levels in cow colostrum.

In our recent work [8], cows were injected with vitamin formulas (single injection of vitamin A and E, β-carotene) 10–14 days before calving. Although tendencies to higher vitamin concentrations were observed in colostrum of the experimental cows, these changes were not statistically significant. In the serum of cows, no statistically significant differences were observed between the concentration of vitamin E and A of the experimental cows compared to the control group of cows. Experimental group which received β-carotene parenterally, statistically significant differences in the concentration of β-carotene in cow serum were already observed. In addition, parenteral administration of β-carotene to cows before calving helped to maintain its significantly higher concentrations on the day of calving and 5–7 days after calving compared to the first experimental and control group.

Cows supplemented by vitamin A in the diet during the dry period had significantly increased vitamin A concentrations in the colostrum and plasma. The results of this work suggest that most vitamin A was transferred in colostrum in the final stages of pregnancy and the early stage of lactation. Moreover, the calves of the supplemented cows had higher vitamin A concentrations compared to the calves of non-supplemented cows [9].

It turned out that the concentration of vitamins E and β-carotene in colostrum can also be associated with a specific breed of cattle. In the work of Torsein, et al. [3] was a breed significantly associated with the concentration of vitamins in colostrum. Also in the past, it has been observed that the breed has a significant effect on the content of fat soluble vitamins in milk [10].

These works showed that vitamin supplementation usually ensures their sustainable concentration in the serum / plasma of cows. For sufficient concentrations in colostrum, supplementation with higher amounts of vitamins than recommended is likely to be necessary.

The Importance of the Antioxidant Function of Vitamins E, A and β-Carotene for Calves

As far as oxidative stress is concerned, a lot of attention is paid to adult cows. It is well known that cows are prone to oxidative stress mostly during the transition period and thus prone to disease. The lowest concentrations of vitamin E, A and β-carotene were observed in 2-3 days postpartum. Along with the decrease in these vitamins, the lowest total antioxidant status (TAS) values were recorded in these cows [11].

The antioxidant defense system of neonatal calves is immature, and therefore it may be susceptible to oxidative damage [12]. The big challenge for the antioxidant defense system of calves is a weaning stress [13].

Interesting results were observed in the study by Wernicki, et al. [14]. The combination of florfenicol and flunixin in combination with vitamin E or C has been shown to be effective in reducing oxidative stress in calves positive for bovine respiratory syncytial virus (BRSV). The groups of calves which received florfenicol and flunixin in combination with the vitamins had significantly lower concentrations of thiobarbiturate acid (TBARS) and nitrate ions (NO).

In the work of Mattioli, et al. [15] parenteral supplementation of minerals and vitamins with antioxidant effect to heifer calves preserved the TAS concentrations and (glutathione-peroxidase) GPx activity. Similarly, in the work of Bordignon, et al. [16] calves treated parenterally with a vitamin and mineral formula (including vitamins E and A) showed lower concentrations of reactive oxygen species (ROS) and lower lipid peroxidation. On the other hand, higher antioxidant capacity against peroxyl radicals, GPx activity and superoxide dismutase (SOD) were observed in treated calves.

Also, parenteral administration of a vitamin formula containing vitamins E, A and D to pregnant cows had a significant effect on the serum concentration of TAS in their own calves [17]. The results of the work of Otomaru, et al. [18] also confirmed that β-carotene supplementation in Japanese black calves has been shown to be effective in reducing serum oxidative stress (by decreasing the derivatives of reactive oxygen metabolites- d-ROMs) and increasing the biological antioxidant capacity (BAP) test.

We think that the antioxidant defense of calves should be given attention. Calves also go through health-threatening periods, which can represent increased ROS production and catabolism. According to the latest studies, vitamins E, A and β-carotene can be one of the ways to strengthen the calves' antioxidant system.

The effect of Vitamins on the Immune System of Calves

The role of vitamins as antioxidants and their effect on the antioxidant/oxidative status of calves seems to be quite clear. In addition to their antioxidant functions, fat-soluble vitamins are also necessary for the proper functioning of the immune system and the prevention of diseases in adult cattle and calves. The antioxidant functions of vitamins and immunity are connected in some way. The defense function performed by the immune system is itself a source of ROS. The works below also suggests that vitamins are also able to affect certain leukocyte populations or vaccine responses.

Japanese black calves responded to dietary β-carotene supplementation not only by increasing their serum β-carotene levels, but also the supplemented group of calves had increased CD4+ cell counts in peripheral blood at 4 weeks of age [19].

The previous work of the same author Otomaru, et al. [20] was focused on vitamin E and its effect on peripheral blood leukocyte populations in Japanese black calves. Also in this case, vitamin E supplementation changed the number of immune cells in the peripheral blood. The number of CD3 + and CD4 + cells in the group of calves supplemented with vitamin E was significantly higher at the age of 2 months. Also, the number of CD8+ and CD14 + cells tended to be higher in this group.

Vitamin A deficient calves were unable to respond to the bovine respiratory syncytial virus mucosal vaccine. These calves also showed marked abnormalities in the inflammatory response in infected lungs. On the other hand, the infection has also been shown to have a negative effect on circulating retinol and retinol concentrations in the liver [21].

There may be a link between morbidity, mortality and vitamin levels in cattle. As we mentioned at the beginning, there is a certain relationship between the mortality of calves and their vitamin status. The findings of Strickland, et al. [22] showed that vitamin concentrations could serve as a biomarker of certain diseases in cows. Also, lower concentrations of vitamin E, A was observed in cows with metritis compared to healthy cows.

The Effect of Vitamins on Red Line Parameters of Hematology Profile

Another possible beneficial effect of fat-soluble vitamins on calves' health is the effect on the red lime parameters of the hematology profile. The antioxidant effect of vitamins is also reflected in the protection of the biological membranes from oxidation, including erythrocytes (RBC). Results from human studies indicate that the accumulation of lipoperoxidation products during oxidative stress may alter RBC morphometric parameters as well as hemoglobin (HGB) function. It is also questionable whether the vitamins can directly affect erythropoiesis in the bone marrow.

An interesting finding in our work from 2021b was also the increased values of RBC, HGB and hematocrit (HMT) in calves whose mothers were parenterally supplemented with vitamins E, A or β- carotene when compared with calves from non- supplemented mothers. Similar results were observed in Moosavian, et al. [23] where calves were administered vitamin A with or without iron. Treated calves tended to have higher RBC counts and higher weight gain.

The intramuscular application of selenium and vitamin E to fallow deer (*dama dama*) resulted in an increase in the erythroblastic cell line in the bone marrow on day 15 after the applicant [24]. The experimental group had an increased HGB. The number of reticulocytes was also significantly increased, which suggests that selenium and vitamin E affect the process of erythropoiesis in the bone marrow [25].

Based on these works, it can be stated that vitamins can affect the hematological parameters (RBC, HGB, HMT) of calves. The question therefore arises as to whether vitamin supplementation could have a preventive effect against neonatal anemia. However, more studies performed directly in cattle/ calves are necessary to answer it.

Conclusion

The results of recent studies confirm the importance of vitamins E, A and β-carotene, especially in terms of their effect on the antioxidant and oxidative stress parameters in calves. As mentioned, the antioxidant functions are closely related to the immune system, thus the sufficient concentrations of vitamins E, A and β-carotene may predispose to the proper functioning of the immune system. However, more studies are needed on vitamin supplementation for calves' immune status. Likewise, interesting findings of the beneficial effect of vitamin supplementation on calves on hematological parameters of the red line (RBC, HGB, HCT) may lead to possible prevention of neonatal anemia. Therefore, the introduction of calf supplementation with vitamins E, A and β-carotene in farms could be one way to raise healthy cows. The question also remains how we can achieve the sufficiently high levels of vitamins in colostrum for calves in order to maintain a sufficient concentration of vitamins in the organism of cows during the difficult transition period. As the results of some studies show, not only cows but also their calves themselves can benefit from vitamin supplementation to cows before calving.

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