Review Article

Transition Stress in Dairy Cattle: Role of Energy Balance and Micronutrients

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Abstract

Dairy cattle undergo enormous metabolic modulations during peripartum or transition period in terms of negative energy balance (NEB), oxidative stress and impaired immune function. Series of metabolic processes are involved in mobilizing body fat, protein, and energy to compensate for insufficient supply of nutrients in cows during a transition period. The altered physiological state of an animal during the transition period affects the metabolic and hormonal changes to support fetal development and onset of lactation. Eventually, immunological conquest results in to peri-parturient illness and reduced fertility of animal. Thus, the inclusion of additional energy along with required micronutrients (vitamin E, Se, Cu, Zn, and Cr) evident to successful completion of the transition phase with minimal incidence of periparturient disorders such as mastitis, metritis and retained fetal membranes. This combination of supplementation ameliorates inimical consequences of transition stress over reproductive and productive potential of the animal.

Key words: Dairy Cow, Energy, Micronutrients, Transition Period

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Introduction

Dairy farm animals are vital part of agriculture worldwide, supplying many products in addition to milk for the human populace. The earnings that a dairy cow generates come from her milk production and sale of offspring. The efficient production of these products is of utmost importance and high reproductive performance is absolutely crucial to this. In the 19th livestock census, the number of milch cattle and buffaloes has increased from 111.09 million to 118.59 million (increased by 6.75%) and exotic milch cattle has increased by 23% in rural areas during 2007-12 as compared to 2003-07. Transition period refers to the period from 3 weeks before calving extending up to 3 weeks after calving and consider the most critical period in dairy animals, where animals are challenged to undergo through many biochemical, metabolic and endocrine adjustment (Grummer, 1995). The transition period is characterized by dynamic changes in the hormonal profile, loss of appetite, negative energy balance, nutrient and vitamin deficiencies, compromised immunity and oxidative stress. These factors can disrupt at the tissue, cellular and molecular level, thus enhancing the occurrence of the diseases that commonly affect cows during transition period, including postpartum paraplegia, slow uterine involution, retention of placenta, ketosis, mastitis, fatty liver disease and abomasum displacement (Sobiech *et al*., 2015). Major physiological, nutritional, metabolic and immunological changes occurs during this period as the production cycle of the cow shift from a gestational non lactating state to the onset of copious milk synthesis and secretion (Bell, 1995; Sordillo *et al.*, 2013). Nutrient demands for support of fetal growth and initiation of milk synthesis are increased during the transition period. In contrast, this period is characterized by a 30% reduction in dry matter intake at 5 to 7 day pre-partum followed by a steady increase from 0 to 21 (but also after it) day of postpartum. Onset of lactation leads to fourfold increase in the total energy requirement for the additional metabolic activities of the mammary gland and approximately 85% of total body glucose is partitioned to the mammary gland to sustain copious milk secretion (Bickerstaffe *et al*., 1974). The increase in nutrient demand, drastic changes in endocrine status and reduced dry matter intake (DMI) during late gestation influence metabolism, which results in to body reserve mobilization. Adipose tissue, liver, gut, and mammary gland are key components of the adaptations that dairy cows experience to achieve the necessary balance to adapt to the onset of lactation. Increased non esterified fatty acids (NEFA) level in transition period have adverse prints over cell and tissue functioning.

Immunosuppression during this period leads to increased susceptibility to invading pathogens and the incidence of health problems during this time relative to the rest of the lactation cycle is significantly greater (Mallard *et al*., 1998; Brvenich *et al*., 2003). In addition, the transition period is where the risk for mammary infections, displaced abomasum, milk fever, ketosis, retained fetal membranes and metritis is at a peak. Besides infectious diseases it is also important to mention that a high susceptibility for metabolic disorders occurs during this time and these can be also responsible of pro-inflammatory cytokine raise with consequent negative effects. There are more than 20 nutrients that are essential for animal health, including 7 macro-minerals (calcium, phosphorus, potassium, sodium, chloride, magnesium and sulfur) and 15 micro-minerals (iron, iodine, zinc, copper, manganese, cobalt, molybdenum, selenium, chromium, zinc, vanadium, fluoride, silicon, nickel and arsenic) (Radwinska and Zarczynska, 2014).

Energy Balance in the Peri-Parturient Cow

In general, animals attempt to achieve energy equilibrium regardless of physiological and environmental circumstances using the available energy in the diet and the tissue reserves. In the case of dairy cows during transition, as mentioned before, there is a marked decrease in DMI which in turn limits the consumption of

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dietary energy, and has a negative impact on the energy balance equilibrium (Betrics *et al*., 1992). Meanwhile, nutrient demands for fetus needs and for mammary gland development as well as for initiation of milk synthesis are increased aggravating the energy balance status. Post-calving, as milk production increases, the energy needed for milk production increases resulting in a stage of negative energy balance (NEB). To meet the energy requirements of this period, dairy cattle rely on mobilization of adipose and muscle tissue. This period of NEB lasts until the yield of milk starts to decline (6-10 week after parturition) and the energy from the DMI becomes sufficient to meet the cow's requirements (Butler *et al*., 1989). The degree of NEB that cows experience most likely would be a function of the milk yield since high producing dairy cows would require a greater amount of energy for lactation. A period of severe NEB, where extended mobilization of adipose tissue has occurred, could result in the incidence of metabolic disorders such as ketosis and fatty liver. Additional energy supplementation two to eight weeks postpartum evident to ameliorate impact of NEB and improves the subsequent reproductive performance (Khatti *et al*., 2017).

Role of Micronutrients during Transition Period

Oxidative stress during transition period is also believed to contribute to the increased disease risk. Changes in the metabolic profiles associated with moving from the dry period to calving to early lactation may increase the production of reactive oxygen radicals causing oxidative stress. Oxidative pressure occurs when the reactive oxygen radicals weigh down the antioxidant protection mechanisms. Immune cells are extremely sensitive to oxidative stress due to the fact their mobile membranes contain polyunsaturated fatty acids which are oxidized by way of the reactive oxygen radicals resulting in extra reactive oxygen radicals. Several trace minerals and nutrients are crucial for an effective antioxidant protection gadget. An antioxidant including vitamin A and selenium are important inside the weight-reduction plan of transition animal due to its capability to neutralize ROS, thereby prevents inflammation.

Selenium and Vitamin E

Selenium is an essential micronutrient for metabolic processes, and it is a cofactor of many enzymes and selenoproteins such as glutathione peroxidase, iodothyroninedeiodinases, selenoprotein P (the main serum selenoprotein, a glycoprotein that contains around 10 selenocysteine residues, binds up to 60% of micronutrients and acts as selenium transport protein, SeP) and selenoprotein W, found in skeletal muscles, heart and brain (Whanger, 2000; Zarczynska *et al*., 2013). Selenium and vitamin E are complementary in allowing the cow to handle immune system challenges (Khatti *et al*., 2017). Both selenium and vitamin E are required to optimize the effectiveness of neutrophils when attacking and destroying invading bacteria. Chemotactic migrations of neutrophils closer to invading organisms become reduced by way of a selenium

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deficiency in goats (Aziz and Klesius, 1986).The complementary nature of selenium and vitamin E in lowering the incidence and severity of mastitis turned into really proven by Smith *et al.* (1984).

Selenium deficient cows had greater peak bacteria concentrations in milk than selenium supplemented cows (Erskine *et al*., 1990) and the plasma concentration of vitamin E decreased throughout the transition period because vitamin E is used in the colostrogenesis (Weiss *et al*., 1990) and antioxidant status imbalance is associated with transition cow disorders (Mudron *et al*., 1997). Numerous trials have proven that selenium supplementation of selenium-poor diets reduced the occurrence of retained placentas in dairy cows. Often, if dairymen suspect a deficiency, they wonder whether selenium should be given by injection rather than feeding due to variation in feed intake by individual cows. Reduced concentrations of vitamins A and E, and Zn, are also observed at calving, which also can have negative effects on the immune system.

Copper

Copper is important to the antioxidant system because it is part of the copper-zinc superoxide dismutase enzyme. This enzyme helps convert superoxide radicals to hydrogen peroxide in the cell. Copper deficiency can arise in diets generally considered good enough due to high levels of antagonists including sulfur, iron, and molybdenum which reduce bioavailability. Copper is involved in Cu-Zn superoxide dismutase (SOD) enzymes and ceruloplasmin in the antioxidant system. Cu-Zn SOD is responsible for dismutation of superoxide radicals to hydrogen peroxide in the cytosol (Halliwell and Gutteridge, 1999). Supplementing Cu in the diet affects phagocytic as well as specific immune function (Spears, 2000; Weiss and Spears, 2006). Harmon (1998) explicit that supplementation of heifers with the marginally copper deficient diets (6-7 mg Cu/kg diet) leads to 60% infected mammary glands at calving compared to 36% in heifers supplemented with normal copper containing diets (20 mg Cu/kg).

Zinc

Zinc is essential as a cofactor for over 80 enzymes, many of which are needed for the synthesis of DNA or RNA and also synthesis of metallothionein; a metal binding protein that scavenges hydroxide radicals (Prasad *et al*., 2004). Thus zinc may impact immune function because of its essential role in cell replication and proliferation. Severe zinc deficiency in calves has been shown to impair immunity. Plasma Zn concentrations usually decrease in farm cows at birth, however typically comes back to traditional within three days. The precise role is yet to be fully identified and increased incidence of post-calving sickness has not been investigated.

Manganese

The effects of manganese on the health status of transition cows have not been fully explored. Manganese plays an important role in immune and nervous systems, and together with zinc and copper, it is a cofactor

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of SOD. Manganese also influences carbohydrate and lipid metabolism (Andrieu, 2008). There is limited evidence to indicate that manganese supplementation has a positive influence on bovine mammary glands by increasing the ability of macrophages to eliminate bacteria responsible for mastitis (Linn *et al*., 2011). Manganese also plays an important role in the synthesis of cholesterol which is essential for the production of steroid hormones such as progesterone (Tuckey, 2005). A manganese deficiency can inhibit the synthesis of the above hormones and lead to reproductive disorders. Krolak (1968) reported that manganese supplementation can shorten postpartum anestrous and increase fertilization success during the first estrus after calving.

Chromium

It is a Component of Glucose Tolerance Factor (GTF). The daily dietary intake of chromimum for dairy cattle is set at 0.5mg/kg DM (FDA, 2009). Burton *et al.* (1996) found an increase lymphocyte blastogenic responses and reduced cytokine (IL-2, interferon, TNF-α) production by mononuclear cells in cows receiving 0.5 mg of chromium/kg of feed after stimulation with concanavalin A. Chromium Potentiate the insulin activity and facilitate interaction between insulin and insulin receptor in target tissue. It is believed that chromimum indirectly influences the immune system by exerting antagonistic effect on cortisol (Soltan, 2010; Kafilzadeh *et al*., 2012). Chromimun helps insulin metabolism and glucose utilization and its supplementation with feed reduce the occurrence of ketosis. A reduced amount of beta-hydroxybutyrate levels and triglyceride concentration in the serum as well as liver was found in cows whose diets were supplemented with chromimum amino acid chelate in the form of chromium picolinate (Besong *et al*., 2001). Studies in peri-parturient dairy cows reported that Cr supplementation in diets may affect cell-mediated and humoral immune responses. Some of the researchers reported that dietary supplementation one month before and two months after calving can significantly increase the feed intake during early lactation as well as milk production (Mcnamaraand Valdez, 2005; Smith *et al*., 2005).

Conclusion

The periparturient dairy cow experiences transition stress in terms of free radical burden and NEB, which impaired immune function. Eventually transition stress comes over a cost of post parturient disorder and downside reproduction. Careful nutritional management to provide highly bioavailable nutritional profiles and to maximize metabolic health is currently our best strategy to maximize immune function. Antioxidants supplementation along with additional energy is major ameliorative scheme. However, detailed studies with large sample size are warranted to clarify the complex interactions between nutrition and immunity during the transition period in dairy cattle.

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References

1. Andrieu S. 2008. Is there a role for organic trace element supplements in transition cow health? The Veterinary Journal. 176: 77-83.
2. Aziz ES, Klesium PH and Frandsen JC. 1984. Effects of selenium on polymorphonuclear leukocyte function in goats. American Journal of Veterinary Research. 45: 1715-1718.
3. Aziz E and Klesius PH. 1986. Effect of selenium deficiency on caprine polymorphonuclear leukocyte production of leukotriene B4 and its neutrophil chemotactic activity. American Journal of Veterinary Research. 47: 426-428.
4. Bell AW. 1995. Regulation of organic nutrient metabolism during transition from late pregnancy to early lactation. Journal of Animal Science. 73: 2804-2819.
5. Bertics SJ, Grummer RR, Cadorniga-ValinoC and Stoddard EE. 1992. Effect of prepartum dry matter intake on liver triglyceride concentration and early lactation. Journal of Dairy Science. 75:1914-22.
6. Besong S, Jackson JA, Trammell DS and Akay V. 2001. Influence of supplemental chromium on concentrations of liver triglyceride, blood metabolites and rumen VFA profile in steers fed a moderately high fat diet. Journal of Dairy Science. 84: 1679-85.
7. Bickerstaffe R, Annison EF and Linzell JL. 1974. The metabolism of glucose, acetate, lipids and amino acids in lactating dairy cows. The Journal of Agricultural Science. 82: 71-85.
8. Burton JL, Nonnecke BJ, Dubeski PL, Elsasser TH and Mallard BA. 1996. Effects of supplemental chromium on production of cytokines by mitogen-stimulated bovine peripheral blood mononuclear cells. Journal of Dairy Science. 79: 2237-2246.
9. Burvenich C, Van MerrisV, Mehrzad J, Diez-FraileA and DuchateauL. 2003. Severity of E. coli mastitis is mainly determined by cow factors. Veterinary research. 34: 521-64.
10. Butler WR and Smith RD. 1989. Interrelationship between energy balance and postpartum reproductive function in dairy cattle. Journal of Dairy Science. 72:767-83.
11. Drackley JK, Dann HM, Neil Douglas G, JanovickGuretzky NA, Litherland NB, Underwood JP and Loor JJ. 2005. Physiological and pathological adaptations in dairy cows that may increase susceptibility to periparturient diseases and disorders. Italian Journal of Animal Science. 4: 323-344.
12. Erskine RJ, Eberthart RJ and Scholz RW. 1990. Experimentally induced Staphylococcus aureus mastitis in selenium-deficient and selenium-supplemented dairy cows. American Journal of Veterinary Research. 51: 1107-1111.
13. Federal Drug Administration (FDA). 2009. Regulatory Discretion Letter from U.S. Food & Drug Administration Center for Veterinary Medicine to Kemin.pp. 485-543.
14. Grummer RR. 1995. Impact of changes in organic nutrient metabolism on feeding the transition dairy cow. Journal of Animal Science. 73: 2820-2833.
15. Grummer RR, MashekDG and HayirliA. 2004. Dry matter intake, and energy balance in the transition period. Veterinary Clinics: Food Animal Practice.20:447-470.
16. Halliwell B and Gutteridge JMC. 1999. Oxidative stress and antioxidant protection: some special cases. Free radicals in biology and medicine.pp.485-543.
17. Harmon RJ. 1998. Trace minerals and dairy cattle: importance for udder health. In *Biotechnology in the Feed Industry*, Nottingham University Press, Nottingham, UK. pp. 485-495.
18. Kafilzadeh F, Shabankareh HK and TargHibi MR.2012. Effect of chromium supplementation on productive and reproductive performances and some metabolic parameters in late gestation and early lactation of dairy cows. Biological trace element research. 149: 42-49.
19. Khatti A, Mehrotra S, Patel PK, Singh G, Maurya VP, Mahla AS and KumarH. 2017. Supplementation of vitamin E, selenium and increased energy allowance mitigates the transition stress and improves postpartum reproductive performance in the crossbred cow. Theriogenology. 104: 142-148.
20. Krolak M. 1968. Effect of adding Mn salt to the diet on fertility and Mn content of the hair of cows. Polskie Archiwum Weterynaryjne. 11: 294-303.
21. Linn JG, Raeth-Knight M and Golombeski GL. 2011. Trace minerals in the dry period – boosting cow and calf health. Advances in Dairy Technology. 23: 271-286.

22. Mallard BA, Dekkers JC, Ireland MJ, Leslie KE, Sharif S and Lacey Vankampen C. 1998. Alteration in immune responsiveness during the periparturient period and its ramification on dairy cow and calf health. Journal of Dairy Science. 81:585-95.
23. Mcnamara JP and Valdez F. 2005. Adipose tissue metabolism and production responses to calcium propionate and chromium propionate. Journal of Dairy Science. 88:2498-2507.
24. Mudron P, Rehage J, Sallmann HP, Mertens M, Scholz H and KovacG. 1997. Plasma and Liver α-tocopherol in Dairy Cows with Left Abomasal Displacement and Fatty Liver.Transboundary and Emerging Diseases. 44:91-97.
25. Prasad AS, Bao B, Beck FW, Kucuk O and Sarkar FH. 2004. Antioxidant effect of zinc in humans.Free Radical Biology and Medicine. 37: 1182-1190.
26. Radwińska J andŻarczyńskaK. 2014. The effects of mineral deficiency on the health of young ruminants.Journal of Elementology. 19: 915-928.
27. Smith KL, Waldron MR, Drackley JK, Socha MT and Overton TR. 2005. Performance of dairy cows as affected by prepartum dietary carbohydrate source and supplementation with chromium throughout the transition period. Journal of Dairy Science. 88: 255-263.
28. SmithTR, Hippen AR, Beitz DC and Young JW. 1997. Metabolic characteristics of induced ketosis in normal and obese dairy cows. Journal of Dairy Science. 80: 1569-1581.
29. Sobiech P, Żarczyńska K, Rękawek W, Snarska A, Eleusizowa A, Kowalczyk E and IllekJ. 2015. Effect of parenteral supplementation of selenium and vitamin E on selected blood biochemical parameters in H-F cows during the transition period. Med. Weter. 71: 683-689.
30. Soltan MA. 2010. Effect of dietary chromium supplementation on productive and reproductive performance of early lactating dairy cows under heat stress. Journal of Animal Physiology and Animal Nutrition. 94: 264-272.
31. Sordillo LM and Raphael W. 2013. Significance of metabolic stress, lipid mobilization, and inflammation on transition cow disorders. Veterinary Clinics: Food Animal Practice. 29: 267-278.
32. Spears JW. 2000. Micronutrients and immune function in cattle. Proceedings of the nutrition society. 59: 587-594.
33. Tuckey RC. 2005. Progesterone synthesis by the human placenta. Placenta. 26: 273-281.
34. Weiss WP and Spears JW. 2006. Vitamin and trace mineral effects on immune function of ruminants. Ruminant Physiology. Digestion, Metabolism and Impact of Nutrition on Gene Expression, Immunology and Stress. 473-496.
35. Weiss WP, Hogan JS, Smith KL and Hoblet KH. 1990. Relationships among Selenium, Vitamin E and Mammary Gland Health in Commercial Dairy Herds. Journal of Dairy Science. 73(2): 381-390.
36. Whanger PD. 2000. Selenoprotein W: a review. Cellular and Molecular Life Sciences. 57: 1846-1852.
37. Żarczynska K, Sobiech P, Radwinska J and RekawekW. 2013. The effects of selenium on animal health. Journal of Elementology. 18: 329-340.

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