Micronutrient deficiencies and disease in transition cows

Sinnéad Oakes MVB MRCVS discusses the metabolic and immunological challenges of the transition cow and the role micronutrients play in helping to fight disease challenge in this period

As the world population continues to grow, there is an ever-increasing need for affordable food production. Escalating demand combined with fiercely competitive commercial markets have contributed to the global intensification of agriculture. Pressure is applied to every aspect of the food-production chain to achieve marginal increases in yield and efficiency while decreasing outlay. The extensive impact of intensification on soil has led to international concern that 'hidden micronutrient deficiencies are far more widespread than is generally suspected' prompting a call-to-action to 'avoid production problems related to the quantity and quality of foods and feeding stuffs.'[1] Relying on chemical fertilisers (which focus on the main macronutrients) rather than manure, increased yields, use of monocultures, leaching and the excessive application of lime have all been identified as drivers underlying the exhaustion of micronutrients from soil. The more traditional diverse sward type, clovers, weeds and herbs all contained higher levels of trace elements (TEs). In contrast, contemporary commercial agriculture favours fast-growing (fertilised) lush pasture which are typically low in TEs.

CONCERN

The dominant concern regarding TE deficiencies in soil in ruminant farming is the consequent deficiency in animal feeds. Accurate assessments of TE requirements for individuals are complex and are affected by genetics, the physiological status of the animal (lactation, gestation, growth, reproduction, etc.), or the presence or absence of disease. In addition, interactions between ingested nutrients can affect the absorption of a particular TE, how it gets distributed or sequestered in the body or how it is stored or utilised at tissue level.[2] Due to genetic selection and a host of management and nutritional factors, the yield of dairy cows is ever increasing. In Ireland, between 2016-2018, the average yield per cow increased from 5,316L to 5,438L, equating to a rise of 2.3% in just three years. The 2025 prediction is a continuation of this upward trajectory to ≥5,573L/cow.[3] Such increases in yield creates a concomitant increase in nutrient and micronutrient requirements. The escalating utilisation of micronutrients in high-performing animals against a milieu of falling supply levels has prompted considerable research in this domain. Evidence continues to emerge to support the thinking that addressing micronutrient requirements to ensure adequate supply is paramount in the transition cow to optimise health, reproductive efficiency, milk yield and welfare. It is also notable that the guidelines for requirements for beef and dairy cows were last updated in the early 2000s.[4,5] It is reasonable to suspect that, given the genotypic and phenotypic evolution in cattle and cows since then, that these National Research Council (NRC) recommendations may not continue to be an accurate assessment of current requirements of high-producing animals.[6]

TRANSITION PERIOD

The transition period of a dairy cow is typically defined as the phase starting three weeks before to three weeks after parturition.[7] It is characterised by interrelated alterations in physiology, metabolism and immunity, specifically negative energy balance (NEB), immunosuppression and increased disease susceptibility. At the onset of lactation partitioning of ingested nutrients to milk production creates a two-to-five-fold increase in demand for amino acid, fatty acids and glucose.[8] Consequently, lipid reserves are mobilised resulting in increased levels of non-esterified fatty acids (NEFAs).[9,10] Although the precise mechanism is not fully understood, it is widely acknowledged that elevated NEFAs contributes to the impairment (hyporesponsive) of neutrophil function such as reduced chemotaxis, phagocytosis, or reactive oxygen species (ROS) production.[11] The resultant dysfunctional inflammation has been found to be temporally associated with a host of peri-partum disorders including mastitis, metritis, ketosis, retained foetal membranes.[10] Furthermore, cows affected by one such disorder have increased risk of succumbing to another due to the commonality in underlying aetiology.[12]

ROLE OF TRACE ELEMENTS

The essential role of TEs and vitamins in milk production, reproduction and disease resistance in transition cows is widely reported. Work by several authors have demonstrated a significant positive effect of supplying exogenous micronutrients on NEFAs with the conclusion that supplementation of TEs and vitamins to transition cows had a positive effect on blood glucose stability, protein metabolism, NEB and mobilisation of lipids.[13,14] The metabolic activity and cellular metabolism experienced by transition cows gives rise to increases in reactive oxygen species (ROS). If the antioxidant capacity is exceeded, the reduction-oxidation (redox) homeostasis is lost and accumulation of ROS leads to oxidative destruction of cellular macromolecules including proteins, DNA, etc. The main target for ROS, however, is lipid and significant lipid peroxidation is a feature of transition cows.[15,16,17] This has been demonstrated using in vitro studies in which bovine endothelial cells, when subjected to oxidative stress thereby inducing lipid peroxidation, ultimately experienced compromised endothelial and immune cell function.[18,19] Broadly, oxidative stress impairs the physiology, metabolism, immunity and reproduction of the transition cow and increases her susceptibility to a host of periparturient diseases.[20,21] Functional deficiencies of micronutrients in transition cows arising from a combination of reduced intake decreased dry matter intake (DMI) and increased utilisation will facilitate the development of this oxidative stress.[22]

Micronutrients are a key component of several antioxidants which are paramount to mitigate the aforementioned oxidative stress. An example of such is selenium, a component of the glutathione peroxidase enzymes which reduce reactive hydrogen peroxide and fatty acid hydroperoxides to water and alcohol. Copper (Cu) and Zinc (Zn) are both components of the Cu-Zn superoxide dismutase enzymes which cause the dismutation of superoxide radicals to hydrogen peroxide. Manganese functions as a cofactor in several enzymes such as mitochondrial superoxide dismutase. An additional role of antioxidants is to act as free radical scavengers which they achieve by donating an electron to a ROS creating a stable radical. The vitamin A precursor β-carotene and vitamin E (α-tocopherol) have important roles in free radical scavenging. Detailed reviews of the roles and contributions of individual micronutrients in the transition cow are widely available.

CONCLUSION

Managing the transition cow effectively to achieve optimum cow health, calf health, reproductive health and milk yield absolutely requires proper consideration of the micronutrient status and supply. An additional point of note is that the micronutrient supply to the antenatal calf is maternal, and this continues to be relied on in the postnatal period, further emphasising the importance of adequate micronutrient supply for the transition cow.[23,24] In the face of variable DMI, variations in micronutrient levels available in forage and (particularly in the case of some vitamins) degradation in conserved forage, an exogenous supply via a rumen deposited bolus (eg. a dry cow bolus) provides a favourable, practical option for farmers. This obviates the reliance on voluntary intake (eg. as feed or water additive) which may relatively disadvantage the weaker animals. The slow-release aspect of the bolus aims to supply the animal with a constant daily dose of micronutrients for the duration of the life of the bolus, regardless of DMI. Achieving optimal performance from high yielding animals demands a holistic, multidisciplinary approach, a key constituent of which is ensuring micronutrient requirements are correctly supplied and available to the animal.

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