The perils of poor nutrition

Alice Fraser of SVS Labs examines the intimate link between livestock nutrition and immunity.

LIVESTOCK NUTRITION AND IMMUNITY – KEY TO DISEASE PREVENTION

Nutrition is key to the optimal body condition of the dairy cow, which is required for the heavy demands of her genetically controlled, high-production output. Body condition score (BCS) that is below ideal decreases reproductive efficiency, milk production and immunity, and increases susceptibility to disease.

This article reviews the interrelationship of the nutrition and immune functions, focusing mainly on the dairy cow.

1. STRESS

The hard-working dairy cow is put under tremendous 'stress' factors, including nutritional and energy balance stressors (Table 1), most notably during the transition period.

In the 1930s Hans Selye introduced the term 'stress' into the medical field when he proposed that the body would respond in the same physiological manner to all adverse stimuli ('stressors') in an effort to maintain homeostasis. Eight decades later, research has shown that the body does not mount an all-or-none activation of the hypothalamic-pituitary axis (HPA), but rather elicits a physiological response of a magnitude necessary to maintain or return the body to homeostasis.

Research in different species has found that the brain has the ability to distinguish between stressors, such that specific stressors act on different adrenocorticotropic hormone (ACTH) stimulators. For example, haemorrhage causes a release of corticotropin-releasing hormone (CRH), vasopressin (VP), oxytocin and catecholamines, but during hypotension only CRH is released. The end effect is an increased release of glucocorticoids (GCs) from the adrenal gland.

The biological effects of GCs are well documented and include metabolism of carbohydrates and protein, alterations in growth and reproductive axes, regulation of the stress response and influence on overall immune function. GCs support the primary defence response by enhancing the synthesis/release of catecholamines necessary for the flight/fight response. GCs suppress the inflammatory response, which initially is advantageous to the organism, preventing systemic disease.

However, chronic exposure to high concentrations of GCs eventually leads to excessive protein catabolism, hyperglycaemia, immunosuppression and excessive inflammation. In dairy cattle, this means reduced rates of reproduction, suboptimal growth, suppressed milk production, suppression of the immune function (with increased susceptibility to disease) and potential for chronic inflammatory disorders.

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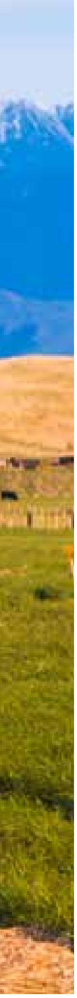


The mechanism of immunosuppression is partly due to a built-in safety precaution to down-regulate the immune effector cells (under continual GC stimulation) to prevent a large-scale immune response attacking body tissues. In time this causes tolerance of the immune effector cells to GCs, which also reduces the control on the inflammatory response. Immune cells such as lymphocytes have receptors for both GCs and catecholamines, which influence cellular trafficking, cellular proliferation, cytokine secretion, antibody production and cytolytic activity (Padgett and Glaser, 2003). Chronic GC release causes increased apoptotic cell death of lymphocytic cells within lymphoid organs and resultant lymphopenia (or low-normal lymphocyte counts).

2. IMMUNE RESPONSE REQUIRES ENERGY AND PROTEIN

There are well-documented mineral and vitamin requirements for optimal immune system function (eg selenium), a review of which is outside the scope of this article. However, the overall effect of nutritional status and energy balance on the immune system is also key. The nutritional status of dairy cows is widely recognised as being closely linked to the maintenance of optimal immune function and health (Sordillo, 2016). Nutritional requirements vary considerably throughout the production cycle of dairy cows, and any mismanagement of dietary requirements is associated with dysfunctional responses and associated health disorders. Both over- and under-conditioned dairy cows have a higher incidence of disease than optimally conditioned cows during the early lactation period (Heuer et al., 1999). The fat cow syndrome has been well documented, but since the average BCS of the dairy cow in New Zealand has decreased (Macky, 2010), the thin cow is more commonly a problem than the fat cow syndrome. Underconditioned cows suffer from insufficient energy and protein reserves required for disease resistance (Hoedemaker et al., 2009).

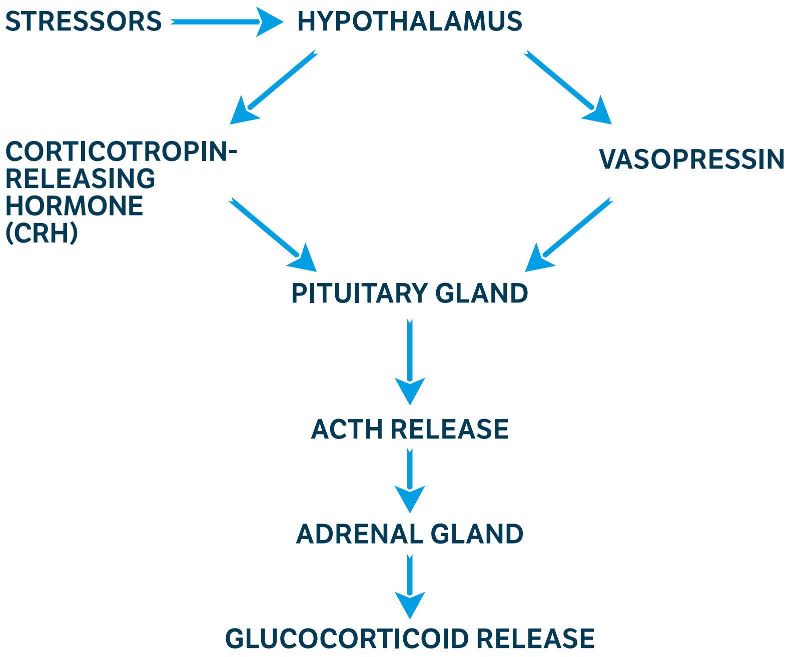
There are two branches of the immune system to consider.

1. **Innate immune response**
   This is the first line of defence against microorganisms, including phagocytosis (eg, neutrophils and activated macrophages), the complement system and cytokine release (proinflammatory factors). The innate immunity is strengthened or weakened by wounds, dehydration, nutritional status, genetics and stress (Carroll and Forsberg, 2007).
2. **Adaptive/acquired immune response.** This involves both humoral immunity (antibody production, B lymphocytes) and cell-mediated immunity (T lymphocytes).

TABLE 1.
LIVESTOCK STRESSORS

TYPE	STRESSORS
Psychological: fear	Mixing new mobs
	New environments
	Loud/unusual noises
Physiological	Nutrient restrictions
	Nutritional deficiencies
	Negative energy balance
	Endocrine factors (pregnancy, parturition)
Physical	Injury
	Hunger, thirst
	Thermal stress (heat/cold)
	Fatigue

FIGURE 1.
OUTLINE OF NEUROENDOCRINE EFFECTS OF STRESSORS



IMMUNITY REQUIRES ENERGY AND PROTEIN. **OPTIMAL NUTRITION IS KEY IN AN EFFICIENTLY FUNCTIONING IMMUNE SYSTEM.**

These two systems intercommunicate, with signals from the innate response regulating the adaptive response. Adequate levels of energy are therefore essential for these cellular activities, which mount optimal immune functions (Calder, 2013). Cells of the immune system can fuel their functions through available fatty acids, glutamine or glucose, with different levels of efficiency.

Immunity requires energy and protein. Optimal nutrition is key in an efficiently functioning immune system.

LABORATORY SIGNALS

Biochemistry changes

Non-esterified fatty acids (NEFAs) in dairy cows are often analysed to indicate decreased energy balance and rapid mobilisation of fat stores. However, the majority of modern ill dairy cows carry very low body fat stores, so there is little adipose tissue to mobilise and NEFAs are unlikely to increase. Instead, protein is catabolised and serum creatinine in sick cows is often decreased.

Although rarely analysed, urinary cortisol has been shown to be a relevant marker in monitoring adrenocortical activity in the dairy cow (Morrow et al., 2000).

In the haemogram, lymphopenia may be seen due to the chronic release of GCs. Low and low-normal lymphocyte counts are common, in addition to evidence of chronic inflammation.

RELATING STRESS FACTORS TO DISEASE

Mastitis, metritis and retained placental membranes are well-documented diseases relating to poor immunity during the transition period. The following are some examples of other significant common diseases related to the effects of stressors on the immune system.

Neosporosis

Neospora caninum is the most common cause of abortion in dairy cows in New Zealand (Weston, 2013). Once infected, a cow remains so for life, with latent (encysted) bradyzoites present in body tissues.

Reactivation of bradyzoites to tachyzoites, which can cross the placenta, can occur during pregnancy (vertical transmission), particularly at four to six months' gestation.

The immunomodulation for this reactivation is not yet entirely understood, but the downregulation of the acquired immune system during pregnancy, together with stressors such as inadequate nutrition (particularly during adverse weather) and concomitant fungal/listerial abortifacient infection (from poorly preserved winter silage), are known factors.

Salmonellosis

Salmonella is an opportunist, particularly in wet seasons (as seen in the recent winter/spring 2017). Any stressors affecting immunity, including parturition susceptibility, suboptimal nutrition and – in relation to peak production periods – overcrowding or increased challenge (pasture/shed contamination) lead to increased susceptibility to *Salmonella*. Changes in the gut flora and a suboptimal immune response predispose to a breach in the mucosal barrier to *Salmonella* organism colonisation and mucosal infiltration.

Bovine adenovirus

Found mostly in young replacement stock around 10 months of age, this viral disease has been seen more commonly in the past few years, causing severe diarrhoea and acute death. Another opportunist, this environmental virus takes advantage of the autumn/winter stressors.

SUMMARY: The continual maintenance and activation of immune responses requires energy and protein, also required by dairy heifers/cows for growth, pregnancy and milk production. Hence the calculation of optimal dairy livestock nutrition should allow for the nutrient requirements of the immune system, particularly at the most susceptible periods. If not, competition for these multiple demands on nutrients leads to increased stress and susceptibility to disease. (VS)

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