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Dairy producers along with their herd nutritionists and veterinarians are keenly aware that there is a cost to a cow's performance when she is under stress. The dairy cow is especially at risk for health problems around calving. During this time she is susceptible to physiological, metabolic, and infectious diseases. Changes to the cow's immune system, with an accompanying inflammatory response, often are associated with health disorders.

In an excellent review paper, Bradford et al. (2015) noted that studies have shown that "essentially all cows experience some degree of systemic inflammation in the several days after parturition." In addition, Sordillo (2015) stated that "...uncontrolled inflammation is a major contributing factor and a common link among several economically important diseases including mastitis, retained placenta, metritis, displaced abomasum, and ketosis."

Inflammation, dry matter intake, and energy balance

Researchers have shown that the sudden increase in nutrients required for milk production, coupled with a decrease in dry matter intake, unavoidably lead to negative energy balance in the cow (Grummer et al., 2004). Other researchers studied the relationship between the inflammatory condition at the time of calving and net energy efficiency in dairy cows. They found that cows with higher levels of inflammatory markers in the blood were significantly more likely to be in severe negative energy balance. These researchers attributed this condition to the animals' lower dry matter intake and to the higher energy required by the immune system (Trevisi et al., 2010).

Inflammation, energy, and milk production



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Esposito et al. (2014) created a diagram (Figure 1), which efficiently illustrates the interactions between the immune, endocrine, and metabolic systems in the dairy cow during the transition period. The authors noted that during the transition period there is a high amount of cellular metabolism as the cow's body prepares for calving and for milk synthesis. In addition, there is upregulation of immune gene expression, that is, there is an inflammatory response. The rise in cellular metabolism along with an inflammatory response increase the energy requirement when there is a reduction in dry matter intake (Esposito et al., 2014).

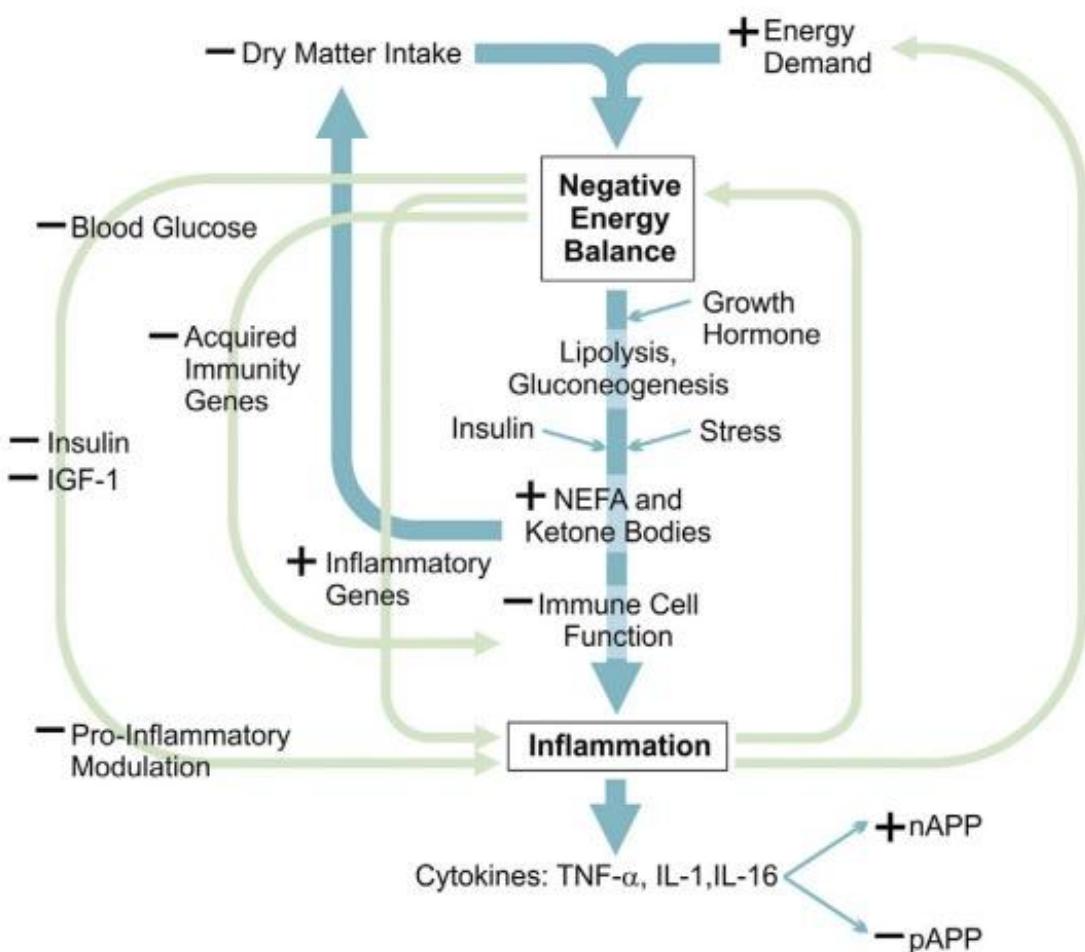


Figure 1. Major interactions between the immune, endocrine, and metabolic systems in dairy cows during the transition period. The symbols + and - indicate an increase (+) or a decrease (-) in biomolecule levels. NEFA, non esterified fatty acids; IGF-1, insulin-like growth factor 1; TNF-, tumor necrosis factor; IL-1 and IL-6, interleukin 1 and 6; nAPP and pAPP, negative and positive acute phase proteins (Esposito et al., 2014).

Glucose and the inflammatory response

Stoakes et al. (2015) conducted a study with dairy cows that estimated the glucose requirement of an activated immune system using lipopolysaccharide (LPS) to cause

an inflammatory response. Their three treatments were: (1) a non-challenged control group ($n = 6$); (2) an LPS infused group ($n = 6$); and, (3) an LPS plus euglycemic clamp group ($n = 6$). "Euglycemic" refers to maintenance of a normal blood sugar level. So in this study, the euglycemic clamp was used to add glucose (as dextrose) back into the bloodstream to maintain normal blood glucose levels, similar to that in the control group of cows.

The researchers took blood samples over a 12-hour period and determined that 90 g glucose/hour were utilized by this activated immune system. If this rate were extrapolated for a 24-hour period, a total of 2160 g (2.16 kg) of glucose would be utilized. Even when glucose (as dextrose) was infused to maintain normal blood glucose levels, there was still a decrease in milk production ($P < 0.01$) when compared to the non-challenged control cows (Stoakes et al., 2015).

The authors noted that this was an "intensely" activated immune system, suggesting that the inflammatory response might be higher than that normally experienced by a cow under stress. However, even if the glucose requirements of a cow undergoing an acute or chronic immune response is a fraction of what was seen in this study, the production cost would still be substantial.

Reynolds (2005) reviewed the glucose balance in cattle and noted that Elliot (1976) had developed an equation to estimate the glucose requirement for a lactating cow. Reynolds used that equation and assumed a lactose content in milk of 4.8% and that lactose output in milk accounts for 70% of the mammary glucose use. He then calculated that a cow producing 60 kg (132 lb.) of milk daily would have a mammary glucose requirement of more than 4 kg/day (8.8 lb./day):

$$60\text{kg milk} \times 0.048\text{ (% lactose in milk)} \div 0.70\text{ (milk lactose \% of mammary glucose use)} = 4.1\text{ kg glucose/day}$$

Calculating the "milk cost" of inflammation

If we use the Reynolds (2005) calculation and the results from the Stoakes et al. (2015) study (where 2.16 kg of glucose were utilized by the activated immune system), we can back calculate how much milk is represented by the activated immune system in a 24-hour period:

$$2.16\text{ kg (glucose)} \div 0.048 \times 0.70 = 31.5\text{ kg (69.5 lb.) of milk}$$

Again, Stoakes et al. (2015) induced an intense immune response that may not represent what happens to a cow after calving, or undergoing heat stress, or fighting a pathogen infection. However, even if the immune response were only 10% of what Stoakes and colleagues saw in their study, the milk represented is still substantial at 3.15 kg (6.95 lb.)!

The implications are clear: When a cow's immune system is activated, there is an energy cost as a result of an inflammatory response. While an acute and temporary inflammatory response is normal and necessary, as in the case of fighting an infection, an uncontrolled or chronic inflammation is not normal and can have adverse effects on the cow's health and her productive performance.

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