Enhancing Immunity of the Calf

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The immune system is composed of two main branches, the innate branch and the adaptive branch, that protect the body from attack. In many respects, an attack against the body by disease causing organisms can be compared to the attack of an army against a fort. The fort and its defenders can be compared to the body and the immune system. The walls of the fort are similar to the skin and mucous membranes of the body. They are physical barriers against an invasion by bacteria. The innate branch of the immune system (composed primarily of neutrophils) is similar to scouting parties that are patrolling the perimeter and have orders to engage any enemy they find. They are effective killers and can send an alarm. The commanding officers of the fort are similar to the monocyte/macrophage cells of the adaptive branch of the immune system. These cells take in much information about the invaders and send signals to other parts of the adaptive branch of the immune system about the best way to fight. The lieutenants and sergeants of the defending forces are similar to the T-cells of the adaptive branch. These cells convey the messages of the commanding officers to the troops defending the walls but they also have their own way of fighting as well. The troops lining the walls can be compared to B-cells in the adaptive branch of the immune system. B-cells are responsible for producing antibodies (or immunoglobulins, Ig) to be used in the fight against invading organisms. The antibodies can be compared to the bullets fired by the defenders in an attempt to repulse the invading army. If reinforcements had started for the fort at the first word of an impending attack, this would have been similar to the response of the immune system to a vaccination or previous exposure. With adequate reinforcements, the fort probably could hold against an invasion. Without reinforcements, the fort may be overwhelmed. When disease-causing organisms overwhelm the defenses of the immune system, an animal becomes sick. Eventually, perhaps with the aid of artillery (antibiotics), reinforcements may arrive to retake the fort and the disease may be banished from the land. Adding nutrition to the picture, certain nutrients may make the components of the immune system stronger, faster, and more prolific. Although it may not be the deciding factor in this scenario, it may bolster the strength of the fort and its defenders so they could hold the fort until the reinforcements and artillery arrive.

In many cases with calves, nutrition or specific nutrients may provide enough extra support to the immune system to allow the calf to hold on until reinforcements arrive. Calves are born with a naïve immune system that must be educated before it can mount an effective immune response on its own and generate its own reinforcements. For approximately the first three weeks of its life, the calf relies primarily on the antibodies acquired from colostrum to protect it against invaders. During the first three weeks of life, concentrations of Ig in the blood gradually decrease from the 24 hour value while there is an accompanying increase in numbers and percentages of B-cells (Franklin et al., 1998; Nagahata et al., 1991). After three weeks of age, Ig concentrations gradually increase as the immune system of the calf begins to provide its own bullets.

The health, performance, and survival of calves, especially during the first three weeks of life, rely on achieving high concentrations of Ig (antibodies) in the blood (Besser et al., 1991). Without question, the successful transfer of Ig from the cow (through colostrum) to the calf is an extremely important component for minimizing death losses of calves (Wells et al., 1996). The method used to supply colostrum to a calf can have a major impact on absorption of Ig and the concentration of Ig achieved in the blood. The majority of studies indicate that calves allowed to nurse their dam for their first colostrum intake may not achieve adequate transfer of passive immunity. Logan et al. (1981) compared serum Ig concentrations of calves that suckled only with those of calves that were left with the dam but were fed approximately 1 L of hand-milked colostrum by bottle for the first feeding. Results indicated that only 23.2% of the calves allowed to suckle naturally acquired sufficient Ig whereas 42.3% of calves fed 1 L of colostrum by hand and also were left with the dam to suckle acquired sufficient serum Ig concentrations. Nocek et al. (1984) reported that Holstein calves fed a total of 5.45 L of colostrum in three feedings by bottle during the first 12 h after birth had higher serum protein and serum IgG concentrations than calves that suckled. Besser et al. (1991) reported that failure of passive transfer (serum protein < 5.0 g/dl or IgG < 1000 mg/dl) occurred in 61% of Holstein calves allowed to suckle at birth compared to 19% failure of passive transfer in calves fed 1.9 L of colostrum by bottle. Further, only 11% of calves experienced failure of passive transfer when fed 2.84 L of colostrum at birth.

We conducted a study utilizing 31 Holsteins calves that were either removed at birth and hand-fed colostrum from the dam or remained with the dam and allowed to nurse (Franklin et al., 2003). Hand-fed calves were fed 2.84 L (3 quarts) of colostrum at birth and 1.9 L (2 quarts) at 12 hours after birth. Serum protein concentrations at 24 hours after birth were greater in calves fed colostrum by hand even though calves allowed to nurse the dams were helped to nurse if they were observed to be having problems. One of the calves that was supposed to receive its colostrum by nursing its dam died during the study. The calf experienced failure of passive transfer of immunity as indicated by serum protein concentrations that did not increase above levels observed at birth.

One of the problems with allowing calves to nurse for their first meal of colostrum is that the quality of the colostrum is unknown. In one study, we administered oxytocin as soon after calving as possible and milked the cow with a portable milker in an attempt to collect all the colostrum produced by the cow (Franklin et al., 2004). We found that of 50 cows collected for the study, four of the cows (8%) produced an inadequate volume of colostrum to feed their calf two quarts of colostrum for the first feeding. Some produced no colostrum at all. We also found that a total of nine of the 46 remaining cows had very low colostrum quality ($\leq$ 50 mg/ml) as estimated by a colostrometer. Therefore, if the calves had been allowed to nurse their dam for their first feeding of colostrum, 26% would not have received either adequate volume or quality of colostrum.

We have found that colostrum quality declines during the summer at the University of Kentucky dairy farm. In the previous study, ten of eleven cows with colostrometer values at $\leq$ 60 mg/ml calved between May 1 and July 31. We also are collecting colostrum for a current study. We began collecting colostrum in December of 2003, and will continue through the end of 2004. Combining the two studies to date and comparing only the winter and summer samples, we found that the winter colostrum quality averaged 105 mg/ml (37 samples) compared with summer quality at 62 mg/ml (26 samples). This summer alone, we had colostrum from six cows that was measured at 40 mg/ml or less. We do not use colostrum with values of < 60 mg/ml. Therefore, it is extremely important to hand-feed calves colostrum that has been evaluated for quality.

The National Animal Health Monitoring System surveyed heifer calves on 1811 farms in 28 states and found that 40% had less than optimal concentrations of IgG (< 1000 mg/dl). In the United States, the most recent national data indicate that approximately 47% of calves are allowed to remain with the dam and nurse while 53% are removed prior to nursing (NAHMS, 2003). While part of the calves that remain with the dam are hand-fed their first colostrum, 30% of all calves received their first colostrum by nursing the dam only.

The most important method for enhancing immunity of calves, therefore, is to hand feed adequate amounts (preferably at least three quarts at birth and two quarts at 12 hours) of high quality colostrum (> 60 mg/ml) from healthy cows that have been vaccinated to provide antibodies against important pathogens of calves. A little extra time and trouble at the beginning of a calf's life may either save a lot of time, trouble, and expense a little later in the calf's life or save the calf's life.

In addition to proper feeding of colostrum at birth, several nutrients may enhance immune function of calves. Some of these include the fat-soluble vitamins A, D, and E, the water-soluble B vitamins and vitamin C, and minerals such as selenium, zinc, and copper. We were interested in determining the effects of vitamin A on health and disease resistance. One thing we learned is that if a little is good, it is not always true that a lot will be better. We supplemented groups of 16 calves with either 0, 1200 (the NRC, 1989 recommended levels of vitamin A), 34,000 (approximately the amount found in many milk replacers), or 68,000 (an excessive amount) IU of vitamin A/d (Hammell et al., 2000). We conducted liver biopsies to monitor vitamin A concentrations as an indication of vitamin A status. We found that calves are born with practically no vitamin A stored in their liver and apparently they like it that way. Even when we supplemented calves with 68,000 IU/d, liver stores of vitamin A did not increase to levels considered adequate until calves were approximately six weeks old. We also found that we obtained better growth rates in the calves with the 1200 IU/d supplementation rate and that plasma levels of vitamin E were decreased in calves supplemented at the two highest rates of vitamin A. A subsequent study investigated levels of supplementation between the 1200 and 34,000 IU rates we used and showed that the most effective rate of supplementation was at 10,000 IU of vitamin A/d.

We have conducted several studies trying to determine how ambient temperature affects the immune system of calves and whether or not nutrition plays a role. Originally, we noticed that types of white blood cells present in the blood differed in winter versus summer calves (Sorenson et al., 1997). In fact, we noticed alterations in the white blood cell types when we would have a wide fluctuation in ambient temperature over a short period of time. This occurred in a project conducted while I was at South Dakota State University. While at the University of Kentucky, we have continued studies regarding effects of temperature on immune function (Meek et al., 2004). We monitored white blood cell types present in blood of heifers during ambient temperature fluctuations from hot to warm to cold, then back to warm. We found that the same general alterations in white blood cell types occurred in calves in Kentucky as occurred in calves in South Dakota. The alterations were not as dramatic, however. A subsequent study led us to believe that the alterations in white blood cell types were in response to a need for extra energy. If calves consumed adequate energy during cold weather, the alterations in white blood cell types did not occur.

Finally, one of our recent studies evaluated the impact of supplementing cows with mannan oligosaccharide (MOS) during the close-up dry period on immunity of the cows and transfer of immunity to their calves (Franklin et al., 2004). We used data from 39 cows to compare the effects of a control diet (n = 19; 14 Holsteins and 5 Jerseys) versus a diet supplemented with MOS (n = 20; 14 Holsteins and 6 Jerseys) on immune parameters of cows. Data from their calves, including one set each of Holstein and Jersey twins, were analyzed for effects of the control diet (n = 19) versus the MOS diet (n = 22) on transfer of passive immunity to the calves. At 4 weeks prior to expected calving, blood samples were obtained from the cows and they were vaccinated against rotavirus. At 3 weeks before calving, cows were weighed, assigned to treatments, and moved to the close-up dry cow lot where they were fed the control diet or the control diet plus MOS. Cows were vaccinated a second time at 2 weeks before calving and blood samples were obtained through parturition. The cows were milked as soon after calving as possible. All cows received an intramuscular injection of oxytocin to facilitate complete removal of colostrum. The colostrum was weighed and the quality was estimated using a colostrometer. Colostrum samples were frozen for later analysis of Ig concentrations and rotavirus titers. Calves were separated from the cows prior to suckling. Blood samples were obtained at birth and 24 hours after the first feeding. Maternal colostrum was fed at the rate of 1.9 L for Holstein calves and 1.2 L for Jersey calves both at birth and 12 h after the first feeding. Blood samples were analyzed for serum protein concentrations, serum Ig concentrations, rotavirus titers, packed cell volume, white blood cell counts, and white blood cell types.

The most important findings of this study are presented in Table 1. Feeding MOS during the close-up dry period resulted in significantly greater serum rotavirus titers in cows at calving, numerically greater titers in colostrum, and a tendency for greater serum rotavirus titers and serum protein concentrations in their calves. Measures of nonspecific immunity, such as Ig concentrations and white blood cell counts, were not affected by feeding MOS. The results of this study indicate that it is possible to enhance the immune response of cows during the dry period by feeding a nutritional supplement. The ability of MOS supplementation to enhance the rotavirus neutralization titer in serum of cows immunized against rotavirus, together with the tendency for an enhancement of rotavirus titers in the serum of their calves, provides evidence that improved intestinal protection against rotavirus in calves may be achieved because of the potential for transfer of rotavirus antibodies from the bloodstream to the intestine (Besser et al., 1988). Parreno et al. (2004) reported that elevated rotavirus titers in colostrum provided newborn calves with enhanced protection against rotavirus, resulting in fewer calves with symptoms and fewer days of diarrhea compared with calves fed colostrum from cows not immunized against rotavirus.

The enhancement in the immune response of cows to rotavirus immunization is an indication that responses to other pathogens of economic importance may also be enhanced through supplementation of dry cows with MOS. Further studies are needed to investigate potential benefits of supplementation with nutrients during the dry period on health and disease resistance of the cows during the transition period and transfer of passive immunity to their calves.

Table 1. Effects of supplementation of close-up dry cows with mannan-oligosaccharide (MOS) on immune function and transfer of passive immunity to their calves.

	Control	MOS	Control	MOS	*P* values
	-4 weeks		Calving		
Serum rotavirus titers of cows	977	1071	2344	2818	0.04
Colostrum rotavirus titers			21,777	26,009	n.s.
	Birth		24 hours		
Serum rotavirus titers of calves	110	126	4677	7244	0.08
Increase in serum protein concentrations of calves			1.4	1.8	0.08

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