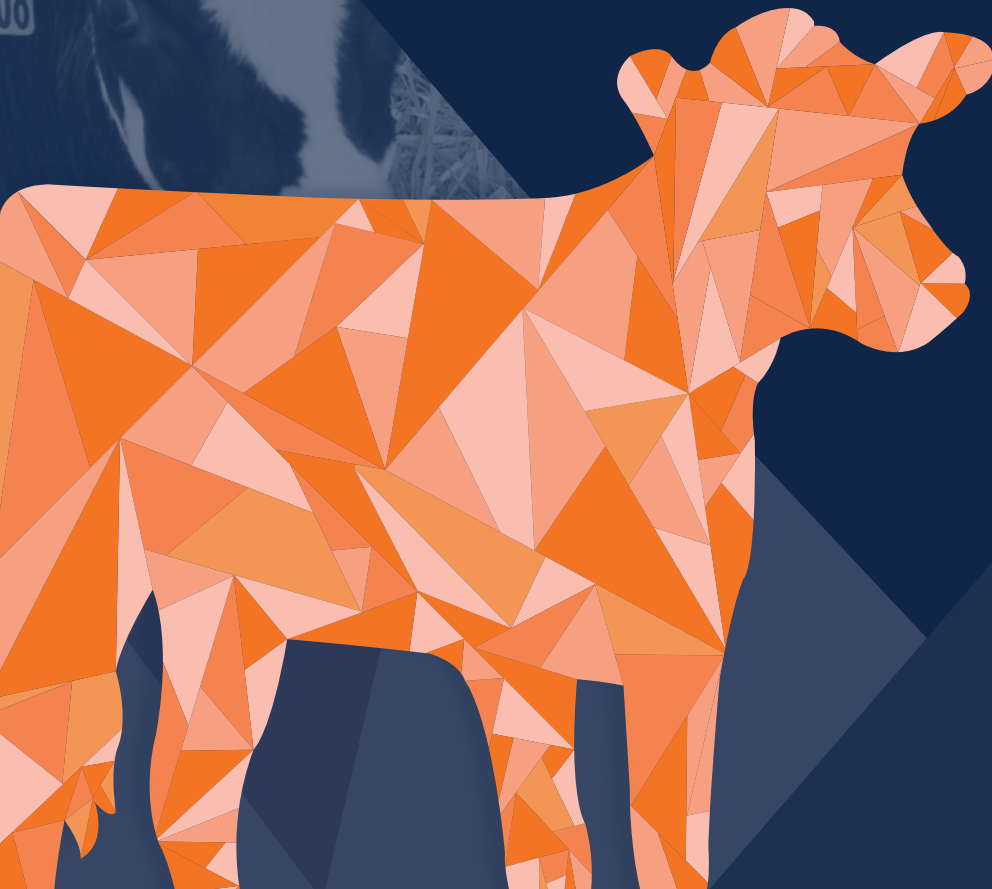


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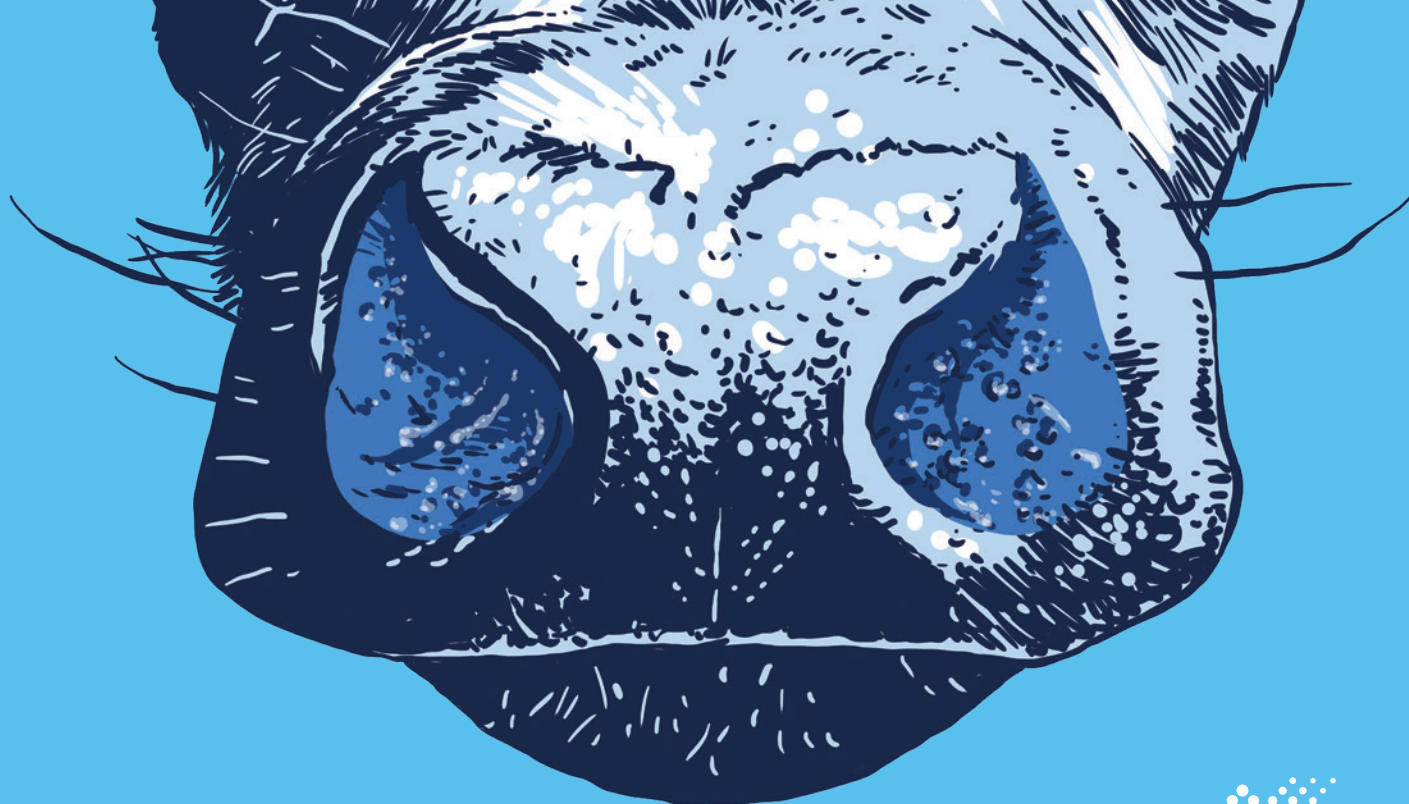
CONFERENCE AGENDA

WEDNESDAY, APRIL 8

- 8:30 a.m.** **Pair housing of calves can be done using outdoor hutches**
Jennifer Van Os, Kim Reuscher and Rekia Salter, University of Wisconsin-Madison
Sponsored by: Calf-Tel
- 9:30 a.m.** **New passive transfer standards for dairy calves and how to achieve them**
Jason Lombard, U.S. Department of Agriculture Centers for Epidemiology and Animal Health
Sponsored by: Land O'Lakes Animal Milk Solutions
- 10:45 a.m.** **Why heifer maturity matters. The Peter Pan problem**
Gavin Staley, Diamond V
Sponsored by: Diamond V
- 1:00 p.m.** **Disbudding practices: Present and future**
Sarah Adcock, University of California, Davis
- 2:00 p.m.** **Understanding the good, the bad and ugly of the innate immune response**
Chris Chase, South Dakota State University
Sponsored by: First Defense
- 3:15 p.m.** **Managing and marketing dairy x beef crossbred cattle**
Grant Crawford, Merck Animal Health
Sponsored by: Merck Animal Health

THURSDAY, APRIL 9

- 8:30 a.m.** **Why aren't we all dead? Building on Mother Nature's plan for inducing adaptive immunity through vaccinations**
John Ellis, Western College of Veterinary Medicine, University of Saskatchewan
Sponsored by: SCCL
- 9:30 a.m.** **Promoting a #WeanClean™ philosophy on your dairy**
Terri Ollivett, University of Wisconsin-Madison School of Veterinary Medicine
Sponsored by: Boehringer Ingelheim
- 10:45 a.m.** **Dairy industry collaboration on animal care**
Emily Yeiser Stepp, National Dairy FARM (Farmers Assuring Responsible Management) Program
- 11:45 a.m.** **Calf nutritional management in 2030: Challenging the dogma**
Michael Steele, University of Guelph
Sponsored by: Land O'Lakes Animal Milk Solutions



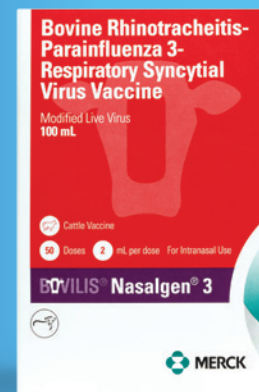
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PROCEEDINGS



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Understanding the good, the bad and ugly of the innate immune response

Christopher Chase, South Dakota State University, Brookings, South Dakota, USA

The innate immune system is the essential component of surveillance and mobilization response to infections and is necessary for a good vaccine response. However, it is dramatically affected by stress and these stress effects can cause the innate response to provide us too much of a “good thing.” Maintaining a balance (homeostasis) is a key feature as we understand that often disease is a result of too much innate response. I will concentrate in this brief paper on the effects, particularly on the gastrointestinal tract (GIT).

Good response

Having a “healthy microbiome” results in optimal GIT mucosa function. For example, certain clostridial species do a good job of producing butyrate. Butyrate and other small chain fatty acids have a calming effect and cause the GIT epithelium to be much calmer and inhibit that inflammatory response (Figure 1). These anti-inflammatory signals are not coming from the host side of GIT but from the bacteria along with metabolites. That’s why commensals are so important. They are affecting the host response. The host response is not to just the bacteria and other microorganisms, but also on microbial cell components and metabolites of bacteria. Very few of the metabolites and microbial components have been characterized, but the ones that have been the most characterized are the fatty acids, and particularly butyrate. Transforming growth factor-beta (TGF- β) is the cytokine that is induced that has the biggest anti-inflammatory effect. It converts naive T cells into Treg cells that then block inflammatory cells (T helper 1, Th1 and T helper 17, Th17) and produce IL-10 that turns on slgA production. Other lymphocytes also produce signals to make enterocytes produce more antibacterial peptides; again, this helps the defense mechanism (Figure 2). This achieves homeostasis in the GIT mucosa by inducing the protective responses to pathogens maintaining the regulatory pathways for tolerance to innocuous antigens and prevents inflammation, making for a happy gut and an animal that can more closely achieve its maximum genetic potential (Belkaid 2014; Khosravi 2013).

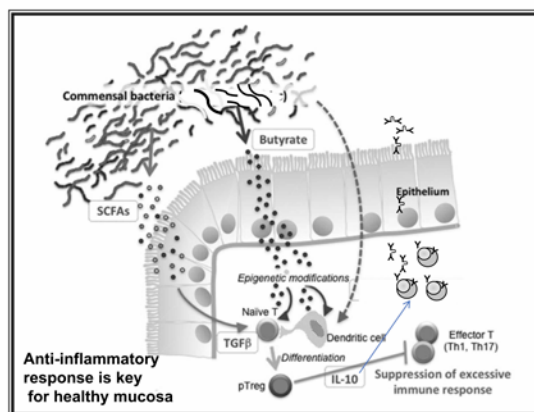
Bad response

When homeostasis is achieved between the GIT mucosa and microbiome, there is a solid “kill zone” and healthy microbiome (Figure 2, left half). When the microbiome is disrupted due to stress (weaning, transportation, parturition, surgical procedures, etc.), changes in feed intake (after weaning, feed changes, etc.), dehydration and/or the use of oral antibiotics, the microbiome becomes depleted and undergoes dysbiosis and the kill zone decreases and the mucosa becomes inflamed (Belkaid 2014)(Evans 2017) (Figure 2, right half). The innate immune system, particularly macrophages,

becomes activated and begins to produce interleukin-1 beta (IL-1 β), interleukin 6 (IL-6) and tumor necrosis factor alpha (TNF), and begins to recruit inflammatory cells (Figure 3) (Marchiando, 2010). TNF then stimulates a kinase pathway MLCK that results in the breakdown of the tight junctions and the development of leaky gut, which can be a vicious circle – more bacteria and antigens leak through and a more severe inflammatory response develops. The inflammatory mediators, TNF, IL-1 β and IL-6, enter the portal bloodstream and affect the liver and cause it to switch from being an efficient metabolism machine to becoming an inefficient “immune organ.” This results in poorer growth and performance of the animal (Iseri, 2013). If the “leak” and inflammation are controlled, the animal recovers but will expend energy for tissue repair and the activation of the liver, which will decrease performance (average daily gain, feed efficiency, etc.) (Iseri, 2013).

Figure 1.

Microbiome and Anti-inflammatory Response



Adapted from Cell 156, Issues 1–2, 2014, Pages 7

Figure 1. Microbiome and Anti-inflammatory Response. Commensal organisms (probiotics) can produce short chain fatty acids (SCFAs, i.e. butyrate), other metabolites (prebiotics) and/or microbial components (flagella, etc.) that induce the anti-inflammatory response (Sartor 2017). Transforming growth factor-beta (TGF- β) is the cytokine that is induced that has the biggest anti-inflammatory effect. It converts naive T cells into Treg cells that then block inflammatory cells (T helper 1, Th1 and T helper 17, Th17) and produce IL-10 that turns on slgA production. Other lymphocytes, like natural killer cells and innate lymphoid cells (ILC), also produce signals to make enterocytes produce more antibacterial peptides; again, this helps the “kill zone” defense mechanism (Figure 2).

Ugly response

The immune system is a major consumer of energy and in times of negative energy, like seen in the newly weaned calf or a transition cow, can be difficult times for the immune system to respond. In addition, the mobilization of energy from adipose tissue (fat) results in infiltration of macrophages as activity of adipocytes (fat cells) results in inflammation (Winer 2012). These macrophages are particularly sensitive to signals from gut bacteria, including endotoxin from Gram-negative bacteria (Cluny 2012). Animals with “leaky gut,” along with other metabolic or major stressors, are at higher risk. With diet changes that occur at weaning or at parturition for the dairy cow, the microbiome has major changing populations. This combination of adipose remodeling, macrophage activation and “revamped” microflora can result in a cytokine storm, which is the “bad inflammatory” response, described above, going crazy. A cytokine storm (hypercytokinemia) is the systemic expression of a healthy and vigorous immune system, resulting in the release of more than 150 known inflammatory mediators (cytokines, oxygen-free radicals and coagulation factors). It is an overreaction of the immune system. Both pro-inflammatory cytokines (TNF, IL-1 and IL-6) and anti-inflammatory cytokines (such as interleukin 10 and interleukin 1 receptor antagonist) are elevated in the serum of people or animals experiencing a cytokine storm. This results in systemic spillover affecting other systems. An animal with a systemic inflammatory response (cytokine storm) will not only have GIT symptoms but will have increased bovine respiratory disease, and in cows more severe mastitis and metritis. The development of cytokine storms in people are believed to be responsible for many of the human deaths during the 1918 influenza pandemic, which killed a disproportionate number of young adults. In this case, a healthy immune system may have been a liability rather than an asset. Preliminary research results also indicated this as the probable reason for many deaths during the sudden acute respiratory syndrome (SARS) epidemic in 2003 in China and likely the cause of deaths in the Coronavirus 2019 (COVID19) outbreak.

Figure 2

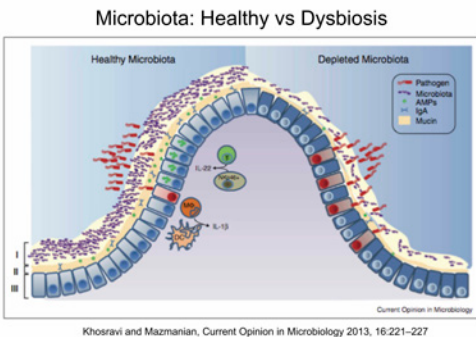


Figure 2. Healthy mucosal defenses and mucosal dysbiosis. The intestinal microbiota promotes three levels of protection against enteric infection. (I) Saturation of colonization sites and competition for nutrients by the microbiota limit pathogen association with host tissue. (II) “Kill Zone” – Commensal microbes prime barrier immunity by driving expression of mucin, immunoglobulin A (IgA) and antimicrobial peptides (AMPs) that further prevents pathogen contact with host mucosa. (III) Finally, the microbiota enhances immune responses to invading pathogens. This is achieved by promoting IL-22 expression by T cells and NK cells, which increases epithelial resistance against infection, as well as priming secretion of IL-1b by intestinal macrophages (MF) and dendritic cells (DCs), which promotes recruitment of inflammatory cells into the site of infection. In conditions in which the microbiota is absent, there is reduced competition, barrier resistance and immune defense against pathogen invasion.

Figure 3. Pathogenesis of leaky gut.

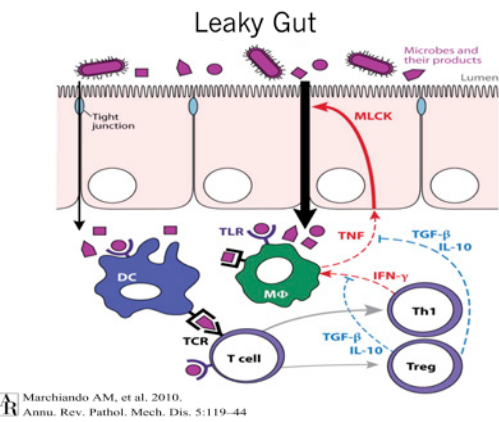


Figure 3. Pathogenesis of leaky gut. The epithelial barrier normally restricts passage of luminal contents, including microbes and their products, but a small fraction of these materials cross the tight junction. This diagram shows how dendritic cells (DC), macrophages (M) and T cells react to these materials. The naive T lymphocyte (T cell) responds to antigenic and other stimuli within the lamina propria, becoming a Th1-polarized cell (Th1), a T regulatory cell (Treg) or other differentiated T cell types. These innate and adaptive immune cells release cytokines that exert proinflammatory (TNF and IFN-γ) and anti-inflammatory (IL-10, TGF-β) effects. If proinflammatory signals dominate and signal to the epithelium, MLCK can be activated to cause barrier dysfunction, which would allow an increase in the amount of luminal material (“leaky gut”) presented to immune cells. In the absence of appropriate immune regulation, this activation may cause further proinflammatory immune activation, cytokine release and barrier loss, resulting in a self-amplifying vicious cycle that can result in disease. Abbreviations: IL, interleukin; MLCK, myosin II regulatory light chain kinase; TGF, transforming growth factor; TNF, tumor necrosis factor.

Modulation of the response

What can we learn from human medicine? Although we have been using prebiotics, probiotics, essential oils and/or organic acids in animal production for years, the approaches have often been empirical and based on one or two components with little understanding of the mechanism of action. In looking at human medicine and the prevention and treatment of inflammatory bowel disease, there has been a more holistic multipronged approach developed (Figure 4) (Santor, 2017). Like veterinary medicine, the initial approaches for prevention and/or treatment of GIT disease were pharmaceutical based, with antibiotics being a major tool. Using a multipronged approach in humans has been aimed at reducing the use of exogenous corticosteroids and/or antibiotics (Figure 4, circle lower left). There are several GIT health goals from these multipronged approaches. First, maintain a healthy “kill zone” and mucosa and block specific pathogen attachment (Figure 4, center green box). Second, correct dysbiosis and restore normal microbial function (Figure 4, upper left blue box), and normalize the immune dysfunction and repair barrier defects (Figure 4, upper right lavender box). These approaches may be accomplished by using traditional approaches (probiotics, organic oils, high fiber diets or combinations of these), cutting edge methods (fecal microbial transplants, synthetic mixtures of defined microbes [personalized for an individual’s specific microbiota profile] and personalized diets). Then, there are novel experimental approaches (bacteriophages targeting key aggressive bacteria, using synthetic microbial metabolites or recombinant bacterial species) that also have promise.

In livestock, we have several other unique approaches to improving GIT health in addition to the traditional approaches (probiotics, organic oils, high fiber diets or combinations of these). These approaches include prebiotics (refined functional carbohydrates [RFC]; inhibiting bacterial attachment, promoting a more anaerobic environment; blocking bacterial receptors; stimulating protective mammalian pathways), mixtures of defined microbes based on culture and sensitivity testing that are herd and/or region specific, and hen egg IgY antibodies against specific organisms. With ruminant housing and pasture management exposure to feces (and rumen content transplants), there is an on-farm “microbial transplant” opportunity.

Figure 4. Targeting the mucosa with nutraceuticals that specifically enhance the microbiota and improve barrier and immune function.

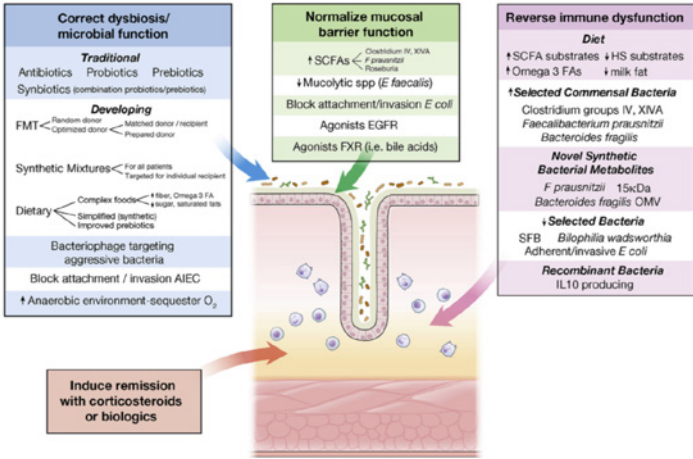


Figure 4. Targeting the mucosa with nutraceuticals that specifically enhance the microbiota and improve barrier and immune function. AIEC, attaching and effacing E. coli; EGFR, epidermal growth factor receptor; FA, fatty acid; FXR, farnesoid X receptor; FMT, fecal microbial transplant; HS, hydrogen sulfide; IL-10, interleukin 10; OMV, outer membrane vesicles; SCFA, short chain fatty acids; SFB, segmented filamentous bacteria. Sartor RB, Wu GD. *Gastroenterology*. 2017;152(2):327–339.e4

Summary

The gastrointestinal tract is the largest immune organ of the body. The mucosal barrier, the tight junctions and the “kill zone,” along with the gut mucosa and maintaining an “anti-inflammatory” state, are essential for “good gut health.” The microbiome, the microorganisms in the GIT, which has more cells than the entire animal’s body, is essential for immune development, immune response and maximizing ruminant productivity. Management of the bovine GIT immune system is not a simple process. It begins with colostrum consumption. Stressors, along with feed intake and hydration, affect the microbiome and intestinal epithelial cells, resulting in important immune interactions. Nutraceuticals (i.e., probiotics, prebiotics, hen yolk IgY, essential oils, organic acids) aid in both microbiome stability “homeostasis” and immune function.

References available upon request.

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Using vaccines to improve Mother Nature's plan for immunity in cattle

John A. Ellis, *University of Saskatchewan, Saskatoon, Saskatchewan, Canada*

Cattle, humans and other animals are born into a dirty world – a world filled with “germs,” viruses, bacteria, and other microorganisms – many of which cause disease. Many of these microorganisms are endemic – or always there in the animal populations they infect. So, how does Mother Nature protect animals from infectious disease and how can we learn from what she does and improve on Mother Nature's “program” with vaccines? That is the subject of this brief review.

Protection from disease is a multi-step immunological process. The first step is one that all successful dairypersons are very familiar with, even if they don't think about it very much; it's become a matter of course. Colostrum management is a first essential step in protecting young cattle from infectious disease and establishing a foundation for immune responses later in life. Today, virtually all dairypersons know that a calf should receive about 2 liters of high-quality colostrum as soon as possible after birth – and certainly before 12 hours of age. This can be in the form of maternal colostrum or a high-quality colostrum replacement product that is high in antibodies or “immunoglobulins,” as immunologists call them. Immunoglobulin (Ig) G1 is the most important antibody in colostrum. The timely use of vaccines in the cow can increase the amount and quality of IgG1 in the colostrum. Immunoglobulin, and other constituents in colostrum, are absorbed directly through the cell lining of the calf's intestinal tract. But, timing is of the essence in colostrum delivery, since this transport process gradually slows down and stops altogether by about 24 hours after birth. Overall, this process is called “passive” immunization, because the calf is the passive recipient of the components of immunity, primarily the immunoglobulin. As with most things in biology, passive immunity is rarely an “all or none” phenomenon, but rather a sliding scale or bell curve, unless the calf receives no colostrum at all. Therefore, the duration of passive immunity is variable and mostly dependent on the amount of IgG1 that is absorbed from the colostrum. Good husbandry of the calf can enhance the absorption process. Nevertheless, usually, by about 2 months of age effective passive immunity will have disappeared, because absorbed antibodies decay as a normal physiological process. So, how come most calves don't die of infectious diseases at that point?

The second part of Mother Nature's plan for protecting populations from dying in massive numbers from infectious disease is maybe not as obvious as the importance of colostrum to most people. It actually involves the natural exposure of young animals to germs, both in the environment and those shed from immune adults in the population who

can be infected by various germs but not get sick. And, of course, the reason why this exposure to germs doesn't sicken or kill most young calves or other babies is the protective effect of maternal antibodies that have been absorbed and can effectively neutralize or kill pathogens. This process of exposure to germs in the presence of maternal antibodies, in effect, is an important first “free vaccination” for the calf. This natural exposure that, importantly, occurs at mucosal surfaces, in other words, the lining of the respiratory and gastrointestinal tracts, effectively “overrides” maternal antibodies and results in “priming” of the calf's immune system. This is a necessary first step in the development of “active” or “adaptive” immunity in calves and other neonatal animals.

Once a young animal has been effectively primed, the third part of Mother Nature's plan comes into play – boosting the primary responses. Boosting, or effectively strengthening, a single primary exposure is necessary because young immune systems are not mature and just one exposure usually doesn't result in a long-lasting immune response. As mentioned, most of the important infections in human and other animal populations, historically, have been endemic or always there. Moreover, what most people perhaps don't realize is that immunity is rarely complete or “sterilizing.” Instead, what usually happens is that exposed individuals develop “clinical immunity” that prevents or reduces disease but does not completely prevent infection or “shedding” of germs in nasal secretions or feces, depending on the germ. What this means is that normal day-to-day interactions that occur in herds of cattle, humans, cats, or crocodiles provide opportunities for boosting primed responses. Overall, this process contributes to “herd immunity” or immunity in the population overall.

Admittedly, this story of “free vaccination” may sound like some sort of happy-ending academic fairy tale. But, there are numerous epidemiologic data, or examples from populations, that make this story a reality. Things are usually best appreciated in their absence. One of the best examples of what happens when this process of natural vaccination *doesn't* happen is the history of the Western Hemisphere. Many important human germs, such as smallpox and measles, were endemic in Europe for centuries before vaccines were available. Exposure to them resulted in herd immunity for those pathogens. In other words, there was reduced disease in the face of natural exposure. These germs, and others, were not endemic in indigenous populations in the “New World”. So, when clinically immune European settlers came and exposed

indigenous people to their germs, the native Americans, who had no protective immunity, died in massive numbers and the rest is history.

But, what moves all of this beyond a history lesson to a place where its application results in more rational use of the tools we have available, and, importantly, in improved health in cattle? Certainly, cattle and other animals survived for eons without humans or vaccines. So, how can we learn from the natural history of infectious diseases and improve on Mother Nature, or at least, hopefully, better manage infectious diseases? In summary, perhaps consider these three practical applications – both the obvious, and, maybe, the not so obvious:

First, pay attention to colostrum management! This is obviously not a new concept. But, without optimal passive immunization, subsequent vaccination will most often be futile – a waste of money – because the calf will either succumb to *E. coli* diarrhea or be too unhealthy to respond most effectively to vaccines. Remember, colostrum quality can be improved with timely vaccination of cows, with modified-live vaccines prior to breeding, or with inactivated vaccines three weeks prior to calving, depending on management systems.

Prime calves (and other animals) early in life (as early as day 1) with mucosally delivered vaccines – intranasal or oral. Effective, combination intranasal vaccines are available for important respiratory pathogens in calves, including bovine respiratory syncytial virus and parainfluenza-3

virus. The use of intranasal vaccines containing temperature-sensitive bovine herpesvirus is preferable for safety concerns. Oral vaccines for bovine coronavirus (and rota-virus), which cause both enteric and respiratory disease in calves, are probably most effective if administered intranasally; some will be swallowed and some will more effectively expose the respiratory tract. Traditional approaches aside, do NOT use injectable vaccines in passively immune animals and expect to get much priming of the immune system. Just as maternal antibodies protect, they effectively block most effective priming of immune responses.

Boost primed responses with injectable vaccines. This can be done at about 2 months of age when maternal antibodies will have substantially decayed. Waiting until weaning (about 6 months of age, at least in beef cattle) is unlikely to result in effective boosting of neonatally primed responses, as they will generally be short lived. The choice of vaccines to most effectively achieve boosting will vary with the pathogen. Stay tuned for additional applied studies that address this issue.

At a time when there is increasing concern about the use of antibiotics in food animals, and, relatedly, the development of resistance to antibiotics in both humans and veterinary patients, more timely and judicious use of vaccines, will not only improve calf health but also address consumer concerns about “food safety.”



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2008²

54%
1998²

41%
1988²

Percent of all BVDV cases
attributed to **TYPE 1B.**

¹ Data on file, Boehringer Ingelheim and BVDVTracker.com. Data collected November 1, 2018 through November 1, 2019.

² Ridpath JF, Lovell G, Neill JD, et al. Change in predominance of bovine viral diarrhea virus subgenotypes among samples submitted to a diagnostic laboratory over a 20-year time span. *J Vet Diagn Invest* 2011;23(2):185-193.

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RELENTLESS PROTECTION

Disbudding practices: Present and future

Sarah Adcock and Cassandra Tucker, *Center for Animal Welfare, University of California-Davis*

Disbudding practices have changed over the past decade

Dairy cattle normally grow horns, but this growth is stopped to avoid injuries to humans and other animals. Calves less than 8 weeks old are disbudded by using a hot iron or caustic paste on the horn buds before they attach to the skull. Older calves are dehorned by amputating the fixed horn from the skull using tools such as scoops, saws, or wires.

In the United States, 94 percent of dairy producers routinely disbud or dehorn their calves. A hot iron remains the most popular tool for disbudding, with almost 70 percent of operations reporting that they used this method in the 2007 and 2014 U.S. Department of Agriculture surveys. However, more operations are using caustic paste, from 9 percent in 2007 to 16 percent in 2014. Amputation dehorning decreased from 45 to 30 percent over the same time. Use of pain relief for hot-iron disbudding doubled (14 to 30 percent), but is less likely to be given for caustic paste. Producers have also begun to disbud calves at a younger age. On average, hot-iron and caustic paste disbudding occurs between three to four days sooner, or 21 percent younger, than a decade ago.

Given increasing public scrutiny and changing standards for quality assurance programs, disbudding practices will continue to transform in the coming years. In order to mitigate risk and help ensure the sustainability of the dairy industry, we can use science to inform best practice.

Hot-iron disbudding causes long-lasting pain

Hot-iron disbudding causes a thermal burn that destroys horn-producing cells. It can be performed as soon as the buds are visible, within the first week of life, and before they have attached to the skull around 8 weeks of age. Hot-iron disbudding is painful. Studies that have carefully tracked changes in behavior and physiology have found signs of pain, such as increased ear flicking, head shaking and head rubbing, as well as increased cortisol (a measure of stress) and heart rate. Signs of pain are reduced if the calf receives local anesthesia and a non-steroidal anti-inflammatory drug (NSAID) before disbudding.

Hot-iron disbudding wounds take six to 13 weeks to heal. During the healing process, calves are more sensitive to pressure applied to their wounds than after they have healed, telling us that the wounds are painful throughout this time. Others have reported increased sensitivity for at least 14 weeks, after the wounds had healed. Disbudded calves will also seek pain relief during the healing period, which tells us that the wounds are painful even when they are not being touched.

Caustic paste is painful, but the long-term effects are unknown

Caustic paste prevents horn growth by liquefying the horn bud. Caustic paste is only for use in calves under 1 week of age that can be kept dry and separated from other animals for 24 hours after treatment. Few studies have evaluated caustic paste, but it is clear it is painful for at least three hours. We do not know how long pain lasts beyond this time in calves. In goat kids, chemical burns persist for at least six weeks after paste was applied, so long-term effects are an important area for future research.

The jury is out on which method is more painful

Although caustic paste has been recommended as a less painful alternative to hot-iron disbudding, no research supports this claim. Only two studies have compared hot-iron and caustic paste methods in calves, and their results disagree with one another. In goats, caustic paste causes a greater pain response than hot-iron disbudding. Caustic paste has been banned in some European countries because of the risk of it spreading into the eyes or onto other animals.

Pain relief is necessary, for all ages and methods

More and more quality assurance programs, including the National Milk Producers Federation FARM (Farmers Assuring Responsible Management) initiative, require pain relief for disbudding. Combining a local anesthetic and an NSAID before hot-iron or caustic paste disbudding is more effective at controlling pain than either drug alone.

To give local anesthesia, 5 ml of 2 percent lidocaine hydrochloride is injected at the cornual nerve on both sides of the head 10 minutes before disbudding. An NSAID can be given immediately before or after the lidocaine block. There are limited options for NSAIDs in the United States: transdermal or intravenous flunixin (brand name: Banamine), and oral meloxicam (brand name: Metacam). Only flunixin is Food and Drug Administration approved for use in cattle. Meloxicam is used extra label under veterinary supervision. A sedative can also be used to reduce handling stress but does not provide pain relief.

Although it is widely believed that younger animals feel less pain, there is no scientific support for this claim. Calves experience pain no matter how young they are and pain control is needed at all ages and with all methods.

The future is polled

The available drugs only control pain from two to three hours (lidocaine; some NSAIDs) to one to two days (NSAIDs). We do not have practical solutions for managing pain over several weeks. Unmanaged pain could increase consumer concerns about disbudding. As awareness about animal welfare continues to grow, we can expect increased demand to incorporate polled or hornless genetics into the herd.

Polled genetics are gaining popularity but remain a specialty market because of the risk of increased inbreeding and slower genetic improvement. As the number of polled sires continues to grow, the gap in genetic merit between horned and polled animals is shrinking. Polled genetics have been successfully adopted in the beef industry, in which 88 percent of cattle are polled. Gene editing technologies could rapidly increase the use of polled genetics in the dairy industry, but it is still unclear how that option will be handled by the federal government. As adoption of polled genetics becomes more widespread and consumer acceptance for disbudding decreases, it is likely that polled herds will become the expectation and not the exception.

Take-home points

- Disbudding is always painful, regardless of the method and calf's age
- Disbud before 8 weeks of age to avoid the need for more invasive methods
- Combining local anesthesia and NSAID is the best practice for pain mitigation
- Stay ahead of changing markets by using polled genetics

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Why heifer maturity matters. The Peter Pan problem

Gavin Staley, *Diamond V*

How does one know when to breed virgin heifers? On many dairies, the decision is entirely subjective. The heifers look “big” enough, or reach a certain age or the pen is getting crowded and they need to move on. But the critical question should be, when are they mature? The following discussion will show that breeding immature heifers has a profoundly negative impact on the entire herd’s future productivity. Heifer maturity, in this discussion, is the phenotypic characteristics (such as body weight) that allow full expression of milk production during subsequent lactations.

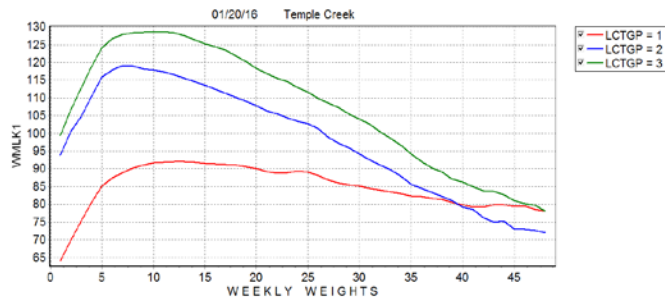
In recent years, the potential financial benefits of calving heifers earlier were recognized and promoted, resulting in an industry-wide trend to breed heifers earlier. Unfortunately, the necessary management changes to achieve the required maturity goals with earlier calving have been widely ignored. This has been due, in large part, to limited use of objective growth data to evaluate heifer raising.

The evaluation of DairyComp305 (DC305) records from a large number of herds, primarily in the western United States, resulted in the identification of significant patterns associated with heifer maturity and the following observations were made.

Observation 1

The average annual milk production of a dairy approximates to the 10-week milk production of Lactation=1 animals (see Graphs 1 and 2). The percentage of Lactation=1 animals in the herd can influence this association. For example, at 38% Lactation=1 these numbers are very close. At lower % lactation=1 (e.g. 34%), the annual milk is 1-2 pounds higher than 10-week milk; and at higher % Lactation=1 (e.g. 42%), the annual milk is 1-2 pounds lower, typically.

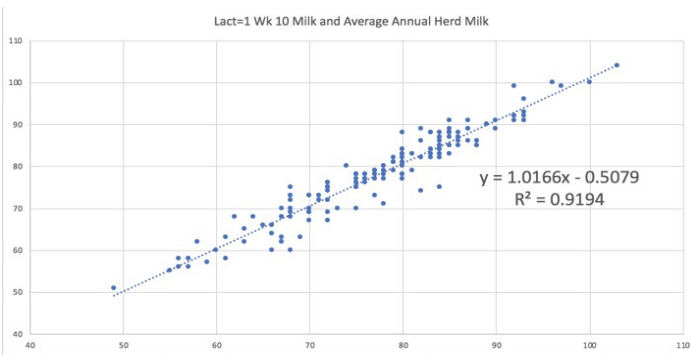
Graph 1. Lactation curves for Lactation Groups 1-3
Milk production (WMLK1) and days in milk (DIM, weekly weights)



In Graph 1 3X Holstein herd, the average annual milk production (as recorded in Econ\ID, Reports) was 92 pounds. The 10-week milk of Lactation=1 is approximately 92 pounds. The above observation is important because it strongly suggests that the heifer milk production sets the “ceiling” for the entire herd. A herd cannot overcome the restrictions placed on it by under-performing heifers. It also goes without saying that high-producing herds have high-producing heifers.

To validate this observation, DC305 data, from 149 herds representing 401,000 cows, were collated and the relationship determined (see Graph 2 below).

Graph 2. Average Annual Milk production and week 10 milk production of Lactation=1 (401,000 cows in 149 herds; no recombinant bovine somatotropin-supplemented herds included)

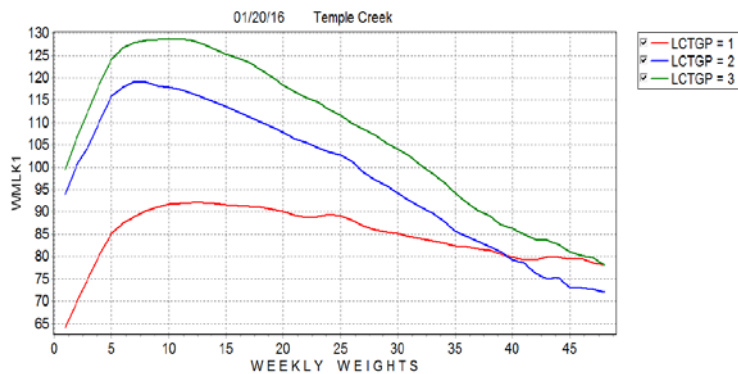


In the above graph, average annual milk production is on the y axis and week 10 milk for Lactation=1 is on the x axis. The above graph shows the strong correlation (R squared=92%) between these two variables. Furthermore, the slope of the equation indicates that as 10-week milk increases by 1 unit (pound) so does the average annual milk (pound). An improvement of a pound of milk at 10 weeks of Lactation=1 will translate to an additional pound of milk for every cow, every day, as these Lactation=1 animals move on up into later lactations.

Observation 2

The production difference between Lactation=1 and 2, at 5 weeks of lactation, is 30 pounds (13.6 kg) (Holstein) (Graph 3). Five-week milk production was chosen as a comparative time period to accommodate for the difference in peaks between lactation groups. This observation is consistent in “stable” herds. Stable herds in this discussion are herds where there is very little fluctuation in average annual milk production year to year and little intentional change to the heifer program over time. In other words, all animals in the herd have had a similar heifer-raising experience. This observation is independent of milk production level.

Graph 3. Milk production by LCTGP (Holstein) (annual production)



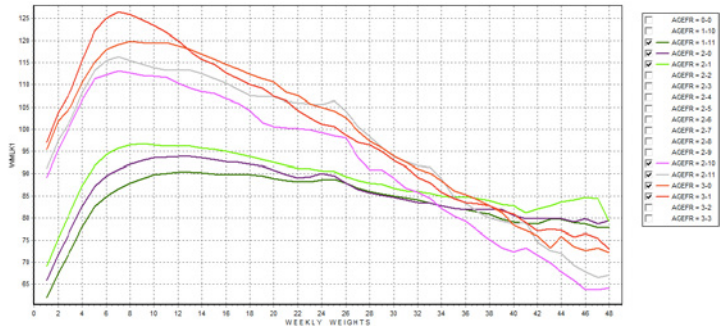
The above observation is important because it clearly demonstrates the predictable change in herd milk production resulting from a change in heifer management. For example, if the difference between Lactation=1 and 2 at 5 weeks decreases by say 3 pounds (i.e. is now 27 pounds), we can predict that the following year the difference between Lactation=1 and 2 will increase back to 30 pounds and Lactation=2 production will have increased the incremental difference. Similarly, a drop in Lactation=1 production will predictably drop milk production. Metaphorically, “all ships rise on a rising tide,” suggesting improved heifer performance lifts production of all parities with time.

Observation 3

The age at calving (AGEFR) impacts milk production in both Lactation 1 and 2. This is best visualized in herds that breed by age and not size. In the next example herd, the age at calving is later (23-25 months)

and yet a clear impact of age at calving on Lactation=1 production is still demonstrable. The impact of age at calving is especially obvious in herds that calve heifers at 20-21 months (personal observation).

Graph 4. Milk production of Lactation 1 and 2, by age at calving



In the above graph, it is apparent that as heifers mature (i.e. grow) they produce more milk in lactation=1. This is not surprising. It is noteworthy that all these Lactation=1 animals are subject to the same management, reproductive programs, culling philosophies, transition, nutrition and facilities. The variable is AGEFR. Also, the lactation curves reveal that the lactation curves differentiate almost immediately after calving, suggesting that culling of Lactation=1 animals is not a likely or significant reason for any variation in production. Furthermore, culling of virgin heifers is unlikely to influence subsequent Lactation=1 production curves since the two categories representing most culls in virgin heifers, namely deaths and open heifer culls, are not represented at all.

At a growth rate (average daily gain) of approximately 2 pounds per day, the breeding heifers will grow 60 pounds per month. And in this herd, that will be approximately 2-3 pounds more milk per cow per day for every month increase of AGEFR (from the logic of Observation 1). Since virgin heifers have a high conception rate (55% plus), it also means that in the above lactation=1 production curves there will be more 23-month animals than the other two-month cohorts. This is significant because it means that most of these Lactation=1 animals will underperform relative to their cohorts.

Furthermore, the Lactation=2 lactation curves reveal a similar production and AGEFR pattern. Although these are not the same animals, almost all of the Lactation=2 animals that calved at 34 months would have calved at 23 months the year before. It is apparent that if a herd has excellent herd fertility and immature heifers, these younger immature

animals will be “locked” into lower Lactation=2 production. Since the average lactations of many herds in the United States is low (e.g. 2.2), it follows that if immaturity negatively impacts both Lactations 1 and 2, it will seriously impact the entire herd’s production. It is not unreasonable to suggest that these herds effectively never reach full genetic potential. They never “grow up.” They are experiencing the “Peter Pan Problem.”

Recommendations

It is not good enough to rely on subjective criteria for breeding heifers. Objective criteria, such as body weight, wither or hip height, and average daily gain, can greatly assist in determining the best time and size to breed heifers. While body condition score is not included in this conversation, the assumption is made that over conditioning must be avoided. A suggested approach is laid out in the right column.

1. Determine the mature body weight (MBW) of the herd. This is not the average of cull cows. This means weighing a cohort of cows in the third and fourth lactation between 80-120 DIM.
2. Weigh either close-up (days carrying calf >260) or fresh cows (DIM <7) to calculate the % of MBW of these animals. Close-ups should be approximately 95% of MBW and fresh cows should be close to 85% MBW.
3. Determine the difference between desired and actual weights. This will be the increased body weight that must be made up by either delayed breeding of virgin heifers or increased ADG.
4. Determine the weight and age that virgin heifers need to achieve to be at 55% of MBW.

The image is a promotional graphic for SCCL Bovine IgG Colostrum. It features a background photograph of a black and white cow's head and a black and white calf lying in straw. In the foreground, several SCCL Bovine IgG Colostrum products are displayed: a large white tub with a red lid, a white bag, and three smaller bags in red, green, and yellow. A yellow banner in the upper left corner contains the text "COLOSTRUM" in large white letters and "ONE SIMPLE INGREDIENT" in smaller red letters. The SCCL logo, featuring a red maple leaf and the text "SCCL SCIENCE • NATURE • CARE", is in the upper right corner.

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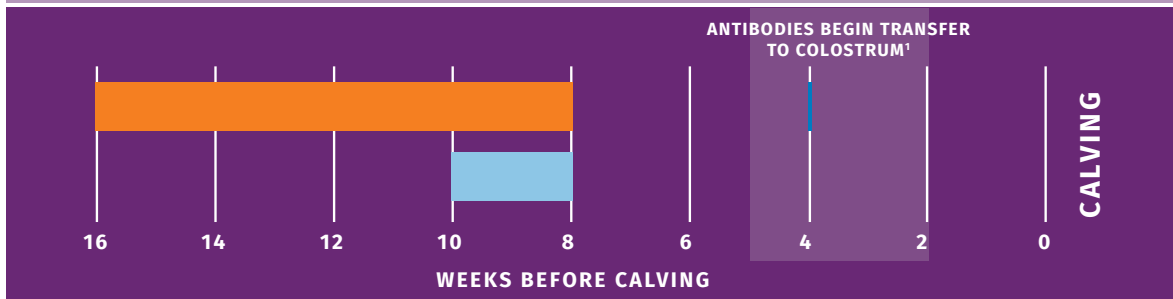
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¹Herr M, Bostedt H, Failing K. IgG and IgM levels in dairy cows during the periparturient period. Theriogenology. 2011;75(2):377-85.

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PM-US-20-0504



Dairy industry collaboration on animal care

Emily Yeiser Stepp, *National Dairy Farmers Assuring Responsible Management Program, Arlington, Virginia, USA*

The dairy industry has prided itself on the quality care of animals for generations. Throughout the changes in the U.S. society, there has become a greater interest in how food is produced, including the care of the animals. In turn, the dairy industry, over a decade ago, formalized an animal care initiative under the name of Farmers Assuring Responsible Management (FARM). In doing so, the dairy industry was able to provide verifiable data and proof points to demonstrate dairy farmers' ongoing commitment to the highest standards in the industry and that they are doing what is right for the cows, customers and consumers.

Launched in 2009, the FARM Program helps earn the public's trust, demonstrating that dairy farmers share their values and are committed not only to quality animal care, but also to ensuring safe, wholesome milk, high standards of environmental stewardship and exceptional work environments through its four program areas. The Animal Care Program is the cornerstone of the FARM Program. More than 98 percent of the U.S. milk supply comes from participating farms and is now in its fourth iteration. FARM is a joint initiative that is facilitated from the National Milk Producers Federation and funded by the national checkoff organization, Dairy Management, Inc.

In comparison, the beef industry has had a formalizing quality assurance program since the mid-1980s when the Beef Quality Assurance (BQA) program was implemented, using a hazard analysis critical control point- (HACCP) like approach to food safety and quality. Over the past 30 years, BQA has evolved with the same core mission of maximizing consumer confidence in beef by focusing the producer's attention to daily production practices that influence the safety, wholesomeness and quality of beef through the use of science, research and education initiatives.

Additionally, specialized segments of both the dairy and beef industries have developed educational programming and standards that focus on continuous improvement. The Dairy Calf and Heifer Association (DCHA) first published its Gold Standards for calf and heifer raisers in 2009. The goal of these standards was to enhance the animal health, welfare and performance focusing on economics, research and new technologies in order to produce a better adult dairy animal. Furthermore, the veal industry initiated the Veal Quality Assurance (VQA) program in 1990. Through science-based best practices, VQA aims to address all aspects of animal care that will enhance veal calf quality.

Individually, these programs are facilitated through their industry's respective trade or membership association, with governance structures that provide a voice for all stakeholder involvement, including

farmers, veterinarians, cooperative/processor staff, academia and other subject matter experts. Through the governance structure, each program reviews and revises their program standards based on the latest scientific research and industry best practices.

The customer and consumer interest in the social responsibility, and in particular, animal welfare in livestock agriculture, continues to be a driver of buying decisions – both at an individual and company-wide level. Also, as the consolidation of all livestock industries continues, the importance of collaboration on social responsibility for meaningful and unified impact is greater today than it ever has been. Therefore, in 2019, FARM, BQA, DCHA and VQA staff met to discuss the potential opportunities for collaboration in the animal care space across the various segments each program represents.

The goal of the Calf and Heifer Management Working Group is to align, develop and disseminate a training and education platform in an outcome- and science-based framework, for the growing industry of calf raisers. Each organization selected stakeholder representatives to serve on the Working Group, ranging from farmers, veterinarians and industry, along with the staff members of each program. Throughout 2020 and beyond, the anticipated deliverables from this collaborative work will include: 1) a training framework for calf raisers and employees, 2) a self-assessment tool with the ability to be used in a second- or third-party evaluation approach, 3) educational resources and support materials, and 4) issues management support.

With each of these components in place, the desired outcome is alignment of the calf-raising industry around unified standards that can be used for dairy, beef and veal youngstock producers and their operations. The working group is confident that the results of this initiative will allow for the formalization of assurances necessary for customer and consumer confidence in the care of all bovine youngstock.

Resources

The National Dairy FARM Program www.nationaldairyfarm.com

Beef Quality Assurance Program www.bqa.org

Veal Quality Assurance www.vealfarm.com

Dairy Calf and Heifer Association <https://calfandheifer.org/>

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Managing and marketing dairy x beef crossbred cattle

Grant I. Crawford, *Merck Animal Health, Jasper, Minnesota, USA*

In recent years, dairy producers have begun to explore the use of beef genetics to add value to a portion of their milking herd. This is not a new practice. In reviewing scientific literature, it appears that about every 10 years there is a resurgence in breeding dairy cows to beef genetics. Research from Skelley et al. (1980), Comerford et al. (1992), Shanks (2003), and Huuskonen et al. (2013) illustrate this approximate 10-year cycle of interest in dairy x beef crossbreeding.

There are several reasons for the resurgence of beef x dairy crossbreeding. Traditionally, bull calves from dairy operations were often destined for veal production systems. However, U.S. production of veal has dropped significantly in the last 20 years, from 225 million pounds in 2000 to 74.5 million pounds in 2019 (USDA ERS). Dairy bull calves, therefore, are now most likely to enter a feedlot system where they are raised to finishing weights more typical of beef-breed cattle. The 2016 National Beef Quality Audit (NBQA) estimated that dairy-type cattle represent 16 percent of all slaughter cattle in the United States, which was a 6-percentage unit increase compared with the 2011 NBQA (Boykin et al., 2017). When beef cow numbers, and therefore available beef feeder calves, are low, Holstein steers help fill the void and are of great value to the dairy operation. From 2012-2016, with declining beef cow numbers, Holstein steers were very valuable and in demand, and this value was passed down to the dairy operation. However, as the beef cow herd expanded from 2016 to current, there were more beef feeder calves available, and the demand and value for Holstein calves decreased.

Low milk prices also contributed to the resurgence in crossbreeding. From 2015 through mid-2019, milk prices rarely surpassed \$17 per hundredweight and milk production continues to increase (USDA AMS). The U.S. dairy herd has remained at approximately 9-10 million cows for at least 30 years. And with the increase in milk production per cow and the relatively low milk prices up until mid-2019, there has been less of a need for replacement heifers.

One additional factor is preference among packing plants for beef-breed cattle. As with the feedlot industry, the packing industry purchased Holstein feedlot steers to fill the void left by low beef herd numbers. The packers also shifted back to purchasing more beef-breed cattle when the supply was available and this led to greater discounts and less demand for dairy-type cattle. The large frames of Holsteins can cause logistical issues at older packing plants not designed for large cattle and the low muscle-to-bone ratio of Holsteins compared with beef breeds is also not desirable to a packer. In an extreme

case, Tyson Foods ceased buying Holstein steers in 2017, causing a steep decline in the prices received for fed Holstein steers.

With this backdrop of forces from the beef, dairy, and packing industries, crossbred steers and heifers are beginning to appear in feedlots. Various estimates place the number of crossbreds harvested in 2019 at around 1.5 million and it is expected that number may double or even triple in three to five years. Semen sales have reflected this shift, with a 1.5 million unit increase in beef semen sales between 2017 and 2018 (a 60 percent increase), and a corresponding 1.2 million unit decrease in dairy semen sales (National Association of Animal Breeders).

To date, however, there is still some unease among feedlot operators and packers regarding the quality and likely more so the consistency of dairy x beef crossbreds. Crossbreds generally will attract a \$100 or greater per head premium than Holsteins as newborn calves, but some calf growers and feedlot operators have ended up having to sell these cattle for Holstein prices. This is partially due to poor genetic decisions at the dairy, where the focus at times is simply calving ease and a black hide. This can lead to “black Holsteins” or “dirty Holsteins” – essentially cattle possessing a Holstein frame and carcass attributes – while having a black hide. Genetic companies are taking note and many have worked diligently on developing programs for selecting ideal beef genetics for dairy crossbreeding.

Because of this unease among buyers, the recent resurgence of crossbreeding is at a crossroads. Dairy operators must focus on matching quality beef genetics – mainly carcass and growth traits – in addition to important calving traits. In a quality-driven beef market where Premium Choice and Prime-grading carcasses attracted heavy premiums in 2019, Holsteins provide an advantage. Dairy-type cattle had higher marbling scores (an indication of quality grade) than beef-breed cattle in the 2016 NBQA. Dairy-type cattle also had slightly lower yield grades than beef breeds, indicating a higher percent of retail cuts from the carcass. The negative against dairy-type cattle in the 2016 NBQA was a smaller ribeye area. Dairy-type carcasses had, on average, a 12.5-square-inch ribeye, whereas beef-breed carcasses had a 14.1-square-inch ribeye (Boykin et al., 2017). In addition, ribeyes from dairy-type steers are often narrower in shape than a ribeye from a beef-breed carcass, which can lead to discounts due to consumer preference.

Beyond the improved carcass quality, crossbreeding can also add growth compared with the typical Holstein steer. Duff and Anderson (2007) estimated Holstein steers had approximately 13 percent lower average daily gain, 3.5 percent better feed conversion, and over twice the death loss of beef steers. These data compared Holstein steers and beef

steers of all in-weights, so it should be noted that Holstein steers were on feed longer and entered the feedlot lighter than beef steers, which would affect all three of these parameters. Regardless, crossbreeding can add growth and possibly improve health compared with Holsteins.

To date, there has been no known new research on feeding and management strategies specific to crossbreds. Calf raisers and cattle feeders have typically taken the same calf-fed approach as is used with Holstein raising. Potentially, if more moderate-frame beef genetics are used, there could be opportunities for backgrounding or stocker growing programs prior to feedlot entry. The use of implants, beta-agonists, and melengestrol acetate (for heifers) is recommended, though to date no specific research has been conducted to assess the ideal dose and/or duration of such products.

As for marketing, confidence is the key. Confidence comes from the cattle feeder and/or calf raiser in calf quality and confidence from the packer that the crossbred will produce a desirable carcass. For those that are selling calves immediately after birth, working with a feedlot partner to ensure that desirable genetics are used is recommended. There are also some buy-back programs available where feedlots will purchase

calves that are bred with specific genetics. For dairies that are feeding cattle to harvest, using quality genetics, documenting those genetics, and working closely with the packer to collect carcass data and adjust as needed is important. Packers will likely be looking closely at the carcass quality of these cattle before they become confident in the product.

One intriguing alternative to crossbreeding is the use of beef embryos in dairy cows. This approach would produce a calf with 100 percent beef genetics, thereby avoiding the potential marketing pitfalls with crossbreds. This approach is new and many questions remain as to the cost effectiveness (embryo transfer costs much more than artificial insemination with variable success rates), as well as the value of resulting calves.

As mentioned before, crossbreeding appears to be at a crossroads. It is a practice that can work if attention is given to the genetic traits that matter. However, dairy operators, calf raisers, and feedlot operators must still adhere to all the important practices, such as cattle health and comfort, which are critically important to raising quality calves.

References available upon request.

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New passive transfer standards for dairy calves and how to achieve them

Jason Lombard, U.S. Department of Agriculture Animal and Plant Health Inspection Service Veterinary Services, Fort Collins, Colorado, USA

Colostrum and calf health

Newborn calves must ingest colostrum in order to acquire nutrition, immunoglobulins (Ig), and other immune-related factors. Ingestion of colostrum and transfer of immunoglobulins to the calf has been termed transfer of passive immunity (TPI). Calves rely on TPI for immunoglobulins because the placenta does not allow Ig transfer from the dam to the calf. TPI is evaluated by measuring calf serum IgG or total protein. Although there are many other components of colostrum that are important for calf health, serum IgG and total protein are good proxies for transfer of passive immunity.

High levels of immunoglobulin in calves are achieved by providing sufficient quantities of high-quality colostrum (greater than 50 g/L IgG) to calves very soon after birth. The Dairy Calf and Heifer Association (DCHA) Gold Standards for colostrum management recommend collecting colostrum within four hours of calving, following strict hygiene protocols to prevent bacterial contamination, and hand feeding colostrum equal to 10 percent of the calf's body weight within the first two hours of life. When serum total protein is measured between 2 and 7 days of age, this protocol should result in 90 percent of the calves having serum total protein values of 5.2 g/dL (DCHA, 2016). This serum total protein value equates to approximately 10 g/L of immunoglobulins, which has been the recommended industry standard for more than 30 years (Gay, 1983). Calves with less than 10 g/L are considered to have failure of passive immunity while those above 10 g/L are categorized as having successful passive immunity.

National dairy studies conducted in 1991-92 showed that 41 percent of calves had failure of passive immunity using these criteria (USDA, 1993). Since then, education and outreach campaigns have been conducted to improve colostrum management and increase TPI in dairy calves. The campaigns have been very successful and in 2014 only 13 percent of calves had failure of passive immunity and the average serum total protein was 6.0 (Urie et al., 2018). Preweaning dairy heifer calf mortality decreased from 10.8 percent in 1996 to 6.4 percent in 2014. However, preweaning calf morbidity, primarily scours and respiratory disease, remained at nearly 30 percent.

Consensus passive immunity standards

Based on the fact that the percentage of calves with failure of passive immunity had decreased significantly yet preweaning calf morbidity remained steady, the current standard of 10 g/L of IgG (~5.2 g/dL total protein) was scrutinized. In the spring of 2018, a group of U.S. and Canadian calf experts met to discuss proposing new passive immunity standards. The common theme through the discussions of calf- and herd-level standards were that they needed to be realistic and achievable by commercial dairy herds. Through multiple discussions and evaluation of the National Animal Health Monitoring System (NAHMS) Dairy 2014 calf component data and other published literature,

the group came up with consensus recommendations on calf- and herd-level passive immunity of dairy calves in the United States (Lombard et al., In press). Rather than having a simple dichotomous standard, the new standard has four categories: Excellent, Good, Fair, and Poor. The consensus serum IgG concentrations, equivalent total protein and percent Brix measurements, and percentage of calves recommended in each transfer of passive immunity category are provided in Table 1.

Table 1. Consensus serum IgG concentrations and equivalent total protein (TP) and Brix measurements, and percentage of calves recommended in each TPI category. Modified from Godden et al., VCNA 2019.

TPI Category	Serum IgG categories (g/L)	Equivalent TP (g/dL)	Equivalent Brix %	Farm Level % calves ¹	NAHMS Study % calves ²
Excellent	>25.0	>6.2	>9.4%	>40%	35.5%
Good	18.0-24.9	5.8-6.1	8.9-9.3%	~30%	25.7%
Fair	10.0-17.9	5.1-5.7	8.1-8.8%	~20%	26.8%
Poor	<10.0	<5.1	<8.1%	<10%	12.0%

1 Consensus recommendation for percent of a farm's calves in each category.
2 Percent of calves in NAHMS 2014 Dairy study in each consensus category.

The construction of the four levels were based on evaluation of calf morbidity and mortality in the NAHMS calf component study, as well as other published literature. Studies have reported reduced morbidity in calves with higher serum IgG levels than traditionally recommended (Furman-Fratczak et al., 2011; Windeyer et al., 2014; Urie et al., 2018). Studies evaluating passive immunity in beef calves also found similar associations between higher serum IgG concentrations and decreased preweaning morbidity (Dewell et al., 2006; Todd et al., 2018).

Although classification of individual calves is the most common method of evaluating TPI, on-farm colostrum management programs require a farm-level classification method. Based on data from the NAHMS Calf Component study, the recommended percentage of calves in each TPI category were determined (Table 1). The recommended farm-level percentage of calves in each TPI category is very similar to the percentage of all study calves in those categories in 2014. The consensus recommendations are achievable by commercial dairy operations with good colostrum management programs.

Colostrum feeding to achieve the new standards

Another goal of the expert group was to provide colostrum feeding recommendations that would assist producers in meeting these TPI goals. Colostrum management practices for 705 heifer calves that achieved excellent TPI in the NAHMS Calf Component were evaluated and summarized to provide recommendations. A single feeding of colostrum achieved excellent TPI in 251 calves. These calves were fed 286.7 g of IgG at an average of 2 hours of age and averaged 32.0 g/L of serum IgG. An additional 453 calves were fed multiple feedings of colostrum. The first feeding provided an average of 226.6 g of IgG at 2.8 hours of age. The additional feedings provided approximately 195 g of IgG within the first 24 hours of age. These findings led to the following recommendations:

- 1) A single feeding of colostrum at approximately 2 hours after birth, delivering approximately 300 g of IgG, or alternatively,
- 2) Feeding multiple colostrum feedings and delivering approximately 400g of total IgG in the first 24 hours.

One of the consistent findings from multiple studies has shown that feeding high-quality colostrum within two to four hours after birth will achieve excellent TPI. Halleran et al. (2016) fed 100 Holstein heifer calves either 4 L or 5.6 L within the four hours of birth. Two of the calves fed 4 L had serum IgG concentrations less than 10 g/L, while the average serum IgG level was 23.5 g/L – very close to the excellent category in the new standards. The average serum IgG concentration for calves fed 5.6 L was 39.5 g/L and none of the calves had serum IgG levels less than 10 g/L.

Although many farms will choose to provide a single feeding of colostrum and the consensus standard can be achieved, there are benefits to multiple colostrum feedings. One study reported that calves fed transition milk (combination of colostrum and milk) had larger intestinal villi – allowing for more absorption of nutrients (Inabu et al., 2019). Normal bacteria populations in the gut were more numerous when calves were fed within 45 minutes of birth, compared with calves fed their first feeding of colostrum at 6 and 12 hours of age (Fischer et al., 2017).

Heat treatment of colostrum – 60°C (140° F) for 30 minutes – has been shown to reduce bacterial concentrations while maintaining colostrum IgG concentrations (Elizondo-Salazar and Heinrichs, 2009). Their evaluation of calves fed heat-treated and unheated colostrum showed higher serum IgG concentrations in the heat-treated calves but found no differences in growth or health scores. It is important to note that the average serum IgG concentration was more than 20 g/L in both study groups, which might be why a significant difference in health and performance was not observed.

Conclusion

The previous standard of 10 g/L for serum IgG has served its purpose in challenging producers to improve their colostrum management practices. With almost 90 percent of calves currently meeting these standards, it is time to once again challenge producers to continue making improvements. Dairy producer and consultant education of the new TPI standards, for both heifer and bull calves, should improve the health and productivity of dairy calves.

References available upon request.



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Calf nutritional management in 2030: Challenging the dogma

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Over the past two decades, we have gained tremendous momentum in the field of dairy calf nutritional management, with publications related to “dairy calf nutrition” tripling from only 1,220 publications in 2000 to more than 3,400 in 2019. Calves are the future of the milking herd and proper early life nutrition has been shown to positively influence cow survival, milk yield, and reproductive efficiency (Faber et al., 2005; Soberon et al., 2012). As such, this recent resurgence in calf nutrition research is crucial to ensuring the profitability and sustainability of the dairy industry. Although calf management has improved over the past decade, calf morbidity and mortality rates still reach 34% and 5%, respectively, with digestive disorders accounting for over half of illnesses and one-third of deaths (Urie et al., 2018). In 2010, the Dairy Calf and Heifer Association reported that the target morbidity rate for young calves is less than 25%, demonstrating that there is still a significant need to reduce current morbidity rates. The abundance of knowledge generated on a yearly basis pertaining to calf nutrition and the recent implementation of automated feeding provides many opportunities to develop new feeding programs to improve calf productivity and health, while simultaneously improving the efficiency of dairy operations. Therefore, this review will focus on the future of calf nutrition and opportunities to challenge the traditional dogma of dairy calf management.

Prenatal programming

We are becoming increasingly aware of the importance of prenatal programming in the livestock industry, with the majority of current research focusing primarily on swine and beef cattle. To date, the majority of dairy calf research focuses on the first two months *ex utero* and often discounts the impact of prenatal programming, when developmental plasticity is highest. Recent work has demonstrated that heat stress, macronutrient composition of the diet, and health of the dairy cow during gestation can impact calf development, and in certain instances, may influence the calf's capacity for milk production later in life (Bach, 2012; Gonzalez-Recio et al., 2012; Dahl et al., 2017). Although this research provides a concrete foundation, the rapid advancement of DNA technologies over the past five years have enabled us to study the specific epigenetic mechanisms that facilitate these effects. As this field of study continues to advance, the industry can effectively develop new strategies to manage the dam during the peripartum period to optimize fetal development.

Colostrum bioactivity and optimal transition to milk

The passive transfer of immunoglobulin (Ig) G is one of the most important factors in ensuring the health and survival of the young dairy calf. As such, IgG has been the main focus of research related to bovine colostrum over the past decades; however, IgG is only one of an estimated hundreds of bioactive molecules that can positively influence calf development and health. For instance, colostrum contains high levels of growth factors, hormones, prebiotic molecules, fatty acids, and antimicrobial compounds

compared to whole milk (Fischer et al., 2019). Certain compounds have been well documented to positively influence gut and metabolic function, while others have received relatively less attention in regard to their impact on neonatal calf development. Further research investigating colostral bioactive compounds is crucial to understanding calf developmental responses and maximizing the benefits of colostrum. Beyond the elevated levels found in colostrum, these compounds are also present at higher levels in transition milk (TM, milkings two to six). Unfortunately, after feeding the first colostrum meal, many producers transition calves directly onto milk and sometimes discard TM. Recent studies have demonstrated that feeding TM for an extended period after birth can have positive effects on intestinal development and may improve calf health (Fischer et al., 2019). However, these studies fail to investigate whether or not the observed effects are due to increased nutrient supply in TM compared to milk and there is little work investigating the optimal transition from colostrum to milk to maximize calf productivity and gut function. Research addressing these large knowledge gaps may provide the industry with a feasible strategy to improve newborn calf gut development through feeding TM or mixing colostrum and whole milk during the first days of life.

Milk replacer vs. whole milk

From a practical standpoint, it is clear that calves are able to perform well on whole milk or milk replacer (MR). However, both feeding regimens require attention to the composition of the liquid feed provided to the calf. For instance, gut health issues may occur when feeding whole milk due to contamination with antimicrobial residues or pathogens (i.e. waste milk), or when feeding MR, in which problems likely occur due to macronutrient composition or ingredient quality. One of the most talked about areas of milk feeding is the composition of MR compared to whole milk, in which the large quantity of whey in MR drives up lactose concentrations (45 vs. 35%) at the expense of fat (18 vs. 30%) in the formulation. These formulations may potentially disturb gut mucosal structure and function, and negatively affect glucose homeostasis (Wilms et al., 2019; Welboren et al., 2019). However, further research in this field is needed, especially when calves are fed elevated levels of MR during early life. Furthermore, the composition of each macronutrient within MR requires further attention. For instance, whole milk contains medium- to long-chain saturated fatty acids, while many of the plant-based fats used in MR contain high levels of polyunsaturated fatty acids, which can result in poor growth and high incidences of diarrhea (Jenkins et al., 1985). Currently, fat quality is receiving the majority of attention in MR formulations; yet, further investigation into the quality of each macronutrient is needed.

Weaning and post-weaning programs

Significant improvements have been made in the optimization of the weaning transition of dairy calves – including the integration of step-down weaning protocols and weaning later in life – to ensure the health and productivity of calves weaned from elevated planes of milk

nutrition. Recent work by Benetton et al. (2019) has demonstrated that each calf experiences the transition to solid feed differently. With the implementation of automated feeding, it is becoming highly feasible to synchronize pre-weaning dry feed intake with a weaning strategy to create individualized weaning programs. Furthermore, the composition of calf starter and its integration with an elevated milk feeding program is often neglected. For example, calves are often fed starter that is high in starch in an effort to initiate rapid rumen development, with starch content often exceeding 30%, or even up to double what we would feed to a cow. As weaning is already one of the most challenging periods of a calf's life from a production and health standpoint, feeding high levels of starch in starter may further exacerbate this stress – especially when calves are weaned from elevated levels of milk. There is currently little work integrating the amount of milk fed and starter composition, and it is pertinent to address this large knowledge gap to improve the weaning transition.

Although research has focused on both the pre- and post-weaning periods, the months following weaning are essentially the “black box” of calf and heifer nutritional management. This is a critical period in heifer development. However, industry tends to underfeed calves during the months post-weaning, as we assume they eat a large amount of forage and underfeed concentrate. Evidence suggests that high planes of post-weaning heifer feeding programs can result in improved productivity; thus, determining the ideal age and strategy for step-down from the high concentrate are essential to improving heifer development.

Automated and precision management technologies

The rapid implementation of automated technologies in the dairy industry will result in future reliance on and utility of these systems to increase the efficiency and profitability of dairy operations. Importantly, automated scales and feeders will dramatically increase our knowledge of calf growth performance, intake, and behavior in response to specific feeding strategies on farm. These data will enable automated feeders to be programmed on an individual calf basis, based on calf behavior, body weight, growth rates, intake, and health metrics.

In addition, the past decade has resulted in tremendous developments in our ability to evaluate the genome, microbiome, and their downstream products. The development of these techniques will advance our understanding of calf developmental processes and are already being used in the field of nutrigenetics to genotype embryos and newborn calves to determine optimal feeding programs. Furthermore, the combined use of automated calf technologies and “omic” techniques will allow for the integration of phenotypic and genotypic data to improve calf predictions, which will eventually lead to more effective and efficient intervention strategies.

Conclusion

It is clear that the next decade will be an exciting time to study and work in the field of calf nutrition. Continuously challenging the dogma of dairy calf nutritional management will enable dairy producers to make confident decisions that promote calf health, welfare, and productivity to ensure the long-term success of the dairy industry.

References available upon request.



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