Does the Physical Form of Feeds Offered to Young Calves Make a Difference in Performance?

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In the late 1800’s and early 1900’s there were already reports about the benefits of feeding hay or straw to young calves. Later, between the 50’s and the 70’s, the emphasis of research related to calf feeding was centered on providing good quality hay (mainly alfalfa in the US and different grasses in Europe and New Zealand) and progressively moving towards reducing the amount of forage fed aside and including forage or substitutes such as corn cobs within pelleted starter feeds. In the early 70’s, work from the University of Cornell set the stage towards texturized starters that could be fed without forage. This type of starter is based on ensuring a course physical form and avoiding fines, and their implementation in the field has been backed by the common recommendation that forages should not be fed to calves younger than 2 months. Since then, most of the research in this topic has focused on the effects of different ingredients (cottonseed hulls, corn cobs, whole corn, whole oats, etc...) on intake, performance, and rumen development, and just a very limited number of studies have evaluated the consequences of providing forages to calves.

The aim of solid feeds while calves are offered milk is 1) to provide nutrients, and 2) to prepare both the digestive tract as well the feeding habits of calves to enable them to consume and efficiently digest a fibrous ration after weaning. Our research group and others have re-opened the case of physical forms of starter and feeding forages. Overall, results show that providing free access to poor quality chopped forages to calves improves solid feed consumption, digestibility, growth, rumination, and diminishes abnormal behaviors. Some concerns have been raised about confounding between growth and potential increases in gut fill when providing forages to calves. We have recently demonstrated that gut fill is negligible when poor quality chopped forages are offered free choice. In addition, offering chopped forages to calves seems to improve rumen function and absorption of fermentation end-products. Overall, it seems that offering chopped poor quality forages rather than increasing fiber content and modulating the physical form of starters should be the preferred method to foster intake and minimize abnormal behavior of calves around weaning.

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Management, including nutrition and the housing environment, can influence pre-weaning leukocyte responses and the health of dairy calves. Both nutrition and housing environment can alter the short and long-term health of cattle. The relative risk for infectious disease, primarily enteric, occurs during the first few weeks of life. This may be associated with adaptation of the gastro-intestinal tract of the calf to the ex utero environment, as many other leukocyte responses have not changed or actually have decreased during this period. It is likely that nutrition and feeding strategies, such as frequency of feeding, as well as the composition of the milk (replacer) influences the gastro-intestinal integrity and consequently immunity to enteric disease. Data also suggest that calves that are fed a restricted plane of milk replacer nutrition have more active neutrophil responses during the pre-weaning period. Calves that were also housed in small groups of 3 had more active neutrophil responses during the pre-weaning period when compared to individually housed calves. The short and long-term impacts of the more active neutrophil responses are unknown, but it may impact future immune responses, both the innate and adaptive branches of the immune system. It is known that early life experiences can influence biological responses later in life. Therefore, it is important that future research identify how management of dairy calves during the pre-weaning period influences the health of an animal during its entire life cycle.

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Active Immunity in the Calf While all the essential immune components are present in the neonate at birth, the parenteral response vaccines seems to favor predominantly a cell mediated T cell response while antibody do not seem fairly functional until at least 2-4 weeks of age. The developing and newborn calf is subject to a number of immunomodulatory effects. The placenta produces progesterone, prostaglandin E2 and cytokines such as IL-4 and IL-10 that effect both the near term fetus and the dam and suppress cell mediated and memory (TH1) responses but promote TH2 antibody responses. In addition the cow produces estrogen and cortisol prior to parturition that all also have immunosuppressive effects. Finally the calf, as part of the parturition process produces high levels of cortisol that remain elevated for the first week of life. The cumulative effect of these hormones is to suppress the immune system and to direct the immune response away from the TH1 memory response to the short term TH2 immune response.

Innate immunity The humoral components of the innate system are suppressed. Interferon activity in the epithelial cells appears normal but the production by leukocytes is lower. The cellular component is also affected. The number of dendritic cells is lower and their ability to present antigen to the acquired immune system is also decreased. Natural killer cells are also low at one week of age (3% of total lymphocytes) and increases to 10% by 6-8 weeks of age.

Acquired immunity The neonatal calf is agammaglobulinemic and is dependent on colostral intake for immunoglobulins. The number of B cells is greatly reduced in the neonate at 4% of the total lymphocytes at a week of age and increase gradually to 20% of total lymphocytes at 6-8 weeks of age (normal is 20-30%). This low number of B cells coupled with the TH2 environment induced by the calves endogenous corticosteroids, maternal and placenta hormones results in a lack of an antibody response until at least three weeks of age. T cell subsets are at normal levels in the neonate. Total T cells are 28-34% of total lymphocytes with CD4 helper cells ~20% and CD8 cytotoxic T cells at ~10%. Gamma-delta T cells decrease from 25% of the total lymphocytes in the first week to 16% at 19-21 weeks. The total number of gamma-delta cells does not change but the percentage decreases as the percentage of B cells increase and the numbers of T cells increase. Mitogen activation of T-lymphocytes is slightly less depressed at birth and remains constant through 28 days after birth. The take home message of active immune response in young calves is that cell mediated responses to parenteral vaccines can be induced very early, however animals must be 3-4 weeks of age before vaccines will induce robust antibody responses that will develop in 10-14 days following vaccination. On the other hand, mucosal immune responses seem to be adequate in the newborn calf and can be boosted with subsequent mucosal vaccination.

Conclusion The management of the calf’s immune response requires understanding of the immaturity and development of the calf immune system. Vaccine timing needs to be managed to take advantage of the biology of the immune system and not haphazardly.

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Some factors that potentially cause variance in postweaning dairy calf growth to 6 months of age will be outlined such as nutrition, systems management (confinement and pasture), grouping, health, body condition, dry matter intake, genetics and environmental changes. Variance control and management consistency are emphasized. What are the growth goals for dairy heifers from 2 to 6 months is it 1 kg/day? The dairy calf transitions from a diet predominantly of milk or milk replacer with increasing starter intake up to weaning and then postweaning changes to an introduction of forages with more limited grain intake.

Recent research has suggested that allowing pre-weaned calves access to chopped forage is beneficial for rumen development and growth during pre- and postweaning. The calf at weaning still has an underdeveloped rumen and preweaning diet composition and intake is critical. The developing rumen in calves under 4 months of age often results in a less than adequate feed retention time for proper digestion. During the transition period there are important changes in diet composition, digestion, and metabolism plus social and environmental changes that need to be controlled. Grouping strategies pre- and postweaning will be addressed. Fiber levels, processing and feed combinations for 2 to 4 month old calves will be highlighted. Fibrous feeds that may take more time to ferment and digest and may be poorly digested in the young postweaned calf compared to an older heifer. Options using complete diets with varying levels of fibrous feedstuffs are discussed in relation to metabolism and growth. Intake and daily gain of the young weaned calf is inversely proportional to the amount and digestibility of the forage fiber fed. Energy intake is shown as being the nutrient most limiting to growth. Additionally, excessive fiber retained in the rumen of young calves can result in gut fill, growth of gut mass, and accumulation of non-carass tissue. Typically, growth of young calves is efficient and fattening is considered minor compared to growth of muscle and bone. There are limited definitive studies in many of these areas. An example of a standard procedure of weaning calves at 42 days, allowing them to remain in individual pens for a further 2 weeks then moved to group pens of 7 will be presented in comparison to other options.

If forage is offered free choice from 9 weeks of age with limited grain mix, the proportion of the forage consumed for the first month has been shown to be 35% of the total diet increasing to over 70% of the diet by 6 months of age. Diets fed during the first month after moving group pens can be quite flexible. The effect of forage hay quality fed postweaning demonstrates the premise that NDF intake as a percent of body weight and digestibility affect dry matter and energy intake. Nutrient guidelines for feeding Holstein heifers post weaning are discussed and examples of environmental factors that need energy adjustments. Bunk management and feeding variance control is very prevalent in these times of high feed prices. Maintaining consistency of nutritional management and an understanding of management practices that benefit heifer is an important goal.

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Calf milk replacers were originally designed to do just that – to replace milk. Feeding calves an alternate feedstuff, in this case milk replacer, allows farmers to sell more milk. This practice is acceptable as long as calves still grow efficiently and the cost of feeding the milk replacer makes economic sense. Replacing the fat in milk with alternative fats, such as edible lard or tallow seems appropriate and has proven to be the industry norm, especially when these fats are processed to a small particle size and combined with emulsifiers.

However, milk fat compared to either edible lard or tallow has some properties that may be of importance to the overall digestion and performance of the calf. Milk fat contains a wide range of fatty acids, including short-, medium-, and long-chain fatty acids, all distributed in a non-random manner on to glycerol backbones to form triglycerides. Edible lard and tallow both lack short- and medium-chain fatty acids. Short- and medium-chain fatty acids are digested and absorbed differently than long-chain fatty acids in preruminant calves. They can be hydrolyzed from the glycerol backbone in the abomasum and pass directly into portal blood attached to the carrier protein serum albumin. These fatty acids, travel directly to the liver where they can readily be oxidized by the calf as a quick source of energy.

On the other hand, long-chain fatty acids are digested more slowly and are absorbed primarily in the small intestine with the help of bile and pancreatic secretions. Absorbed long-chain fatty acids are eventually packaged into chylomicrons or other lipoproteins, which then enter the lymphatic system and pass through the thoracic duct where they empty into the jugular vein and general circulation. After chylomicrons or other lipoproteins reach general circulation they are available for further metabolism.

In addition to the properties mentioned above, milk fat is slightly more digestible than edible lard or tallow. Some purported reasons for this include the greater short- and medium-chain fatty acid content of milk fat and the positional distribution of specific fatty acids on the glycerol backbone of the triglyceride.

As scientists look forward, it may be of value to investigate stage feeding of dairy calves (more short- and medium chain fatty acids and triglycerides offered in milk replacers for the youngest calves, perhaps). Stressed calves or calves known to be suffering from malabsorption (scouring calves) may also benefit from more short- and medium chain fatty acids and triglycerides in milk replacers or electrolytes. Finally, “designer fats” may be of interest in the future; with this, fatty acids of desired chain lengths could be esterified on to glycerol at desired positions so that the resultant triglycerides might be digested by the calf in a more efficient manner. In recent years, coconut oil and palm kernel oil, commonly in combination with edible lard, have received increased research attention by those interested in the continued advancement of calf milk replacer formulation. Presumably this is for some of the reasons outlined above; both oils are rich in medium chain triglycerides.

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Replacing Milk-Derived Proteins and Carbohydrates in Milk Replacer

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Milk replacers were developed to allow farmers to sell all usable milk and to feed calves with a less expensive liquid feed before weaning. Most high-quality milk replacers still rely on milk proteins (principally whey proteins) for 50% or more of total protein, and lactose provides the primary carbohydrate source. Thus, milk replacer manufacturers are still highly dependent on milk byproducts. With the surging price of whey proteins and lactose in recent years, and the forecast for sustained high prices for those commodities, economic pressure to find suitable non-milk-derived ingredients for calf milk replacers continues to mount. While not a new problem, the increasing food security issues faced in the coming years may make supplies of milk-derived ingredients scarce for animal feeds.

The calf is born with the digestive system designed to digest and utilize milk. Capabilities for digestion of non-milk proteins and carbohydrates are low at birth but increase rapidly over the first few weeks of life. Attempts to use non-milk ingredients for calves less than 3 weeks old are in direct conflict with the biology of the calf. Nevertheless, alternate proteins are widely used in milk replacers today. The most common and best utilized ingredients are plasma proteins, wheat proteins, and soy protein concentrates. Growth of calves fed higher amounts of non-milk proteins often is less than with milk ingredients such as whey protein concentrate. Possible reasons for decreased performance include inadequate energy intake, lower digestibility, anti-nutritional effects, and imbalanced amino acid supply.

Newborn calves have little capacity to use any carbohydrates other than lactose and its constituent glucose and galactose. Small amounts of starch can be tolerated. Calves may be able to use considerable amounts of dextrins such as corn syrup solids, although the proper size and inclusion rates have not been determined definitively. Glycerol can be used to replace 10% or more of lactose but its incorporation into dry milk replacers is problematic.

The dairy industry is thus faced with a dilemma, in which the well-being and biology of the calf may be pitted against the economic necessity to lower costs of feeding. This situation need not be an absolute, all-or-nothing issue, and compromises of lower-cost ingredients and satisfactory well-being are possible. Many of these problems could be managed through appropriate processing technology and improved nutritional practice. Research should continue the search to improve utilization of non-milk ingredients by young calves.

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FACTORS INFLUENCING IgG UPTAKE
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Dairy calves are born with a naïve immune system and most receive their initial immunity from colostrum. The primary immunoglobulin of importance to the calf is immunoglobulin G (IgG). According to U.S. data, 7.8% of preweaned calves die primarily due to diarrhea, 20% of U.S. calves fail to meet the minimum standards of 10 g IgG/L of serum. Approximately 60% of the colostrum produced in the US fails to meet minimum standards of 50g IgG/L. Increasing IgG uptake reduces morbidity and mortality, resulting in improved growth and milk yield when the heifer enters the milking herd. Decreased costs to raise the calf and more saleable product for the producer will be realized along with an inexpensive high quality food product (dairy) for the consumer.

To help decrease morbidity and mortality and realize improved profits, dairy producers need to use high quality colostrum. Therefore testing using a colostrometer or refractometer should become commonplace. Also, colostral IgG drops in colostrum for every hour after calving before it is removed from the cow. It is imperative that colostrum be removed as soon as possible and provided to the calf. Many U.S. dairy producers still allow the calf to nurse the cow; it is recommended that colostrum be provided either by nipple bottle or esophageal feeder to ensure that IgG reaches the small intestine soon after birth. However, there appears to be some data suggesting that IgG uptake may be enhanced by the calf remaining in proximity to the cow, possibly by reducing stress to the calf. While allowing the calf to remain with the cow may not be practical, there may be ways to enhance IgG uptake through tactile stimulation of the calf. More research needs to be conducted in this area. Reducing heat stress of the cow improves IgG uptake in the calf. Providing fans and sprinklers for prepartum cows reduces heat stress resulting in increased IgG uptake in the calf. Providing good quality colostrum either all at one time (3.8 L) or split into two feedings, as long as the second feeding is within 12 h of birth, is appropriate.

Additives for colostrum such as trypsin inhibitor and sodium bicarbonate have shown positive responses to IgG uptake in some, but not all experiments. Responses with sodium bicarbonate addition may be related to the dam’s diet. Research with beef cows indicate that feeding a restricted energy diet did not alter the IgG concentration in colostrum, but reduced IgG uptake in calves born of cows fed the restricted energy diet. If dairy producers feed good quality colostrum through a nipple bottle or esophageal feeder as soon after birth as possible, morbidity and mortality of the nation’s calf herd should be reduced while growth and future milk yield should be enhanced. Research needs to be conducted to determine the optimal diet to feed a prepartum cow to promote colostrum quality along with IgG uptake by the calf.

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EFFECTS OF HEAT-TREATING COLOSTRUM ON COLOSTRUM CHARACTERISTICS AND CALF HEALTH

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Despite its importance in supporting calf health, growth and development, the frequent contamination of colostrum with microbial pathogens may result in acute or chronic disease in calves. Additionally, several studies have described a negative relationship between colostral bacteria counts and IgG absorption in neonatal calves. Heat-treatment (HT) is one approach available to producers to reduce microbial contamination in the colostrum fed to newborn calves.

Effects of on Colostrum Characteristics: Heat-treatment at 60°C for 60 minutes significantly reduces or eliminates specific inoculated pathogens, including *Mycoplasma spp.*, *Listeria spp.*, *Escherichia coli*, *Salmonella spp.* and *Mycobacterium avium* subsp. *paratuberculosis*, and significantly reduces total plate counts (TPC) and total coliform counts (TCC) in colostrum. However, the HT process does not negatively affect colostral immunoglobulin G (IgG) concentrations, a variety of nutrients tested (e.g. fat, protein, lactose, macrominerals, trace minerals, vitamins A, E and β-carotene), and a number of other colostral components including insulin, lactoferrin and insulin-like growth factor. The HT process does reduce the viability of a significant proportion of colostral leukocytes, the significance of which is yet to be determined. Finally, while the HT process does inactivate the alkaline phosphatase (AP) enzyme in a significant proportion of colostrum samples, this does not occur consistently, precluding using AP enzyme testing as a tool to monitor adequacy of HT on farms.

Effects on Calf Health: Several University-conducted randomized controlled studies have demonstrated that calves fed HT colostrum experience improved efficiency of absorption of IgG (%) and higher serum IgG concentrations (mg/ml) as compared to calves fed fresh (FR) colostrum. The current hypothesis to explain this effect is that HT colostrum contains fewer bacteria, particularly coliform bacteria, which may interfere with the passive absorption of colostral IgG in the small intestine. Although several hypotheses exist, the exact biological mechanism(s) by which bacteria in colostrum may interfere with passive transfer of IgG is yet to be determined. One large field study, involving more than 1000 calves in 6 Minnesota and Wisconsin dairy herds, has proven that producers can achieve the same results feeding HT colostrum as have been previously described in University-conducted studies. In this field study calves fed HT colostrum had improved serum IgG concentrations during the first week of life, were at 25% reduced odds of being treated for scour, and were at 32% reduced odds for being treated for any disease, as compared to calves fed FR colostrum, during the preweaning period. Path analysis suggested that HT of colostrum causes reduced TCC counts, which in turn is associated with improved serum IgG concentrations, and subsequently, improved calf health.

In summary, HT of colostrum results in reduced bacterial exposure through colostrum, improved serum IgG concentrations in calves, and reduced morbidity in the preweaning period. Research is ongoing to describe if there any long term benefits to cow health or lifetime productivity for calves fed HT colostrum at birth.

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For over 80 years the importance of passive transfer of maternal immunity for the protection of the newborn calf from infectious disease has been well recognized. In spite of this awareness the rate of failure to attain adequate passive transfer is about 20% of all dairy heifers. Thus there is a need to develop tools and strategies to improve the quantity of passive transfer in calves.

The parameters that result in successful passive transfer are relatively straightforward and well documented. The gastrointestinal tract of the newborn is only able to absorb the intact immunoglobulins (and other factors) from the colostrum for the first hours of life and so early feeding is of the essence. In addition it is clear that the quantity of immunoglobulin absorbed is proportional to the mass consumed. Thus mass consumed along with age at feeding will be the two largest determinants of successful passive transfer.

The apparent efficiency of absorption (AEA) is a calculation that takes into account the body size of the calf and estimates the proportion of the immunoglobulin consumed that is measured in the blood. Since this value is often only about 1/3 of the mass consumed there have been many studies to attempt to find means to increase the AEA. Factors such as IgG concentration, routes of feeding (bottle vs. tube) and bacteria levels have been shown to have an impact on AEA however most other interventions have not been effective.

In the past two decades several companies in the USA, Canada and elsewhere have developed commercial colostrum products to supplement or replace maternal colostrum. Dairy cows, as a consequence of selection for production of large quantities of milk also often produce excess colostrum so some products are derived from colostrum, others from whey (a by product of cheese manufacture) and others from blood obtained from slaughtered animals. Thus there is great variability in the product formulations and in their similarity to maternal colostrum.

Increasingly it is recognized that the benefits of early feeding of ample amounts of colostrum extend far beyond the neonatal period and are not linked to the health outcomes of the young animal (whether the calf suffered illness or not). Other colostral factors such as fat, anti-microbials and growth and metabolic factors may have important roles in optimizing the long-term performance of the heifer. Thus the quality of the colostrum including the presence of these other factors should be considered in assessing the products to be used in a colostrum program to deliver optimal passive transfer.

Colostrum products have merit if they can be shown to deliver the key ingredients of maternal colostrum and may have additional benefits beyond maternal colostrum in that the heat treatments will ensure freedom from pathogens and the pooling effects will ensure uniform presence and titers of antibodies to all the important infectious agents.

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The transfer of colostrum has been recognized to have a salutary effect on the development of calves for many years. Both an immediate effect on the capacity of the neonatal calf to resist infectious diseases and longer-term effects of receiving colostrum on growth and development have been reported. The roles of live immune cells, cytokines and growth factors, and microbes transferred from the mother to the neonatal calf with the delivery of colostrum is not yet well understood, and not all workers in this area necessarily share a common view of their importance and function.

My research group has spent a long time trying to understand what all the cells, cytokines and growth factors, and (more recently) bacteria found in the mammary gland during the immediate pre-delivery period are designed to do. The level of each of these components found in the gland and in colostrum is greatly reduced within 2 to 3 days after delivery. Further, no clear role in the development of milk production by or protection of the mammary gland have been demonstrated for any of these components.

An examination of live maternal cells in colostrum as they relate to the neonatal have shown the following: 1) Exposure of maternal lymphocytes to colostrum induces changes in their surface that impacts how they traffic across epithelial cells, 2) Maternal cells in colostrum cross the intestine and traffic in the circulation of the neonate during the first 30 hours after birth. 3) The absence of maternal cells in colostrum appears to be associated with a delay in antigen presenting function in leukocytes in the neonatal circulation; 4) The transfer of maternal cells has an impact on the development of lymphocyte responses to antigen – inducing both more rapid responses to foreign antigens and tolerance to maternal antigens; and 5) Memory cells from the mother appear to circulate in the neonate and to retain their capacity to respond to antigens to which they were primed in the mother. Maternal cells have an uncertain fate, but it appears that they home to secondary immune tissue in the central and mucosal compartments of the body.

In addition colostrum contains cytokines and growth factors and bacteria. It has been demonstrated that mammary quarters from more than 80% of heifers tested were colonized with bacteria during the last few days before birth. Most were Staphylococcus or Streptococcus species. This colonization was typically cleared by 2 days after birth. Both of these genus produce enterotoxins and virulence factors that non-specifically activate lymphocytes. Other microbial components also activate innate immune activity. This microbial activation, dampened by transferred maternal antibody and focused by transferred cytokines and growth factors, appears to prime and promote immune development in the calf, starting in mucosal tissue. Others have studied a role for bacteria in early immune development but the full ecological system involved is not clearly understood.

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The management of the pre-weaned calf has evolved over the past 50 years. Research in the 1950’s led to feeding programs aimed at developing low cost strategies to encourage rumen development using limit feeding of liquid diets and early weaning as a means to reduce daily costs. However, beginning in the 70’s research questioned this strategy as it deviated from rearing programs of most other mammals which emphasized more liberal feeding programs and higher daily growth during the milk based feeding period. Enhanced milk or milk replacer feeding programs have increased daily feed costs, but with improvements in feed efficiency, resistance to disease, earlier calving and reductions to rearing expenses until first calving. Further research is needed to determine if more liberally fed liquid diets pre-weaning is related to improved lifetime lactation yield and longevity. Traditionally housing and feeding systems have focused on individual housing as a means of controlling feed intake of liquid and solid feeds and reducing risk of disease transmission. More recent research indicates potential benefits to animal welfare in group housing systems using acidified liquid diets or computer controlled automatic feeding systems. However, the implications for disease of the young calf have yet to be determined for the young dairy calf.

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FORMULATION AND PHYSICAL FORM OF CALF STARTERS
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Form of a grain-based starter fed to dairy calves in their first 2-3 months of age has been found to affect their rumen development and function since studies in the 1940s, and especially in the 1950-1970s. When calves are born, they have a true stomach digestive system oriented to digest milk or milk replacer diets, similar to humans. Their rumen is non-functional at birth, and it is stimulated to develop by dry feed emptying into it. Dependent on how that dry feed ferments largely determines the functional development of the rumen papillae—the little finger-like projections that in turn absorb the volatile fatty acids produced in rumen fermentation. These fatty acids and their absorption are the major energy source for ruminants.

That fermentation depends on the nutrient content of the dry diet, and also on its physical form. Coarser dietary particles stimulate the calf to “chew its cud” or ruminate the larger particles back into its mouth from the rumen. The calf then chews these particles to make them smaller for better rumen microbial fermentation. In the process of chewing, the calf also produces considerable quantities of saliva which has a high buffering capacity. When swallowed, this saliva buffers the rumen fermentation to prevent it from becoming too acid. This scenario provides the optimum situation for rumen development and function in calves. It also then allows the calf to later better utilize hay. In the first 2 months of life, hay can retard rumen development as it does not provide the optimal fermentation, is slow to ferment and digest, and creates fill in the rumen which limits dry feed intake and distorts true body growth.

Pelleted starters, in which all ingredients are ground fine before pelleting, do not facilitate chewing/salivation and thus create marginal acidosis in the rumen. Marginal acidosis can decrease intake and lower feed efficiency. Properly texturized or coarse starters avoid these problems.

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The Effects of Housing on Calf Health
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During the winter of 2005, we conducted a study of housing risk factors for respiratory disease in preweaned calves in naturally ventilated barns (Lago et al, JDS, 2006). Significant factors associated with reduced risk of respiratory disease included reduced airborne bacterial counts, high “nesting” scores related to the depth of bedding, and having a solid panel between each calf. Related to the solid panel, the study also showed a confounding finding in that the solid panel was also associated with increased airborne bacterial counts.

Because of the confounding findings, we explored the idea of using positive pressure tube systems to supplement natural ventilation and deliver fresh air between the panels of individual calf pens. While positive pressure tube systems have been used in calf and dairy barns for more than 30 years, the earlier systems mounted the fan inside the barn where it served as a recirculating system within the barn. Our change was to mount the fan in an exterior wall with access to only outside air, thereby making it a ventilation system. The systems were sized to move minimal volumes of air and run non-stop year around. The initial installations into commercial calf barns were remarkably successful in reducing respiratory disease, according to anecdotal reports of herd owners.

Using these systems to drive a small quantity of air, sometimes very cold, into the micro-environment of the calf requires a relatively precise control of both quantity of air as well as velocity of delivery. Neither of these criteria mattered in the old recirculation systems. More specifically, the new system requires design to create appropriate “throw” distances of air from the tubes to avoid subjecting the calf to “drafts,” as well as sizing the diameter of the tube so as to create a uniform distribution of air along the entire length. These criteria can be met using the principles of fluid mechanics in the design process.

Because of the importance of calves “nesting” in bedding during cold weather, drainage below the bedded surface has emerged as an important management tool. Anecdotal reports from operators suggest that equivalent depth of bedding can be maintained with approximately half the volume of bedding if placed over tiled gravel base.

For larger scale dairies, it appears that developing “all-in, all-out” barns for preweaned calves is helpful in limiting outbreaks of infectious disease problems. Usually there are a series of 4 or more barns. Having excess capacity so that the space can be cleaned after weaning and allowed to rest for a week appears to be a very attractive feature.

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Abomasal hypomotility and decreased rate of abomasal emptying are believed to play important roles in the pathophysiology of abomasal disorders in both adult cattle and calves. Abomasal emptying rate is largely controlled by nutrition, or what the calf is being fed. The volume and caloric content of an ingested fluid meal are the most important determinants of abomasal emptying rate. Calorically inert isotonic fluids, such as isotonic sodium bicarbonate, are evacuated from the stomach in a rapid and exponential manner. In contrast, fluids such as isotonic glucose solution and milk replacer are emptied in a slower, more linear manner. This is a normal physiologic response that ensures nutrients are being presented to the small intestine at a relatively constant rate. Other important determinants of abomasal emptying rate include the type of protein or fat, osmolarity, and duodenal pH (with luminal pH <2.0 or > 10.0 decreasing the abomasal emptying rate in calves.

Nutrition of the calf and abomasal emptying is thought to be a primary factor in the development of abomasal bloat. Abomasal bloat is a syndrome in young calves characterized by anorexia, abdominal distension, bloat and often death in 6 to 48 hours. This condition occurs most commonly in dairy calves and seems to have a sporadic occurrence with some farms having multiple outbreaks at times. Risk factors can include feeding a large volume of milk in a single daily feeding, cold milk (or milk replacer), not offering water to calves, erratic feeding schedules, and failure of passive transfer. Recently the abomasal bloat syndrome was experimentally reproduced by drenching young Holstein calves with a carbohydrate mixture containing milk replacer, corn starch, and glucose mixed in water. Although the exact pathogenesis of abomasal bloat is not completely understood, the disease is likely to be multifactorial in origin. Having large amounts of fermentable carbohydrate present in the abomasum (from milk, milk replacer, or high energy oral electrolyte solutions) along with the presence of fermentative enzymes (produced by bacteria) would likely lead to gas production and bloat. This process would be exacerbated by anything that slowed abomasal emptying or caused gastrointestinal ileus. Thus control of this disease should be aimed at dietary management more so than therapeutic or prophylactic medications.

Ultimately what and how we feed calves has a significant influence on their health and well being. Milk replacers and feeding schedules that promote faster abomasal emptying will help decrease bloat and potentially improve performance. Hypertonic solutions decrease abomasal emptying rate in calves relative to isotonic solutions, with profound inhibition of emptying occurring when osmolarity is >600 mOsm/L. Feeding large volumes of milk also slows abomasal emptying. It is important for the calf nutritionist to consider the effect of both the type of milk they are feeding and the feeding schedule on abomasal motility when designing milk feeding programs for calves.

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The choice of how much and how milk is given to dairy calves has a huge impact on their welfare. In fact, nourishment is part of the definition of animal welfare developed by the World Organization for Animal Health. However, being well nourished is not the only measure of welfare. The volume and method of feeding calves also impacts their ability to express their innate behavior and can lead to feelings of hunger even if the basic nutrient needs are met. Currently, 93% of calves in the USA are fed twice a day, 70% are fed between 4-5 quarts of milk per day (USDA, 2011). In eastern USA, 73% of calves in the east are fed by bucket (USDA, 2011). As we look at the time budget of calves in most calves we see a great disconnect between the amounts of time they are motivated to suckle versus the time spent consuming milk from a pail or bottle. This reduced feeding time and intake results in sucking behaviors that are inappropriately directed at the environment or other calves. This behavior is not a flaw of the calves but rather represents a failure to meet the needs of dairy calves to suckle. Calves fed at these rates also display behaviors indicative of hunger, lower growth rates, and frustration.

Group housing has become more popular in recent years and has changed the dynamic of how and when calves are fed. There is evidence that early socialization has benefits to calves in terms of improved adaptation to new environments, neurological changes, and increased feed intake. Failure to meet the needs of calves during milk feeding can result in high rates of non-nutritive sucking (cross-sucking) that will impact the welfare of targeted calves. As such there is a need to feed more milk to calves that are being group housed in the nursery compared to individually housed calves. This is not a negative of the system but rather an opportunity to encourage both increased socialization and a larger number of feeding bouts.

For the long-term welfare of calves, it is important that we not only meet the needs of calves while they are on milk but also find the least stressful method to prepare them to transition to a roughage-based diet. Examples of behaviors calves display during weaning distress include increased vocalization and changes in activity. Lower average daily gains are also observed during this period and are commonly referred to as post-weaning slump. As the industry begins to move to higher feeding levels and group housing, the issue of how to encourage grain intake becomes an even more important issue. Higher milk feeding is associated with a later start to consume grain and decreased grain intake. If calves are not consuming adequate grain levels at the time of weaning they will show a greater response to weaning.

Looking to the future, we need to meet the nutritional and behavioral needs of preruminant calves. This will require substantial changes from the current method of caring for calves. This will be done through an increase in milk volume and meals as well as the use of group housing. Current limitations include adoption costs, managing the health of groups of calves, and weaning methods.
The benefits of increased rates of gain in milk-fed calves have been documented through a number of key research trials and meta-analyses. In addition to the apparent health benefits to the young calf, the long-term effect on future milk production has been well recognized.

As accelerated calf feeding programs have evolved, there has often been the challenge of allowing the calf to consume sufficient milk to meet the needs of accelerated growth. Free access to milk or milk replacer has provided the opportunity to maximize intakes and capitalize on some of the potential benefits of early socialization in a group environment. Additionally, acidification of milk or milk replacer has been shown to have some direct benefits in reducing enteric diseases.

Some new challenges have also arisen with these feeding and management systems. The ability to provide sufficient ventilation, space and bedding is a key aspect of minimizing the effect of disease in the group-housed environment.

This presentation will review the benefits of optimal nutrition and growth in the milk-fed calf and introduce general concepts for the practical implementation of ad-lib feeding programs.
An objective of Animal Scientists is to develop strategies for domestic animals, in this case cattle, to be more productive throughout their life. We have done this through various management strategies with the greatest emphasis during the dry period and lactation cycle once the cow has calved and initiated milk secretion. Continually improved genetic selection, housing and nutrition have all been strategies to enhance productive efficiency once the animal becomes an adult. We have learned that the dam, through colostrum and milk secretion, has the ability to alter the productive efficiency of her calf. These apparent change in productive efficiency be it growth, feed efficiency, or future milk yield, appear to be accomplished through bioactive factors in colostrum and through the nutrient profile and amount of milk the dam would provide to the calf if the calf was allowed to nurse. The general management strategy of the dairy industry over many years was to limit the amount of liquid feed (milk or milk replacer) offered to calves in an effort to reduce the cost, labor required and the potential for a health incident (diarrhea for example) and encourage them to consume dry feed and become a ruminant. This reduced milk or milk replacer strategy, although cost effective in the short-term, does not follow normal biological behavior, since it does not allow the calf to display normal eating behavior and consume the amount of nutrients and subsequent growth it would normally display under more natural conditions.

Colostrum intake has been shown to affect intake and feed efficiency. Calves fed greater amounts of colostrum consumed 8.5% more milk replacer, had an 18% increase in pre-weaning ADG, a 12% increase in post-weaning feed intake, and a 25% increase in post-weaning ADG through 80 days of life indicating that colostrum potentially affects appetite regulation which enhances growth and possibly feed efficiency. Overall, colostrum is an important vehicle of communication between mother and offspring, through lactocrine signals that enhance developmental functions beyond the immune system.

Further, data are now available that demonstrate greater first and subsequent milk yield in adult cattle that were fed greater nutrient intake prior to weaning from milk or milk replacer. This milk yield difference due to the increased pre-weaning growth ranges from 450 kg per lactation to over 1,400 kg milk in the first lactation alone. This is a significant increase in productive efficiency and many times greater than is realized from current genetic selection programs. The data demonstrates that nutrient intake from milk or milk replacer during the pre-weaning period positively impacts long-term productivity of dairy calves and provides new management opportunities to improve milk yield of dairy cattle and suggests there are significant developmental functions being programmed that require further investigation.

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Development of dairy calves for optimal performance requires attention to their health. NAHMS surveys in 2002 and 2007 confirmed that the most common health problem for preweaning dairy calves is diarrhea, followed by respiratory disease. For postweaning dairy calves, respiratory disease is the most common health problem. It is becoming common for dairies to send calves to rearing operations. A NAHMS survey of heifer rearing operations was completed in 2011. In contrast to previous surveys, respondents indicated that respiratory disease caused the highest proportion of death of preweaning calves. Respiratory disease may be common in part because calves on rearing operations are often allowed to come into contact with calves from various sources (co-mingling). Similarly, European research indicates that group housing of preweaning calves increases respiratory disease. The “cost” of time at a heifer rearing operation and/or preweaning group housing may be increased risk for respiratory disease, but more research is needed to confirm this in North American systems.

The calf’s immune system can help it resist disease; the immune system of the calf at birth is functional, but naïve and immature. Colostrum helps with this situation. Antibody in colostrum is well-known to be critical to calf health, but live maternal cells in colostrum can also influence calf immunity. Because live whole cells are not present in frozen or dried colostrum, research is ongoing to characterize the impact of these cells and to determine whether a stable component can be added to frozen or dried colostrum to provide the effect.

Nutrition impacts immunity, but the relationship between nutrition and immunity is not always predictable. Some research has shown that a diet deficient in energy and protein suppresses immune function, while other research has not. Unfortunately, most research to date has not characterized the effect of diet on disease resistance. More research is needed to answer persisting questions regarding the relationship between feeding calves for physiological growth, and immune function and disease resistance. Various feed supplements are sometimes added to calf diets to improve immunity and disease resistance. Recent research has shown that these supplements or additives can sometimes improve immune responsiveness or disease resistance, but the effect is not always predictable. Ongoing field research, with relevant health outcomes measured, is needed to clarify when and where feed additives can meaningfully and cost-effectively improve calf health.

Vaccination can also be used to improve calf health; in particular, many vaccines are available to prevent or limit respiratory disease. However, challenges to vaccinating preweaning calves for respiratory disease include the fact that disease can occur very early in life, and high concentrations of maternal antibody may suppress responsiveness to vaccination in very young calves. Intranasal vaccination may be superior to injectable vaccination in this setting. Intranasal vaccines are widely used; unfortunately, no properly designed clinical trial has yet confirmed whether they improve calf health in a North American calf management setting. More research is needed to confirm how vaccination can best limit respiratory disease in pre- or post-weaning dairy calves.

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