# Managing the challenges in transition dairy cows

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### Abstract

The transition from late gestation to lactation is a period of many physiological changes, and a critical time to ensure cows are well prepared for a profitable and healthy lactation. There are many opportunity areas to implement management practices mitigating the risk of early lactation catabolic armageddon. Most dynamic activities will be better implemented if they are consistently measured and monitored. While comparison to external benchmarks is inherently dangerous to sound decision making, we aim to provide a framework such that a dairy can begin to internally calibrate its management metrics. Monitoring performance metrics that have little momentum, bias, and lag will help dairy farms reach their goals.

Systematic recording of clinical diseases with consistent case definitions is 1 of the best groups of metrics to monitor. We suggest lactational incidences of DAs < 3%, clinical milk fever < 2%, and retained fetal membranes of < 8%. Subclinical disease has also been shown to be very costly to dairy performance. We advise hyperketonemia (defined as BHB concentration >1.2 mmol/L) prevalence < 15 to 20% and fresh-cow mastitis prevalence (defined as first test day linear score > 4) to be < 10% for multiparous cows and < 7% for first-parity heifers.

To achieve these low disease risks and have high milk production, there are many management areas to also monitor. For nutritional management of far-off cows, we suggest examining diet formulation and aiming for 110 to 120% of metabolizable energy (ME) requirements and over 1000 g/d of metabolizable protein (MP). The diets of close-up cows should be formulated to provide 110 to 130% ME, but not more, and over 1200 g/d MP. Routine inspection of the dietary cation anion difference (DCAD) should be performed to ensure herd goals are being met. If aiming for a negative DCAD by feeding anionic salts, monitoring urine pH weekly, and ensuring it's adequately acidified is good practice. Delivery of this diet is equally important to formulating it. Given the bulkiness and potential palatability challenges of these recommended diets, it's prudent to monitor the particle size and using the Penn State Particle Separator weekly. We counsel 10 to 20% on the top screen, 50 to 60% in the middle, and < 40% in the bottom pan, with the long straw or hay particles not more than 4 cm. Further, it is important to continuously measure the DM and keep the TMR wet enough to be 46 to 48%. Our field observations corroborate that stocking transition cows at 80% of headlocks or 2.6 ft (0.8 m) of bunk space per cow is beneficial, and these metrics should be evaluated often. Consistent and accurate recording of actionable metrics can allow for timely interventions to ensure the dairy is proactively addressing transition cow opportunities.

**Key words:** dairy, bovine, metabolism, ketosis

### Résumé

La période de transition entre la fin de la gestation et le début de la lactation comprend plusieurs changements physiologiques. Cette transition est importante pour s'assurer que les vaches soient bien préparées pour une lactation saine et profitable. Il existe plusieurs voies prometteuses pour mettre en place des pratiques de régie afin de réduire le risque d'un désastre catabolique tôt en lactation. La plupart des activités dynamiques s'instaurent mieux lorsqu'elles sont mesurées et surveillées constamment. Parce que la comparaison avec des étalons externes peut nuire à une bonne prise de décision, nous voulons promouvoir une structure permettant à la ferme laitière de calibrer à l'interne les indicateurs de régie. La surveillance d'indicateurs de performance qui sont peu dynamiques, ont peu de biais et de décalage devrait aider la ferme laitière à atteindre ses buts.

La notification systématique des maladies cliniques avec une définition de cas uniforme fournit l'un des meilleurs ensembles d'indicateurs à surveiller. Pendant la lactation, nous suggérons une incidence de déplacement de caillette < 3%, de fièvre vitulaire clinique < 2% et de rétention de membranes placentaires < 8%. On recommande que la prévalence de l'hyperacétonémie (définie avec une concentration de BHB > 1.2 mmol/L) soit moins de 15 à 20% et que la prévalence de mammite chez les vaches fraîchement vêlées (définie comme un pointage linéaire au premier jour de test > 4) soit < 10% pour les vaches multipares < 7% pour les génisses primipares.

Il y a plusieurs facettes de régie à surveiller pour atteindre des risques de maladies aussi bas et avoir une production de lait élevée. Pour la régie de l'alimentation chez les vaches taries, nous suggérons de surveiller la formulation de la ration et de fournir 110 à 120% des besoins en énergie métabolisable (EM) et d'avoir plus de 1000 g/j en protéines métabolisables (PM). La ration des vaches

taries devrait fournir entre 110 et 130% des besoins en EM mais pas plus et avoir plus de 1200 g/j de PM. L'inspection routinière de la différence alimentaire cation anion dans la ration (DACA) devrait se faire pour s'assurer que les buts au niveau du troupeau se réalisent. Si on recherche une DACA négative en faisant des apports de sels anioniques, il est suggéré de surveiller le pH de l'urine à toutes les semaines et de s'assurer que l'urine soit suffisamment acidifiée. Fournir cette ration est aussi important que sa formulation. Parce que ces rations recommandées sont volumineuses et possiblement moins appétissantes, il est prudent de surveiller la taille des particules et d'utiliser le séparateur de particules *Penn State* hebdomadairement. Nous recommandons entre 10 et 20% dans la partie supérieure, entre 50 et 60% dans la partie médiane et moins de 40% dans la partie inférieure en s'assurant que les longues pailles ou les particules de foin ne soient pas plus grandes que 4 cm. Il est aussi important de surveiller la matière sèche et de garder la ration totale mélangée assez humide pour qu'elle soit entre 46 et 48%. Nos observations sur le terrain corroborent qu'il est bénéfique de garder les vaches en transition avec un cornadis de 80% ou 0.8 m d'espace à la mangeoire par vache et qu'il est important de surveiller ces indicateurs souvent. La notification systématique et précise de ces indicateurs exploitables permet d'agir en temps opportun pour s'assurer que la ferme laitière adopte une attitude proactive lorsque vient le temps de gérer les vaches en transition.

## Introduction

### Current opportunities in the management of transition cow health

*Physiological changes during the transition period*

The transition to lactation is a period of many physiological changes and a critical time to ensure cows are well prepared for a successful lactation. Immediately after calving, cows experience large changes in nutrient demands and many metabolic adaptations occur to maintain homeorhesis.[1] Of foremost interest are the adaptive mechanisms to maintain calcium and energy homeostasis. Calcium is necessary for all muscle and nerve function, and is especially important during the immediate periparturient period for colostrum synthesis and uterine contraction during parturition.[1] These processes place a large drain on maternal calcium post-partum, and a coordinated hormonal response is necessary to maintain calcium homeostasis and support high levels of milk production. When this system is out of balance, hypocalcemia can result.[14,15]

Occurring simultaneously is the decrease in dry-matter intake (DMI) that occurs in the periparturient period, which is insufficient to support the high milk production of lactation and results in a state of negative energy balance (NEB). With the increased glucose demand for milk lactose synthesis,[2,37] alternative fuel sources are mobilized. This results in increased mobilization of adipose tissue, manifested as the release of non-esterified fatty acid (NEFA) into circulation to be metabolized by the liver and other tissues, and incorporated into milk fat in the mammary gland.[2,11] The formation of ketone bodies (BHB, acetoacetate, and acetone) in the liver provides an alternative fuel source for body tissues.[11] However, when there is excessive ketone body formation, hyperketonemia can result.[16,26] Higher DMI post-partum generally results in lower circulating NEFA and BHB and has been associated with improved health, performance, and less severe post-partum NEB.[18] Optimizing DMI during this post-partum period is especially important to provide sufficient energy to support cow health and production.

The immune system also enters a period of imbalance during the transition to lactation, and cows experience a decrease in immune function surrounding parturition. Ensuring maximal immune system function is essential for expulsion of the placenta after calving, uterine involution, and appropriate efficacy of bacterial defense mechanisms to prevent mastitis. A dysregulated immune system increases susceptibility to infection, and retained placenta, metritis, and mastitis can result.

*Opportunities to improve transition cow management*

Hypocalcemia, NEB, and immune dysfunction are related; while all occur to some extent during the transition period, our goal as managers is to minimize the severity and duration of these states. When states of hypocalcemia, NEB, or immune function imbalance are severe and last for an extended period of time, they can lead to disease states with negative downstream productive and reproductive consequences that impede cows from reaching their full potential. Often producers will record disease or disease treatments on-farm; however, the recording of only disease treatments rather than the disease state can be problematic in that this may be underreporting the true disease incidence or an overestimation of disease incidence if each episode of treatment is recorded as a disease event. For example, in the case of mastitis, herd protocol may be to treat only gram-positive mastitis and if only treatments are recorded, all gram-negative cases might not be recorded, and thus the true incidence of clinical mastitis would be underestimated. Conversely, if each mastitis treatment were entered as a mastitis event, the true incidence of mastitis would be grossly overestimated. Consistent definitions of disease state and reliable recording of these events over time are necessary to appropriately monitor the health of the herd. Particularly in large herds, computer recording of transition cow disease events can facilitate timely monitoring of the herd's health and action for individual cows. Clinical diseases are timely metrics to monitor on a lactational incidence basis, given that the cow is at risk for most diseases only once per fresh period. Mastitis is a notable exception, but using a "gap" definition (e.g. 14 days) aids in proper recording. Internally consistent definitions are important for this recording to be meaningful and avoiding bias. Further, diseases like DA, retained fetal membranes, and clinical milk fever do not suffer from having lots of momentum and lag either. However, most transition cow diseases have a range of severity, and the clinical manifestation of a disease only represents a small portion of what truly exists in a herd.[12,13,35] The consequences associated with the subclinical form of these disease states have numerous negative subsequent health, reproduction, and production penalties that are not accounted for if we only monitor clinical disease.[6,26,32]

Non-esterified fatty acids (NEFA) and β-hydroxybutyrate (BHB) are energy metabolites that can be used as markers of excessive negative energy balance in dairy cows during the transition period. When sampled in the appropriate time frame, pre- and post-partum NEFA and BHB concentration above certain thresholds are associated with negative downstream outcomes such as increased risk of disease, and decreased milking and reproductive performance at the individual cow level. BHB concentrations can be measured qualitatively or quantitatively with several tests of varying sensitivities and specificities both cow-side or in laboratories. Currently, NEFA concentrations can only be measured quantitatively in laboratories. At the cow level, the following metabolite concentrations are associated with negative downstream outcomes: pre-partum BHB ≥ 0.6 to 0.8 mmol/L; pre-partum NEFA ≥ 0.3 to 0.5 mEq/L; post-partum NEFA ≥ 0.7 to 1 mEq/L; and post-partum BHB ≥ 1.0 to 1.4 mmol/L.[27] At the herd level, negative downstream outcomes can be seen when more than 15 to 25% of the individual cows sampled (given the appropriate sample size) are above the metabolite concentrations shown above.[6,32] Herd-level sensitivity is adversely affected by low cow-level test sensitivity, especially at lower prevalences and smaller sample sizes.[33]

An initial sample for prevalence estimation should be performed following the sample size guidelines described elsewhere,[33] e.g., test at least 20 at-risk animals who are subjectively healthy and 3 to 14 DIM. Any animal with a BHB concentration ≥ 1.2 mmol/L is considered positive and should receive 300 mL of propylene glycol (PG) for 5 days. If 15% or fewer of the animals sampled (3 to 14 DIM) have a BHB concentration ≥ 1.2 mmol/L, the recommendation is to sample again every other week to monitor herd-level prevalence of elevated BHB.

More frequent sampling may be indicated when there are significant changes in diet formulation, management, or environment. If > 15 to 40% of the animals sampled (3 to 14 DIM) have a BHB concentration ≥ 1.2 mmol/L, the recommendation is to test all animals that are 3 to 9 DIM twice weekly (e.g. Tuesday and Friday) and treat all positive cows. This more frequent testing scheme is warranted in order to identify and treat most of the cows with elevated BHB, thus reducing their risk of negative downstream outcomes. If at least 2 consecutive prevalence tests independently result in fewer than 15% of the animals testing positive, then one could consider stopping this testing and treating protocol and monitor the prevalence every 2 weeks as described above. If > 40% of the animals sampled (3 to 14 DIM) have a BHB concentration ≥ 1.2 mmol/L, the recommendation is to start treating all fresh cows with PG at 3 DIM for 5 days. This treatment scheme will help reduce the negative effects of elevated BHB concentrations in herds with a very high prevalence.

Recheck the prevalence in 2 weeks to determine the next course of action, e.g. you can stop treating all cows and move to the test-and-treat positive cow scheme or remain in the treat-all-cows protocol. This monitoring scheme should continue until at least 2 consecutive prevalence tests independently result in fewer than 40% of the animals testing positive.

*Economic impact of transition cow diseases*

For cows that develop any transition cow disease, the total cost of that disease can be divided between component costs and attributable costs, where the component costs are the sum of the direct and indirect costs of that particular disease and the attributable costs include the increased risk of developing another related disease. The direct costs of a disease include labor and veterinary services associated with diagnosis and treatment, therapeutic interventions, and discarded milk required for these interventions. Indirect costs consist of future losses such as milk production, premature culling of the cow as a result of the disease, and negative impact on future reproduction. While most people readily realize the direct costs associated with a disease, interestingly these make up a relatively small part of the total cost of a disease.

Hypocalcemia impacts a large proportion of cows post-partum.[15,36] In a study including 55 dairy herds across the United States, herds where ≥ 15% of cows had a plasma calcium concentration <8.4 mg/dL during the first week post-partum had a -8.4/lb/d (3.8 kg/d) milk production at first DHIA test compared to herds below this cut-point; 73% of evaluated farms were above this threshold.[6] Similarly, cows in herds with a ≥35% prevalence of post-partum hypocalcemia had odds of developing a displaced abomasum 2 times higher than herds with a lower prevalence, and herds with a ≥25% prevalence of hypocalcemia had 30% lower odds of becoming pregnant to first service.[6] With such a high percentage of evaluated farms above these thresholds, these data indicate a large degree of downstream costs associated with hypocalcemia at a herd level. Single large-herd annual costs due to hypocalcemia have been estimated to exceed $50,000 per year.[36]

For hyperketonemia, the average component cost per case is estimated to be $117.[28] Interestingly, the direct costs associated with the disease are only approximately 6% of the total cost, with the remaining 94% of associated costs being indirect, largely future reproductive and milk production losses. When including the costs of other diseases attributable to hyperketonemia (i.e. metritis and DA), the total cost per case is almost $290. With herd early-lactation hyperketonemia incidences averaging 40%,[13,26] annual costs due to hyperketonemia are not trivial.

Hypocalcemia and hyperketonemia, as mentioned above, have an effect on proper immune function, thus the risk of infectious diseases is higher in cows with excessive energy or calcium deficiencies. A cow diagnosed with mastitis is 4.2 times more likely to have another case of clinical mastitis during the subsequent lactation,[34] and cows with early lactation mastitis experience decreased milk production and have a poorer pregnancy risk to first insemination.[39] The average total cost for a case of mastitis in the first 30 DIM is $444, with $128 in direct costs and $316 in indirect costs; the majority of indirect cost is associated with future milk loss.[38] Nearly 40% of cows that calve develop metritis, and multiparous cows with metritis produce less milk, have lower pregnancy risks, and are more likely to be culled than healthy cows.[40] The average cost per case of metritis is estimated to be $396, with 30% due to direct costs and 70% to indirect costs.[28] The average cost per case of DA is estimated to be $700, with 70% due to direct costs and 30% to indirect costs.[28] The high incidence and/or high cost of these post-partum diseases highlights the importance of minimizing disease incidence for both individual animal health and herd profitability.

*Key areas of management to optimize post-partum health, production, and reproduction*

Dairy herds vary widely in the degree to which they achieve success in maintaining excellent health, both in terms of clinical and subclinical health disorders, high milk yield during early lactation, and return to estrous cycling with high fertility in the post-partum period. We believe that the degree of success relates directly to the net effects of an integrated and dynamic set of factors that include nutritional management (both ration formulation and implementation), facility characteristics, grouping management, and overall cow/herd management. Herds vary also in their ability to detect and react to changes in each of these areas, which also contributes to their degree of overall success in transition period management. Authors of other chapters will be able to provide more depth related to each of these areas – the purpose of this section is to highlight key areas of management and principles within each of these areas for best practices.

*Nutritional management of far-off dry cows*

Traditionally, nutritional management of dairy cows during the far-off dry period (i.e. approximately 60 to 30 days prior to calving) has received little attention. Indeed, many aspects of nutritional management (e.g., mineral nutrition beyond meeting basic nutrient requirements) appear to be much less important during the far-off period compared to the close-up period. However, several studies[9,10,20,24] suggest that overfeeding cows beginning during this period leads to lower post-partum dry matter intakes, increased mobilization of body tissue, increased circulating concentrations of NEFA and BHB, and increased risk for metabolic disorders and poorer productive and reproductive performance. We typically target diet formulation to meet 110 to 120% of energy requirements during this period and metabolizable protein supply for Holsteins of over 1,000 g/d. During the far-off period, macromineral considerations such as potassium are not of great concern, thus a wider array of forages and feeds are acceptable to form the basis of diets.

*Nutritional considerations for close-up cows*

There are several areas of critical importance for nutritional management of dairy cows during the close-up period (i.e. typically less than 30 days prior to calving). These include macromineral nutrition, energy nutrition, and protein and amino acid nutrition.

*Macromineral nutrition to improve calcium status.* Clinical milk fever is well managed on many dairies. Recent philosophy has shifted the hypocalcemia focus to include management of subclinical drops in blood calcium post-partum. Even in herds with very low milk fever incidence, subclinical hypocalcemia (SCH) after calving can affect 50% or more of the herd, predisposing cows to infectious and metabolic disease and reducing their productive and reproductive potential.[5,25,36] As these associations continue to be understood, the need for strategies to reduce SCH incidence is becoming more evident. Reducing the dietary cation anion difference (DCAD; Na + K – Cl – S = mEq/100 g DM) of the prepartum ration is a tried and true method for decreasing rates of clinical milk fever.[3,16] Strategies for implementing this approach can range from minimizing the dietary potassium (aiming for a low but still positive DCAD) to varying inclusion rates of anion supplements to reach a negative DCAD. Recently, both Weich et al[45] and Sweeney et al[42,43] demonstrated both improved Ca status and increased DMI and milk yield postcalving for cows fed anionic diets during the dry period. Furthermore, strong consensus exists regarding the importance of also supplementing Mg during the prepartum period to help with the homeostatic mechanisms responsible for increasing blood Ca.

Measuring urine pH is an essential component of monitoring prepartum DCAD, and can also provide valuable information about feeding management.[7,21] Urine pH should be measured in midstream urine samples from approximately 12 to 15 cows weekly. It is important that the time relative to feeding is consistent from week to week, since urine pH response may fluctuate throughout the day. Large variation from cow to cow within a week may indicate undesirable consumption of the ration, whether that be a result of overcrowding, social factors, or sorting due to poor diet mixing. Variation in average urine pH from week to week can indicate inconsistency in ration mixing or changes in feed ingredient composition. This information can be used to improve feeding and management strategies to increase transition cow success.

*Energy nutrition of close-up cows.* As described above, controlling energy intake of close-up cows so that they meet, but do not dramatically exceed, their energy requirements during this period is a critical target. As has been well-documented previously and supported by recent research,[30-32] energy intake below requirements as reflected by elevated NEFA concentrations during the close-up period is associated with increased incidence of post-partum metabolic disorders, lower milk production, and poorer reproductive performance. We typically target energy intake of cows during the close-up period at 110 to 130% of energy requirements. For Holsteins, this is in the range of 16 to 18 Mcal/day of NEL. As a starting point, our recommendations would be to formulate the close-up diet at approximately 1.45 Mcal/kg of NEL if the group is a commingled cow/heifer group and approximately 1.38 to 1.40 Mcal/kg of NEL if the group is composed of mature animals and DMI is high. These energy densities are adjusted based upon actual DMI of cows on farms to achieve the overall targets for energy intake during the close-up period described above.

*Protein and amino acid nutrition.* We target metabolizable protein supplies of at least 1,200 to 1,300 grams per day for cows during the close-up period. Given that lower energy diets fed during the close-up period as described above typically contain limited amounts of rapidly fermentable carbohydrate (16 to 18% starch), microbial protein synthesis is limited and diets generally contain 2.2 to 4.4. lb (1 to 2 kg) of ruminally undegradable protein sources in order to meet the metabolizable protein recommendation outlined above. Furthermore, research generally supports formulation of methionine and lysine in close-up rations at levels similar to those used for lactating cows.

*Feeding management of dry cow rations.* Even the best-formulated rations will not be effective if they are not well implemented. Bulky rations with the forage base consisting of either straw or mature, low-potassium hay blended with corn silage and a grain mix can be easily sorted by cows if the straw or hay is not chopped, ideally prior to mixing into the TMR. In new research conducted by our group[23] involving 72 commercial dairy farms in New York and Vermont, only 25% of the prefresh TMR had particle size within recommended ranges (10 to 20% on the top screen; 50 to 60% in the middle; < 40% in the pan) using the Penn State Particle Separator (PSPS). We recommend chopping the straw or hay such that the long particles are no more than 1.8 inches (4 cm) (33% on each of the 3 sections of the PSPS). Often, addition of water or another wet ingredient to decrease the ration dry matter into the 46 to 48% range is also required for optimal effectiveness of these rations. Accuracy and consistency in feed delivery and composition are paramount to a successful transition feeding program.

*Post-partum nutritional strategies and fresh cow diets.* We believe that there will be significant advances in our understanding of the nutritional needs of the cow during the immediate post-partum period during the next 5 years. Evidence from our group and Miner Institute suggests that there are interactions of both prepartum and post-partum starch levels and also starch and fiber levels in fresh diets. Furthermore, there may be opportunities for additional MP and AA during the immediate post-partum period.[22]

*Grouping and facility factors in transition cow management*

Even the best formulated nutritional approach to dry cows can become derailed by issues with grouping and facility management of transition cows. In general, these are difficult areas in which to conduct controlled research because of the need for replicated pen designs if studying group-housed cows for many factors. Thus, our knowledge base is a combination of controlled research, observational studies, and field experience. The major factors at play in most transition management scenarios are stocking density, commingling of cows and heifers, frequency and number of pen moves, and heat abatement.

*Stocking density.* Of all of the grouping/facility factors that have been evaluated in the context of transition cow management, stocking density of groups during the prepartum period has received the most attention.[8,29] Most of the current recommendations (e.g., optimal stocking density at 80% of headlocks or 30 in (0.8 m) of bunk space per cow[8]) are based largely on observational work rather than randomized trials in which the benefits of decreased stocking density were observed in primiparous cows only. Although field experience certainly corroborates the benefits of decreasing stocking density in many situations, these observational studies do not lend themselves to truly determine the optimal stocking density, and the optimal stocking density surely varies across farms based upon other grouping management/facility characteristics.

*Commingling primiparous and multiparous cows.* We think that eliminating the commingling of primiparous and multiparous cows that is common during both the prepartum and post-partum periods, even on larger dairy farms, remains a major opportunity for freestall dairy farms. Data from Ospina et al in which larger freestall dairy farms that almost exclusively commingled cows and heifers during the immediate prepartum period, suggested that a staggering 70% of herds had more than 25% of their primiparous animals with elevated NEFA during the prepartum period, which clearly indicated that DMI was compromised in these animals.[32] Furthermore, nearly 50% of herds had more than 25% of their primiparous animals with elevated NEFA during the post-partum period. Although controlled research on commingling is even more lacking than that for stocking density, it is worth noting that the effects of stocking density reported by Nordlund et al above were confined to milk yield responses in primiparous cows.[29]

*Pen moves.* One of the major areas of focus by Cook and Nordlund was the issue of the number of pen moves made during both the prepartum and post-partum periods.[8] In many freestall transition management systems, it is not un-common for cows to make 5 to 6 moves during the 6-week period around calving. They advocated for elimination of group moves 2 to 5 d before calving and shortening of the period spent in a post-fresh monitoring group. Their basis for this was a collection of older studies that suggested that social adaptation to new groups ranged from 48 h to 7 d, with low-rank cows more affected by the regrouping. Although controlled evidence specifically focused on pen moves, and their timing during the transition period is largely lacking, the overall practice of streamlining grouping changes during this time appears to have yielded dividends on farms in terms of fresh cow health and calving management.

*Heat stress abatement.* Tao and Dahl reviewed the literature related to heat stress and the implementation of heat abatement strategies during the transition period and the effects on the dam and the calf.[44] Their summary suggests remarkably consistent and beneficial results of heat abatement both on the subsequent performance of the dam and also the calf through its developmental cycle.

## Future Opportunities

*Immune regulation and inflammatory response*

As we continue to increase our understanding of immune regulation in the transition dairy cow, it becomes an emerging area for future improvements in dairy management. During the periparturient period, cows experience a period of immune dysregulation. We currently define dysregulation of the immune response as the inability to fight infection efficiently by mounting an adequate inflammatory response and controlling it without excessive damage to the animal. Neutrophils play an important role in the innate immune system and are rapidly mobilized and activated in response to the inflammation stimulated by an infection. The endocrine and metabolic adaptation through the transition period is known to affect the innate immune system's response to infection by reducing the ability to appropriately activate neutrophils and other immune cell types. In addition, the degree of post-partum immune dysregulation and immune recovery response play a key role in the timely reaction to an infectious challenge in order to prevent disease state outcomes such as retained placenta, metritis, endometritis, and mastitis.[41] As with these disease outcomes, increased concentrations of markers of systemic inflammation in the periparturient period are associated with a decrease in milk production and reproductive success,[17] further highlighting the importance of mounting an adequate immune response during the transition period on productive outcomes. Research in post-partum systemic inflammatory response and the effects on health and productivity in transition dairy cows has yet to clarify to what extent and persistency inflammation should be considered a normal adaptive response.[4]

From a management perspective, overcrowding, comingling of fresh heifers and mature cows, competition at the feedbunk, excessive pathogen pressure, heat stress, and stressful handling situations all affect the ability of the transition cow's immune system to adequately react to infectious challenges. The interplay between metabolic adaptation and immune function is particularly important during this period as the dietary supply of energy, protein, macro- and microminerals in relation to requirements, as well as the fatty acid balance, affect immune regulation. The persistency and degree of systemic regulation, as well as tissue-specific inflammation in the post-partum period and its effect on the dairy cow's productivity and health, pose an exciting and challenging field of future research, as we continue to define physiological adaptive changes during this time and improve management strategies to minimize peripartal immune dysregulation.

*Technology and future opportunities*

Interest in using technology to help with on-farm transition cow decision making and early disease detection has increased in recent years. Rumination monitoring technology can be a valuable management tool, allowing for earlier identification and intervention of fresh cows with metabolic disorders as well as assisting with assessment of treatment effectiveness. At calving, rumination sharply decreases with a slow increase post calving, and lower rumination time post-partum has been associated with an increased risk of metabolic disorders. Rumination is highly sensitive to cow well-being, and cows are able to voluntarily control rumination and have the ability to stop ruminating when disturbed. Under periods of acute and chronic stress, rumination activity is depressed; changes in rumination in response to stressors can be detected between 12 to 24 h earlier than traditional measurements such as temperature elevation, decreased feed intake, or decreased milk yield. Using rumination monitoring data can help modify traditional fresh cow examinations with less disturbance of cows, decreased time in headlocks, less labor, and more focus on high-risk cows. This allows for timely identification of individual cows in need of intervention as well as group variations that can be used to evaluate transition cow facilities and management practices. In-line milk analysis systems offer an additional technological improvement for detection of early lactation subclinical NEB disorders and mastitis. These systems increase the ability of identifying individual cows in need of attention and can enable action before clinical signs are visible.

As genomic technologies progress, we have the increasing ability to utilize these technologies to identify sires that are high immune responders and offer improved adaptation to the metabolic challenges of the transition period. We can then use these tools to improve breeding decisions and select for traits that optimize transition cow health and immune competence.

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