EVOLUTION OF TRANSITION COW FEEDING MANAGEMENT

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Introduction
Critical importance of the transition cow has been recognized in achieving efficient lactational productivity and successful reproductive performance. Feeding and management practices in support of the successful transition cow have changed over the past thirty years as a result of research discoveries. However, postpartum disease events plague the dairy industry. Periparturient diseases continue to be the scourge of the dairy industry. Economic loss from decreased milk production is only the tip of the proverbial iceberg in evaluating total disease losses. Total financial losses associated with periparturient diseases result from lost and discarded milk, veterinary fees, increased labor, pharmaceuticals and premature culling. Reproductive performance is also adversely affected by periparturient disease. Conception risk (CR) for cows that have experienced at least one periparturient disease incident is lower (<35% vs. >50%) compared to cows with a disease-free calving (Ferguson, 1999; Loeffler et al., 1999). Only with use of estrous synchronization programs in which high heat detection efficiency can be achieved are we able to approach desired herd pregnancy rates. Survey data suggest that slightly over 50% of all lactations are affected by at least one adverse health event (Bigras-Poulin et al., 1990).

Periparturient health disorders are not totally independent events, but rather a complex of interrelated disorders. Survey studies have characterized risks between disease events (Curtis et al., 1985; Correa et al., 1993) as well as disease, production loss and culling risks relative to blood metabolite concentration (LeBlanc et al., 2005; Chapinal et al., 2012; Ospina et al., 2010ab; Roberts et al., 2012; McArt et al., 2013). Clearly, the premise if a cow makes it through the transition period free of disease problems, then one can expect a productive lactation period with reduced disease culls and efficient reproductive performance. Although nutritional and metabolic factors for managing postparturient disease have been identified (Goff and Horst, 1997), progress in nutritionally managing postparturient disease has not been consistently rewarding. This presentation will review various feeding, diagnostic and management practices that have been used in attempting to best manage the transition cow for success. Integration between nutritional needs and environmental factors that influence positive or negative outcomes during the transition period will be highlighted in understanding the best approach to feeding and managing transition dairy cows.

A Historical Perspective on Dry Cow Research
Research relative to dry cow nutrition and management primarily focused on disease control, mainly parturient hypocalcemia (milk fever) following intensification of agricultural practices starting in the 1940’s (Table 1). Research on issues related to dry or transition cow feeding and management have increased exponentially since the 1980’s. In reviewing general themes to the research focus, seminal papers were identified based on citations within the literature (Table 2).
There are many other papers that have contributed to our understanding of transition cow biology, but those listed were either the first of a collection addressing a specific topic or key papers setting a direction for practical applications or future research activities. From these seminal papers, current applications of the information presented are summarized. Notably a number of research outcomes no longer are being applied as a result of new directions and thinking based on subsequent research.

Table 1. A historical timeline of generalized research activities per decade with associated field applications of the research.

<table>
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<tr>
<th>Time Period</th>
<th>Research Focus</th>
<th>Field Application Outcomes from Research</th>
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<tr>
<td>1950-1960’s</td>
<td>Dietary management, use of vitamin D to reduce milk fever incidence</td>
<td>Dietary formulation manipulating Ca:P ratio, dietary Ca content, Vitamin D supplementation</td>
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<td>1970’s</td>
<td>Documentation of calcium homeostasis mechanisms - Isotope tracer studies looking at Ca regulation, target organ responsiveness</td>
<td>Formulation of diets with lower Ca content prior to calving to stimulate homeostatic system</td>
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<td>1980’s</td>
<td>Interrelationships between disease conditions in postpartum period Dietary cation-anion difference applications to Ca homeostasis</td>
<td>Path analysis of disease conditions, relationships to milk fever Application of DCAD, anionic salts for Ca homeostasis</td>
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<tr>
<td>1990’s</td>
<td>Redefining nutrient requirements in support of pregnancy, relationship to metabolic disease conditions Characterization of dry matter intake and relationship to postpartum disease</td>
<td>Description of role for negative energy balance (NEFA, BHB) in metabolic disease Perceived role for decline in DMI in disease conditions, dietary formulation</td>
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<td>2000’s</td>
<td>Identification of metabolic markers in defining risk of postpartum diseases Role of inflammatory mediators, feeding behavior, insulin resistance as inciting issues in metabolic disease pathogenesis Role of non-nutritional factors (overcrowding, pen moves, facilities) in pathogenesis of periparturient diseases</td>
<td>Practical use of NEFA and BHB testing to define individual or herd disease risks Alternative measures of disease risk explored Recognition of environmental effects on transition cow performance, role of cow behavior in disease risk</td>
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Table 2. Seminal papers addressing transition cow feeding and management practices and their current status in on-farm feeding management practices.

<table>
<thead>
<tr>
<th>Manuscript (number of literature citations)</th>
<th>Implications of research findings</th>
<th>Current status in dry cow management schemes</th>
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<tr>
<td>Block E. 1984. (199 citations)</td>
<td>Initiated further research and application of DCAD formulation in dry cow diets for prevention of hypocalcemia (clinical, subclinical)</td>
<td>DCAD application to improve calcium homeostasis has been well established scientifically, but application to the field is 26.7% of operations with 46.9% reducing dietary potassium (NAHMS, 2007)</td>
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<tr>
<td>Curtis et al., 1985. (255 citations)</td>
<td>Showed the interrelationships between postpartum disease events as a progressive syndrome rather than independent events</td>
<td>Provided a new perspective on milk fever as a “gateway” disease and solidified the importance of preventing postpartum disease risks</td>
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<td>Bertics et al., 1992. (211 citations)</td>
<td>Suggested feeding dry cows for maximum intake could minimize adverse metabolic effects from excess fat mobilization</td>
<td>Current thinking is to minimized decline in intake. Lower intakes prepartum can stimulate postpartum intake</td>
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<tr>
<td>Bell, 1995. (368 citations)</td>
<td>Described adaptive homeorhesis in the transition from pregnancy to lactation and better defined metabolic consequences of poor transition</td>
<td>Redefined nutrient requirements in support of pregnancy that were incorporated into NRC models in 2001</td>
</tr>
<tr>
<td>Cameron et al., 1998. (122 citations)</td>
<td>Identified elevated NEFA as a risk factor for displaced abomasum and other periparturient diseases</td>
<td>Use of on farm measures of NEFA and BHB as markers for periparturient disease risks.</td>
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<tr>
<td>Minor et al., 1998. (69 citations)</td>
<td>Feeding of high NFC diets to promote rumen adaptation, meet late pregnancy needs and facilitate greater postpartum intake</td>
<td>Some increase in dietary energy content from higher NFC is used in close-up grouping strategies, though overfeeding of energy during the dry period increases risk of altered glucose homeostasis</td>
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<tr>
<td>Drackley, 1999. (373 citations)</td>
<td>Review paper that focused attention on transition cow management, feeding and challenges in finding solutions to transition cow problems</td>
<td>Redefined the importance of the transition cow, though it focused mostly on nutrition it did raise the specter of environmental mediation of program success</td>
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<tr>
<td>Bernabucci et al., 2005 (103 citations)</td>
<td>Connected how excess body condition was associated with increased disease risk due to</td>
<td>Drew attention and research focus on the role of inflammatory mediators in</td>
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increased inflammatory mediators released from mobilized fat

pathogenesis of postpartum diseases; current area of intensive research

Huzzey et al., 2007 (95 citations)

Made an association between declining prepartum intake and risk for postpartum disease

Set the stage for greater focus on causation of postpartum disease and role of prepartum intake

*Web of Science search results from January 15, 2014*

**Prepartum Nutrition and Metabolic Disease**

Key nutritional issues to address in preventing periparturient disease were described by Goff and Horst (1997). These have been slightly modified to include: minimize the drop in prepartum dry matter intake (DMI), ensure adequate dietary supply and balance of energy and protein, minimize risk of hypocalcemia, and maintain the immune response.

**Role of Dry Matter Intake**

It has been well documented in research trials that DMI normally declines to some degree in late gestation (Bertics et al., 1992; NRC, 2001; Grummer, 1995; Hayirlı et al., 2003), though the absolute nature of this decline has been questioned (Roche et al., 2013). The interest in this DMI decline relates to its relationship with greater risk for postpartum disease events (Zamet et al., 1979a,b; Huzzey et al., 2007). Force feeding late pregnant cows to overcome DMI reduction resulted in lower lipid infiltration of the liver and improved postpartum DMI and milk component yields compared to cows that were allowed to experience DMI reduction (Bertics et al., 1992). This study promoted the idea of maximizing intake during the dry period. More recently the results of this study and their application have been questioned (Roche et al., 2013).

Additionally, more recent research has suggested excessive energy intake may have negative impacts on metabolic transition success. More recent data and observations would suggest our goal should be to minimize the decline in DMI prepartum.

**Dietary Energy and Protein Intake**

A goal for dietary formulations in transition is to provide adequate energy and protein to meet needs. Adding fermentable carbohydrates to the late gestation diet can have positive effects from increasing dietary energy density, promoting microbial yield and initiating rumen mucosa adaptation to a grain diet (Minor et al., 1998; Vandehaar et al., 1999; Rabelo et al., 2001). Increasing fermentable carbohydrate intake was seen a positive relative to increasing DMI and preparing the rumen for higher concentrate-based lactation diets. Increased dietary concentrate content; however, results in excessive energy intake and risk for body condition gain. Research has shown energy density of the close-up diet does not influence performance (Dann et al., 2005; 2006) and excessive energy intake results in a state of insulin resistance further predisposing the cow to various metabolic derangements (Drackley et al., 2005). Current practices are focused on limiting dietary energy density or DMI to ensure adequate, but not excessive energy intake (Rukkwamsuk et al., 1998; Holcomb et al., 2001; Agenas et al., 2003; Drackley and Janovick-Guretzky, 2007). Feeding management has moved away from higher grain-based close-up diets to feeding single group diets with high fiber, a return to older practices of dry cow feeding.

Of the papers cited in Table 2, missing are any papers addressing protein nutrition. Published
research on potential effects of protein has been equivocal in measured responses (Lean et al., 2013). Albeit this lack of research support, field observations suggest most dairy farms feed dry cow diets exceeding NRC (2001) recommendations for dietary protein content. Additionally, recommendations relative to delivered metabolizable protein (MP) in dry cow diets have gradually increased from approximately 1,000 g/day (adjusted NRC value) to amounts approaching 1,300 g/day. Anecdotal observations are suggesting improved health and reproductive performance with better MP delivery, similar to results of some studies (Van Saun, 1993; DeGaris et al., 2010). Given the cost of protein in the diet, especially when one uses rumen bypass sources, there must be some perceived benefit of feeding higher dietary protein. A challenge of these studies are separating out issues related to rumen available nitrogen, tissue mobilization and MP delivery, but a missing piece of these studies is the understanding of specific amino acid needs in support of pregnancy. A recent study has shown improved metabolic status with supplementation of additional methionine in the late gestation diet (Osorio et al., 2013). From a nutritional formulation perspective, future research should address protein feeding and amino acid requirements of the transition cow.

**Maintain Calcium Homeostasis**

Milk fever is considered a “gateway” periparturient disease as a result of its association with 8 other periparturient disease processes and its negative effect on postpartum DMI (Curtis et al., 1983). The underlying pathogenesis has been related to a failure of the calcium homeostatic system to maintain blood calcium concentrations with the onset of lactation (Goff et al., 2002). Kidney and bone are the target organs of concern, which are unresponsive to parathormone stimulation (Goff et al., 2014). A number of prepartum dietary factors have been identified as influencing this target organ responsiveness; however, there is no consensus on predisposing factor(s) and mode of prevention. In-spite-of a tremendous increase in our knowledge about calcium homeostasis, we have not made consistent gains in minimizing incidence of hypocalcemia, especially subclinical hypocalcemia, in aged dairy cows. Beyond the initial attempts at reducing calcium and phosphorus intakes to various modes of supplementing vitamin D metabolites or their analogs; manipulating prepartum dietary cation-anion difference provides a practical method of milk fever prevention (Oetzel, 1993; Horst et al., 1997; Thilsing-Hansen et al., 2002; DeGaris and Lean, 2009; Lean et al., 2013).

**Maintain Immune Response**

The immune system of the dairy cow has been shown to decline in responsiveness during the transition period (Mallard et al., 1998; Goff and Horst, 1997; Ingvartsen and Moyes, 2013). A compromised immune system may lead to increased incidence of metritis, mastitis or other infectious disease process. Although it is thought that hormonal and metabolic factors may play a primary role in this physiologic immune suppression, it can be further suppressed by nutritional insults. Energy, protein, microminerals and fat-soluble vitamins are all potential nutritional mediators of immune function. Deficiencies of microminerals and fat-soluble vitamins have been related to retained placenta and compromised immune function problems (Weiss et al., 1990; Kimura et al., 2002; Ingvartsen and Moyes, 2013). From the dam’s perspective, gestational micromineral and vitamin losses to fetus and colostrum may significantly affect her reserves and their associated biologic function, especially when mineral and vitamin supplementation is reduced or interrupted during the dry period.
**Transition Management Beyond Nutrition**

Although key metabolic and nutritional factors have been recognized and addressed, nutritional formulations according to suggested practices do not consistently ensure a successful transition cow program. Excessive body condition score has historically been associated with poor transition performance (Morrow, 1976; Grummer, 1993; Rukkwamsuk et al., 1998; Bobe et al., 2004; Drackley et al., 2005). Recent research has implicated excessive condition score or excessive adipose mobilization with an activated inflammatory process that potentially alters metabolic regulation and nutrient partitioning resulting in greater risk for disease and poor postpartum performance (Bernabucci et al., 2005; Ametaj et al., 2005; Bionaz et al., 2007; Bertoni et al., 2008). These data are quite intriguing and may help to integrate energy, lipid and protein metabolism as it relates to disease risk. Clearly continued research is needed in this area combined with techniques of genomics and metabolomics to better understand all relationships.

**Impact of Cow Management**

In addressing issues of transition health, Nordlund and colleagues have moved further from nutritional concerns to focus more on cow management and environment. Nordlund (2009) identified five key non-nutritional factors relative to the risk of periparturient disease. These issues span the realms of management and environmental issues. One concern is adequate feed bunk space in the prefresh and fresh cow groups. These cow groups seem more sensitive to behavioral competition and intimidation that results in altered feeding behaviors (Huzzey et al., 2005; Proudfoot et al., 2009). At least 76 cm of bunk space is recommended per cow in these groups (Cook and Nordlund, 2004). Bunk space is most critical in farms where feed availability is limited or where overcrowding occurs. Recommended stocking density for transition feeding groups is 85% based on observational studies, though controlled studies do not show significant alterations in overall feed intake or sorting behaviors (Hosseinkhani et al., 2008; Proudfoot et al., 2009). Of interest in these controlled studies, meal number and feeding rate were more affected in multiparous cows and resulted in greater standing bouts. Patterns of prepartum feed intake have been characterized sufficiently to be used in predicting risk of postpartum disease (Urton et al., 2005; Huzzey et al., 2006; Gonzalez et al., 2008; Goldhawk, et al., 2009). The question remains, are the feed intakes due to impending disease, or are the feeding patterns induced and then result in increase disease risk?

A second key factor is the number of pen moves through the transition period. As the social hierarchy is more frequently altered, observational studies (Cook and Nordlund, 2004) would suggest a decline in feed intake with observed higher NEFA concentrations and greater disease prevalence. A recent study of transition cow behavior shows reduced feed intake, more feed bunk evictions and lower milk production in groups with recent social changes (von Kesyerlingk et al., 2008). Overton and Nydam (2009) suggest that primiparous cows would benefit to a greater extent from grouping strategies based on parity. In a large herd survey, heifers in comingled transition groups showed a much greater prevalence of elevated NEFA concentrations compared to herds with separated parity groups. Observational data on pen moves also suggest a greater impact on heifers (Cook and Nordlund, 2004). An additional concern with comingled groups is the ability to meet the heifer nutritional needs without over feeding the older cows.

More recently, intense management of the immediately fresh cow (<30 days in milk) has gained significant importance and application on many dairy farms. Comparisons between cows having
one or more disease problems to cows without any problem show a marked reduction in milk production (-8 kg/day) and dry matter intake (-4 kg/day) over the first 21 days of lactation (Wallace et al., 1996). Cows with more significant disease condition or duration will experience greater body weight and condition loss, which leads to negative effects on reproductive performance. Immediately fresh cows already have reduced intake and a weakened immune system and thus are more susceptible to problems. The goal of fresh cow programs is to identify potentially sick cows early and intervene in an attempt to limit the adverse effects of disease. Nordlund (2009) suggested the intensity of fresh cow monitoring practices is another key factor in preventing periparturient disease.

In many herds, immediately fresh cows are provided a special group to themselves. Fresh cows are less aggressive at the feed bunk and will easily be pushed away by other later lactation cows. These fresh cow groups are generally located close to milking parlors or maternity areas where cows can be closely monitored. Most large farms have adopted a standardized protocol to manage fresh cows and have identified key personnel who are solely dedicated to fresh cow management. Most fresh cow protocols focus on early disease detection by frequent animal observation and monitoring. Many farms have adopted the practice of monitoring rectal temperature for at least the first 10 days postcalving. Depending upon the visual appraisal (bright and alert or dull, depressed) and body temperature, further physical evaluation would be completed. Most farms have their fresh cow workers evaluate rumen motility and urinary ketone status. Depending upon results of each of the evaluation criteria (body temperature, rumen motility, urine ketones) a set protocol is established for therapeutic applications. Veterinarians play an important role in establishing appropriate criteria and therapeutic strategies. Other farms have adopted a fresh cow protocol where all cows are treated by a standardized protocol. This might include a drench of all fresh cows with gluconeogenic precursors (propylene glycol, calcium propionate), calcium supplements (oral or subcutaneous), fluids with electrolytes, direct fed microbials, probiotics or some combination of these treatments. A number of commercial drench products are now available.

Environmental Influences
Drackley (2001) best answered his own question regarding the inconsistency in herd response to periparturient disease control in suggesting it is beyond our singular approach focusing on nutrition and includes how a given nutrition program is delivered and the environment in which it is consumed. Overcrowding, exposure to pathogens, changing social organization, among other situations can induce stress-mediated physiologic and metabolic changes. Animals alter how they utilize and partition available nutrients in response to these stress situations, which may compromise availability of nutrients to support productive functions. Other metabolic responses to stress can result in increased fat mobilization leading to greater potential for fatty liver disease, wasting of muscle tissue and immune suppression. A number of physiologic and metabolic responses to stress can result in a decline in dry matter intake, further compromising nutrient availability to support production. It is believed the effects of stress are additive, thereby as stress situations accumulate, greater physiologic and metabolic changes occur ultimately resulting in abnormality seen as metabolic dysfunction or infectious disease. These stress responses will be more exaggerated in animals consuming an imbalanced diet, but may also overwhelm an animal consuming an adequate diet. The foundation for a successful transition period is your ability to provide a properly formulated close-up ration within a “stress-free” environment.
Two of the five key factors for transition success identified by Nordlund (2009) are specific to cow comfort issues, namely, stall design and surface cushion. Traditional freestall design has 122 cm wide stalls, which balances well with barn structural design. However, transition cows are typically wider and would benefit from wider stalls (127 cm recommended). Additionally, stalls should be designed to facilitate normal cow lying, resting and raising behaviors. The need for unimpeded lunge space at the front of the stall to facilitate the cow’s ability to stand has been well documented. Stall design and size recommendations are well described by Cook and Nordlund (2004). Stall surface cushion is recommended to be deep sand as this provides the best footing anchor for the cow when attempting to stand. Mattresses or sparsely bedded stalls do not provide sufficient footing and result in altered cow lying/standing times and further accentuate lameness problems (Cook et al., 2004). For housing bedded pack barns or pasture housing systems, close-up, calving and immediately fresh cows should be provided 11 m² of lying space per cow, not including feeding or walking alleys.

A final, but highly significant environmental factor in transition success is the ability to provide heat abatement. Dry cows not provided shade has lower birth weight calves and reduced milk yield compared to cows provided shade (Collier et al., 1980). Transition cows exposed to heat stress bouts showed a number of significant alterations in blood metabolite parameters indicative of lowered DMI, metabolic acidosis and negative energy balance (Van Saun and Davidek, 2008). In this study, far-off and close-up dry cows as well as fresh cows were equally affected by heat stress as indicated by changes in blood parameters. Recent research has shown heat abatement during transition results in improved milk production, which was mediated through alterations in prolactin concentrations and hepatic gene expression (do Amaral et al., 2009). Recommendations for heat abatement techniques using fans, sprinklers, shade and others are provided (Cook and Nordlund, 2004).

**Final Perspectives on Transition Management**

Research results have provided further guidance in appropriate issues to address in developing a transition cow management program with the expectations for low disease prevalence, high milk production and efficient reproductive performance. The following are general principles that have been established or suggested.

- **Dietary formulation goals:**
  - Address intake capacity for grouping strategy and consider the variation in intake within a group to ensure sufficient nutrient intake for a greater percent of the cows within a given group
  - Meet energy needs through appropriately balanced energy density and fiber content to control intake, some additional grain in close-up diet is optional
  - Ensure at least 1,100 gm metabolizable protein is consumed by all cows, thus potentially requiring delivery of 1,300 gm MP to account for DMI variation (more research is needed here relative to amino acid needs)
  - Maintain calcium homeostasis by addressing dietary macromineral content, especially relationships between potassium and magnesium and calcium and phosphorus
  - Provide sufficient dietary vitamins and trace minerals from available sources to meet needs of cow, colostrum and fetus in order to minimize negative
effects on immune response

- Manage animal grouping strategies and dietary formulations in late lactation and dry period to achieve proper body condition score and minimize the number of excessively fat or thin cows
- Minimize cow stress response by ensuring adequate cow comfort
  - Proper stall resting area
  - Sufficient feed bunk and watering space
  - Heat abatement and good ventilation
  - Clean, dry bedding of sufficient cushion
- Address behavioral needs of the cow
  - Minimize pen moves resulting in social upheavals
  - Minimize overcrowding in critical groups (85% occupancy)
  - Promote the cows’ ability to eat and rest collectively
- Establish adequate monitoring system to assess postpartum health status and disease risk parameters

Conclusions
Over the past thirty years, the dry cow and especially the transition period have been recognized as critical elements to improving dairy productive and reproductive efficiency. Numerous research studies completed over this time period have better explained dynamic metabolic and physiologic changes taking place as a cow transitions from pregnancy into lactation and their potential role in health-related problems. Improved characterization of nutrient requirements and management practices has also been elucidated. Besides the obvious impact on periparturient disease, transition nutrition influences milk production and reproductive performance. Transition nutrition is not the sole solution; it must be coordinated with good cow comfort, feeding management and methods to reduce behavioral and environmental stressors. Future research should address protein and amino acid requirements as well as the interactions between immunologic responses and cow environment.

References


