MANAGEMENT AND ENVIRONMENT FACTORS THAT AFFECT PRODUCTIVITY OF CALVES

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INTRODUCTION

Over the last few years research has demonstrated that enhanced growth rate prior to weaning improves long-term productivity of dairy cattle. Further, more data are emerging that suggest that factors that detract from growth pre- and post-weaning also reduce productivity in dairy replacements. The onset of illness in calves and heifers can result in the increase of body temperature, a decrease in feed intake and a modest to significant period of reduced growth. The effects of sickness can be very acute whereas some are more chronic and separating those effects is difficult given the type of data recording for replacement animals on most farms. This paper will briefly review the available data on productivity and the implications of disease events and the environment influences the long-term productivity of dairy replacement heifers.

LONG-TERM PRODUCTIVITY

There are several studies in various animal species that demonstrate early life nutrient status has long-term developmental effects. Aside from the improvement in potential immune competency, there appear to be other factors that are impacted by early life nutrient status.

There are now many studies that allow us to evaluate milk yield in cattle that were allowed to consume more nutrients prior to weaning (Table 1). The arithmetic average of the twelve studies indicates 1,471 lb more milk in calves provided more nutrients prior to weaning. There are statistical approaches available for existing data that allow us to make reasonable assessments of the body of information without significant bias. Accordingly, the data described in Table 1 were analyzed using a meta-analyses approach to further investigate the impact of nutrient intake and growth rate prior to weaning (Soberon and Van Amburgh, 2012). The analysis excluded Foldager and Krohn, (1991) due to inadequate data and Davis-Rincker et al. (2011) because they did not measure full lactations. The Morrison et al. (2009) study was included in the analysis. The software used was Used Comprehensive Meta Analyses software (www.Meta-Analysis.com) (Borenstein et al. 2005) and the data included were study, treatment size (number of calves) mean milk yield, standard error or deviation, P value and effect direction. The data of Soberon et al. (2012) was initially excluded and then included to test for weighting effects since Soberon et al. contained many hundreds of animals. Inclusion of Soberon et al. did not change the outcome and the data were included in the analyses. The analysis indicated that feeding higher levels of nutrients from milk or milk replacer prior to weaning significantly increased milk yield by 959 ± 258 lb ($P < 0.001$), with a confidence range of 452 to 1,463 lb of milk and an odds ratio of 2.08 ($P < 0.001$). Thus, the calf is two times more likely to produce more milk if she was fed more nutrients prior to weaning.

Table 1. Milk production differences among treatments where calves were allowed to consume approximately 50% more nutrients than the standard feeding rate prior to weaning from liquid feed.

Study	Milk yield, lb
Foldager and Krohn, 1991	3,092
Bar-Peled et al., 1998	998
Foldager et al., 1997	1,143
Ballard et al., 2005 (@ 200 DIM)	1,543
Shamay et al., 2005	2,162
Rincker et al., 2006 (proj. 305@ 150 DIM)	1,100
Drackley et al., 2007	1,841
Raith-Knight et al., 2009	1,582
Terre et al., 2009	1,375
Morrison et al., 2009	0
Moallem et al., 2010	1,600
Soberon et al., 2011	1,217

A further analysis of the twelve data sets was conducted to evaluate the effect of average daily gain (ADG) and milk yield using meta-regression. The regression analyses indicated that for every 1 lb of ADG, milk yield in the first lactation increased by 1,541 lb ($P < 0.001$) with no plateau in response (Soberon and Van Amburgh, 2012). The use of meta-analysis provides a more conservative and appropriate evaluation of the data and helps us realize the importance of this stage of growth because the analyses incorporates the majority of the data from calves fed varying diets (milk vs milk replacer) and from a pail or from the dams teat, thus almost every option for early life feed supply is represented in the dataset. In addition, we evaluated the studies by milk and milk replacer fed calves and the outcome was similar for both demonstrating that nutrient intake, not source of nutrients is the most important variable after colostrum and prior to weaning. Therefore, it appears that any increase in growth prior to weaning enhances the first lactation milk yield response among all the current available data sets.

DIET AND HEALTH INTERACTIONS

At this time the mechanism underlying the enhanced milk yield potential of cattle fed more nutrients as calves is not known. There have several ideas and it appears the effect is strongly associated with body weight gain, and in calves prior to weaning, their body composition and requirements are very high in protein. Thus we believe any management and dietary factor that enhances body protein accretion prior to weaning, which is an outcome of both energy and protein supply, will enhance the long-term milk yield potential. The data from Moallem et al. (2010) provides some insight into this possible mechanism. The calves in the Moallem et al. study were fed either whole milk or a milk replacer with lower nutrient content and alternative proteins. The calves fed whole milk produced more milk in the first lactation as lactating cattle compared to the calves fed the milk replacer. The authors of the study suggested bioactive factors in milk were responsible, but a more likely effect was the lower protein amount and quality provided by the milk replacer and the lower energy availability from the diet compared to whole milk. The growth rate of the calves fed the milk replacer was lower than the calves fed whole milk which directly relates to protein accretion.

To extend this idea, anything that reduces feed intake will reduce protein accretion and growth, potentially reducing the "signaling" that is required to enhance the long-term milk yield response. Illness in many forms can cause a reduction in feed intake and this in turn will reduce growth and depending on the degree of the illness and duration of recovery, the period the calf is sensitive to this intake response will be compromised reducing the long-term effect.

New data indicating that a higher level of nutrient intake from milk or milk replacer enhances the immune system's ability to overcome a challenge, (Ballou, 2012) but doesn't ensure normal growth and feed intake continues during a sickness event. Thus, providing adequate nutrients will help the calf overcome the illness by providing energy reserves prior to the illness.

There is a large literature describing the impact of various forms of bovine respiratory disease on dairy calf health, growth and productivity (Waltner-Toews et al., 1986; Sivula et al., 1996; Virtala et al., 1996). Much of the data describes reduced growth and feed intake during the onset and duration of the disease, and little data exits on the long-term outcome, especially milk yield. Warnick et al. (1995) did not find an association between morbidity and milk yield in herds within NY State despite significant differences in growth and sickness among the calves and herds. In earlier work, heifers treated for respiratory disease, age at first calving was delayed 6 months (Correa et al., 1988) and this has been reinforced in recent research (Bach, 2011; Stanton et al., 2012). Consistent with this observation are the data of Heinrichs et al., (2005) where calves receiving antibiotics prior to 4 months of age tended to have increased age at first calving. All of this demonstrates that as calves experience some level of sickness, growth rate is compromised, most likely through normal sickness behavior including reduced feed intake, thus any developmental function that relies on consistent and high nutrient supply is reduced, reducing long-term productivity.

The response to sickness is an adaptive response that results in several outcomes designed to reduce energy output and energy input. Primarily, the sick animal is responding to some external stimuli such as a virus or bacterial infection that stimulates an internal response in an effort to rid the animal of the problem (Johnson, 1997; 1998). One of the primary responses is the change in energy intake and metabolism that seems necessary to adequately deal with the challenge. For example, if a calf has an infection, there is likely an increase in pro-inflammatory cytokine production (IL-1B for example) from immune cells that causes the animal to reduce feed intake. The actual mechanism behind the decreased feed intake is not well understood and seems necessary. In animal models where sickness has been induced and intake has been either forced, the higher intake animals die at a higher rate (Murray and Murray. 1979;.Quigley et al., 2006) indicating the need for the animal to become anorexic for a short period of time. This observation has led to the management decision to not force-feed calves that are "off-feed" for a short period of time, but ensure that adequate fluids are provided, either intravenously, or subcutaneously to prevent dehydration.

This period of reduced feed intake appears to help the body fight infection, provided there are adequate reserves for the animal to mobilize to support the response. This means some level of energy reserves is very important for an adequate and effective immune response and that factors associated with energy reserves are important for enhanced function of the immune system. For example, leptin, a hormone produced by adipose tissue, helps direct the effect of pro-inflammatory cytokine responses in the metabolism of immune cells, especially T-cell proliferation and function (Lord et al. 1998; Fernández-Riejos et al., 2010). Leptin has been shown to be a significant part of the signaling process for enhanced immune cell growth and killing efficiency and is also implicated in autoimmune disease, thus it plays a central role in the effectiveness of immune responses and helps demonstrate the role for adipose reserves in animals.

Further, the onset of a fever can be part of the immune response and generates behavior that both conserves and enhances energy loss. Most calves will lie down and "nest" when faced with a fever while enhancing their body temperature in an effort to fight the infection. This conserves available energy, especially if the calf has decreased feed intake. To generate a typical fever response, using data from humans and rats (Beisel, 1975; Tocco-Bradley et al., 1987), it takes a significant amount of energy and a conservative estimate is a 15% increase in maintenance requirements for a calf. Depending on the season and environmental temperature, this can be significant energy partition for a calf that is not consuming feed as part of the immune response.

The recovery period of some of these events is days extending out to a few weeks and depending on the cause, various treatments can be provided from analgesics and hydration therapies to antibiotics. During these events, with the animal off feed or with a reduced intake, whether it is a respiratory or gastrointestinal event or something more severe, normal growth is interrupted for a certain period and given our current understanding of the long-term development of the calf, this interrupts the process and the potential milk yield response of early life nutrition is muted.

The data from Soberon et al. (2012) provides more insight into this effect of sickness and long-term response. In the Cornell herd, the effect of diarrhea or antibiotic treatment on ADG was not significant and ADG differed by approximately 30 g/d for calves that had either event in their records ($P > 0.1$). However, for calves that had both events recorded, ADG was lower by approximately 50 g/d ($P < 0.01$). Over the eight year period, approximately 59% of all of the calves had at least one of the recorded events.

In the data from the Cornell herd, first lactation milk yield was not significantly affected by reported cases of diarrhea. Antibiotic treatment had a significant effect on milk yield and calves that were treated with antibiotics produced 1,086 lb less milk in the first lactation ($P > 0.01$) than calves with no record of being treated. However, even if the calves were treated with antibiotics, the effect of ADG on first lactation milk yield was significant ($P < 0.05$). Calves that were treated with antibiotics produced 1,373 lb more milk per kg of pre-weaning ADG while calves that did not receive antibiotics produced 3,101 lb more milk per kg of pre-weaning ADG. The effect of increased nutrient intake from milk replacer was still apparent in the calves that were treated, but the lactation milk response was most likely attenuated due to factors associated with sickness responses and nutrient partitioning away from growth functions (Johnson, 1998; Dantzer, 2006).

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