Early Life Management and Long-Term Productivity of Dairy Calves

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Introduction

The topic of calves and calf management traditionally involves discussions about dry cow management, colostrum, scours, rumen development and weaning. In more recent times the topic of “intensified feeding or accelerated growth” has become a focus of discussion and some debate and the concept has been applied in both research and on farm in various ways. Much of this discussion involves differences in perspectives about how to best manage the nutrition and nutrient intake and weaning of the calf. There are teleological arguments for providing a greater supply of nutrients from milk or milk replacer, e.g. what would the dam provide, and there are also arguments for improving welfare status by following the same concept (Jasper and Weary, 2002; de Paula Vieira et al., 2008). At the recently held 15th American Dairy Science Association Discover Conference on Calves (Roanoke, VA) the overwhelming consensus of the participants was that we need to feed calves for a specific rate of daily gain, much higher than currently considered, and that is significant change in industry perspective.

The calf has a requirement for maintenance and once maintenance requirements are met, growth can be achieved if enough nutrients and the proper balance of nutrients are provided to the calf. The nutrient requirements of the calf have been described in the current nutrient requirements of dairy cattle 7th edition (NRC, 2001) publication. The requirements can be easily actualized and are very useful for diagnosing the impact of temperature on the maintenance requirements of the calf through the computer program that accompanies the publication.

Just prior to and since the release of the dairy cattle NRC (2001), new data were being developed and are now available that help us refine those predictions (Bartlett, 2001, Diaz et al., 2001, Tikofsky et al., 2001; Bascom et al., 2007; Blome et al., 2003; Brown et al, 2005; Meyer, 2004; Mills, 2005). Table 1 summarizes the current knowledge about the requirements for growth of the calf based on the body composition data derived since the 2001 NRC (NRC, 2001) was published.

These values are consistent with the current publication (NRC, 2001), but have slightly lower energy requirements per unit of gain because the original equations were based on heavier veal type calves fed higher fat diets and depositing more fat per unit of weight gain. These predictions for energy requirements are consistent with dairy replacement calves being fed diets more typical of our system. The protein requirement

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is higher than the NRC (2001) publication because of an updated data on the efficiency of use of absorbed protein. The 2001 NRC (NRC, 2001) calculations suggested that absorbed protein was used with an efficiency of 0.80, whereas our latest calculations suggest the efficiency is closer to 0.70, thus the protein requirements are 10 to 12% higher than the NRC (2001) predictions.

These requirements reinforce the idea that what the cow would normally provide to the calf is the appropriate combination of protein and energy required by the calf. Thus, many milk replacers are not really replacing milk because they don't contain the same nutrient levels and they are rarely fed to equal the nutrient intake of whole milk. It further suggests that least cost milk replacer formulations should not be expected to provide much beyond maintenance energy which might exacerbate the lack of immune system responsiveness or at least energy reserves in support of an illness event.

Table 1. The energy and crude protein requirements of calves from birth to weaning (Van Amburgh and Drackley, 2005)

Rate of gain, lb/d	Dry matter intake, lb/d	Metabolizable energy, Mcal/d	Crude protein, g/d	Crude protein, %DM
0.45	1.2	2.4	94	18.0
0.90	1.4	2.9	150	23.4
1.32	1.7	3.5	207	26.6
1.76	2.0	4.1	253	27.5
2.20	2.4	4.8	307	28.7

However, to further this idea of enhanced nutrient status, data are available and emerging that suggest factors such as colostrum status and nutrient status up to at least 8 weeks of age have long-term carry over effects that can be measured in the first lactation. Just like other neonates, it appears that calves might be affected by early life events and that "compensatory mechanisms" really don't exist for this stage of development. It also suggests that we need to alter how we view this stage of development especially as it relates to future productivity. The concept and data to support it are still being developed, but there appears to be a positive relationship with early life nutrient intake.

Early Development and Productivity

Colostrum Status

To maximize calf survival and growth, plasma immunoglobulin (Ig) status and thus colostrum management is of utmost importance. This is obviously not a new concept and there are hundreds of papers describing the management and biology surrounding colostrum quality, yield and Ig absorption by the calf although some recent research in colostrums handling and management suggest we can still make improvements (Godden, 2008). A proper discussion of colostrum includes factors other than Ig and should include the myriad of other factors in colostrum that have shown to be beneficial to the calf. Factors like insulin, insulin l-like growth factor-I (IGF-I), maternal leukocytes, oligosaccharides, other growth factors and many other useful compounds are found in colostrum and are most likely very important in the response of the calf to ingestion of the secretion. Minimizing the bacterial load of colostrum is probably one of the major management concerns with many farms and is usually a factor not considered or analyzed for. Data demonstrate that the presence of bacteria in the gut prior to colostrum ingestion or in the colostrum reduces the uptake of Ig, thus increasing the incidence of failure of passive transfer (James et al. 1981, Godden, 2008). Thus excellent udder health and proper post-harvest colostrum handling is as important, or even more important than vaccination programs to prevent diseases.

Of interest for this paper are the studies have described decreased growth rate and increased morbidity of calves with low serum immunoglobulin status (Nocek, et al., 1984; Robison et al., 1988) and some have even indicated that milk yield during first lactation can be affected (DeNise et al., 1989.) Robison et al. (1988) indicated that calves with higher Ig status are able to inactivate pathogens prior to mounting a full immune response which allows them to maintain energy and nutrient utilization for growth, whereas calves with low Ig status must mount an immune response which causes nutrients to be diverted to defense mechanisms. How severe is this difference or for how long does it persist? The data of DeNise et al., (1989) demonstrated that for each unit of serum IgG concentration, measured at 24 to 48 hrs after colostrum feeding, above 12 mg/mL, there was an 18.7 pounds increase in mature equivalent milk. The implication is that calves with lower IgG concentration in serum were more susceptible to immune challenges which impacted long term performance. As with all longitudinal and epidemiological studies there are inconsistencies. Donovan et al. (1998) found indirect effects of colostrum status on growth and performance of calves, but concluded it was caused by increased morbidity and not a direct effect. The calculations of growth and feed efficiency should in many cases include the calves that were lost to study, thus providing a more applicable value. A similar observation was made by Wittum and Perino (1995) in beef calves where they measured a 24 pounds lower weaning weight of calves with failure of passive transfer but suggested it was due to increased morbidity and not a direct effect.

A more recent study suggested that impact of serum Ig concentrations was not nearly as great as the DeNise et al. (1998) study, but did affect milk yield and survival through the second lactation (Faber et al., 2005). Brown Swiss calves were provided either 2 or 4 L of colostrum just after birth. The calves were monitored after calving for two lactations. At the end of the second lactation three major observations were made, first there was a 30% increase in pre-pubertal growth rates based on colostrum feeding level, under identical feeding conditions. Second, there was a 16% increase in survival to the end of the second lactation of calves fed the four liters of colostrum. Finally, the surviving calves fed the 4 L of colostrum produced 2,263 lbs more milk by the end of the second lactation. Although somewhat subtle, these differences suggest that early life colostrum status was important for long-term productivity. If part of the mechanism is related to maintaining nutrient partitioning towards growth via high immunoglobulin status, then the concept of nutrient status should also demonstrate responses beyond the Ig status of the calf.

Nutrient status and long-term productivity

There are several studies in various animal species that demonstrate early life nutrient status has long-term developmental effects. For a more extensive discussion of this topic, a recent review of these concepts was conducted by Drackley (2005). Aside from the improvement in potential immune competency, there appears to be other factors that are impacted by early life nutrient status.

There are several published studies and studies in progress that have both directly and indirectly allowed us to evaluate milk yield from cattle that were allowed more nutrients up to eight weeks of age. The earliest of these studies investigated either the effect of suckling versus controlled intakes or ad-libitum feeding of calves from birth to 42 or 56 days of life (Foldager and Krohn, 1994; Bar-Peled et al, 1997; Foldager et al, 1997). In each of these studies, increased nutrient intake prior to 56 days of life resulted in increased milk yield during the first lactation that ranged from 1,000 to 3,000 additional pounds compared to more restricted fed calves during the same period (Table 2). Although they are suckling studies, milk is most likely not the factor of interest, but nutrient intake in general and this is demonstrated in the more recent data.

In the study conducted at Miner Institute, Ballard et al. (2005), reported that at 200 days in milk, the calves fed milk replacer at approximately twice normal feeding rates produced 1,543 pounds milk more than the calves that received one pound of milk replacer powder per day. Calving age in that study was not affected by treatment. Overall, averaging the studies, there is a 1,700 pounds response to increasing nutrient intake prior to weaning. The significant observation is that it appears this effect of intake level needs to be accomplished through liquid feed intake.

Table 2. Milk production differences among treatments where calves were allowed to consume at least 50% more nutrients than the standard feeding rate

Study	Treatment Difference, lb
Foldager and Krohn (1994)	3,092
Bar-Peled et al. (1998)	998
Foldager et al, 1997)	1,143
Ballard et al. (2005)	1,543 at 200 days in milk
Rincker et al. (2006)	1,100 based on projected 305d milk
Moallem et al. (2006)	2,500
Drackley et al. (2007)	1,841

The response in the study of Moallem et al. (2006) is significant, specifically because it suggests that milk replacer quality is important to achieve the milk response, as is protein status of the animal post weaning. In that study, the calves were fed a 23% CP, 12% fat milk replacer containing soy protein or whole milk. Further, post-weaning the calves were fed similarly until 150 days of gain, and the diets were protein deficient (~13.5% CP). Starting at 150 days calves from both pre-weaning treatments were supplemented with 2% fish meal from 150 to 300 days of life. The calves allowed to consume the whole milk (ad libitum for 60 minutes) and supplemented with the additional protein produced approximately 2,500 pounds more milk in the first lactation indicating that the early life response could be muted by inadequate nutrition and management post-weaning.

Finally the data of Pollard et al. (2007) again demonstrates a positive response of early life nutrition on first lactation milk yield. In this study calves were fed either a conventional milk replacer (22:20; i.e. 22% protein, 20% fat) at 1.25% of the body weight (BW) or a 28:20 milk replacer fed at 2% of the BW for week one of treatment and then 2.5% of the BW from week 2 to 5 and then systematically weaned by dropping the milk replacer intake to 1.25% of the BW for 6 days and then no milk replacer. All calves were weaned by 7 weeks of age and after weaning all calves were managed as a single group and bred according to observed heats. The heifers calved between 24 and 26 months of age with no significant difference among treatments. Calving BW were also not different and averaged 1,278 lb. Milk yield on average was 1,841 pounds greater for calves fed the higher level of milk replacer prior to weaning.

We are nearing the end of a similar study, but our lactation data is too preliminary to make evaluations. However, the Cornell University T&R Dairy started feeding for greater pre-weaning BW gains many years ago and we have over 1000 weaning weights and 725 lactations with which to make evaluations outside of our ongoing study. What makes our approach to this unique is the application of a Test Day Model (TDM) (Everett, R. W., and F. Schmitz. 1994; Van Amburgh et al., 1997) for the analyses of the data. This approach allows us to statistically control for factors not associated with the variables of interest and is the same approach that has been used to conduct sire summaries and daughter evaluations. Thus the outcome is more robust and allows us to look within a herd over time with less bias.

We analyzed the lactation data of the 725 heifers with completed lactations and ran regressions on several factors related to early life performance and the TDM milk yield solutions. The factors analyzed were birth weight, weaning weight, height at weaning, BW at 4 weeks of age and several other related and farm measurable factors. Year of birth was the most highly significant variable. We do not know what this means, but suggests that epigenetic factors might be important in the response i.e., the nutrient status of the dam or the environmental impact of the grand dam or sire has some impact beyond the genetic code and is realized in the subsequent generation. Our analyses cannot determine this response other than identify it.

From a management perspective the most interesting observation was the relationship between pre-weaning growth rate and first lactation milk yield. In these analyses, the greatest correlation with first lactation milk production was growth rate prior to weaning and the findings are consistent with the data presented in Table 2. In our data set, for every 1 pound of average daily gain (ADG) before weaning, the heifers produced approximately 1,000 pounds more milk. The range in pre-weaning growth rates among the 725 animals was 0.52 to 2.76 pounds per day. Further, 20% of the variation in first lactation milk production could be explained by growth rate to weaning. This suggests that the impacts of Ig status and nutrient intake are playing a significant role in the performance and variation in first lactation milk yield.

Regressions of the lactation data from these studies and the growth rates, when controlled for study, suggest that to achieve these milk yield responses from early life nutrition, calves must double their birth weight or grow at a rate that would allow them to double their birth weight by weaning (56 days). This further suggests that milk or milk replacer intake must be greater than traditional programs for the first 3 to 4 weeks of life in order to achieve this response.

What changes in the animal are allowing for these differences? There is no one answer to that question but investigations are looking for several factors. Although mammary development as has been measured is probably not the appropriate factor (Meyer et al., 2006a, 2006b), it is intriguing to look at very specific cells within the mammary gland. There are a couple sets of data that demonstrate increased mammary cell growth based on early life nutrient intake. Brown et al. (2005) observed a 32 to 47% increase in mammary DNA content of calves fed approximately 2 versus 1 pound of milk replacer powder per day through weaning. Just like the milk production increases discussed earlier, this mammary effect only occurred prior to weaning. In fact, this increase in mammary development was not observed once the calves were weaned, indicating the calf is more sensitive to level of nutrition prior to weaning and that the enhancement mammary development cannot be “recovered” once we wean the animal.

Meyer et al. (2006a) observed a similar effect in mammary cell proliferation in calves fed in a similar manner. The calves on their study demonstrated a 40% increase in mammary cell proliferation when allowed to consume at least twice as much milk replacer as the control group before weaning (Meyer et al., 2006a). Sejrsen et al (2000) observed no negative effect on mammary development in calves allowed to consume close to ad libitum intakes. A more specific attempt to look at stem cell proliferation did not find increased stem cells in calves fed higher levels of nutrient intake (Daniels et al., 2008) and it was hypothesized that the stem cell proliferation might lead to greater secretory cells once the animal becomes pregnant.

Summary

Early life events appear to have long-term effects on the performance of the calf. Our management approaches and systems need to recognize these effects and capitalize on them. Obviously we have much to learn about the consistency of the response and the mechanisms that are being affected. However, it appears that there is some potential profit in spending more time and resources on the animal at this early stage of life.

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SESSION NOTES