

# Taking the Long View: Treat Them Nice as Babies and They will be Better Adults

M. E. Van Amburgh, *PhD*; F. Soberon, *MS*; E. Raffrenato, *PhD*; J. Karzses, *MS*; R. W. Everett, *PhD*  
*Department of Animal Science, Cornell University, Ithaca, NY 14853*

## Abstract

Calf nutrition and management programs have focused on early weaning and modest liquid feed intake designed to encourage dry feed intake for enhanced rumen development. This was done primarily to reduce cost and also to reduce the risk for diarrhea and other disease concerns.

Data are being generated demonstrating that early life management and nutrition, starting with colostrum, positively reinforces the genetic capacity of the calf for feed efficiency and milk producing ability. Factors in colostrum, such as certain growth factors and hormones, appear to enhance the efficiency of use of absorbed nutrients, providing a broader role for colostrum intake and composition beyond the traditional role for immune function. Published data demonstrate differences in feed efficiency of over 26% in calves with higher levels of colostrum intake, independent of Ig status. The objective of doubling the birth weight of the calf by weaning through increased milk or milk replacer intake has demonstrated positive effects on milk production in the first and subsequent lactation. In several studies, the milk yield of calves have been enhanced from 500 to over 3,000 lb in the first lactation through increased liquid feed intake and data are now available indicating the increased milk yield is extended into subsequent lactations. Overall, this data demonstrates that the calf experiences epigenetic modification of their milk producing ability through increased nutrient intake in the first 42 to 49 days of life. The economic consequences of this outcome are discussed.

## Résumé

L'alimentation des veaux et les programmes de gestion mettent l'accent sur le sevrage hâtif et l'apport modéré en liquide qui encouragent l'alimentation sèche pour favoriser le développement du rumen. Ceci se faisait principalement pour réduire les coûts et aussi pour diminuer le risque de diarrhée et d'autres maladies. De nouvelles données démontrent que la gestion hâtive et l'alimentation, en commençant avec le colostrum, augmentent la capacité génétique du veau liée à l'efficacité alimentaire et à la production de lait. Des facteurs dans le colostrum, comme certains facteurs de crois-

sance et des hormones, semblent augmenter l'efficacité de l'utilisation des nutriments absorbés de sorte que le rôle de la prise de colostrum va au-delà du simple transfert immunitaire. Des données publiées indiquent des différences au niveau de l'efficacité alimentaire de l'ordre de 26% chez les veaux qui reçoivent une plus grande quantité de colostrum, indépendamment du statut immunitaire. L'objectif de doubler le poids du veau de la naissance au moment du sevrage en augmentant l'ingestion de lait ou de lait de remplacement a des répercussions positives pour la production de lait en première lactation et dans les lactations suivantes. Selon plusieurs études, la quantité de lait produite par les veaux a passé de 500 à plus de 3000 lbs (de 227 à plus de 1365 kg) en première lactation en augmentant l'alimentation liquide et de nouvelles données suggèrent que l'accroissement de la production de lait se poursuit dans les lactations subséquentes. Au final, ces données démontrent que les veaux subissent des modifications épigénétiques de leur capacité de production du lait par l'augmentation de la prise alimentaire pendant les premiers 42 à 49 jours suivant la naissance. Les retombées économiques de cette nouvelle capacité sont discutées.

## Introduction

Discussing the topic of calves and calf management over the last 40 years traditionally involved dry-cow management, colostrum, scours, rumen development, and early weaning. In the last ten years, the concept of "intensified feeding or accelerated growth" has become a focus of discussion, and during that time the concept has been applied to research programs and on-farm in various ways. Much of this discussion involves different perspectives about how to best manage the nutrition and nutrient intake of the pre-weaned 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 the animals' welfare status by following the same concept.<sup>11,23</sup> At the 15<sup>th</sup> American Dairy Science Association Discover Conference on Calves (Roanoke, VA) the overwhelming consensus of participants was that we need to feed calves for a specific rate of daily gain, much higher than traditional industry standards, which is a significant change in industry perspective.

## Requirements - Maintenance

Once a calf's maintenance feeding requirements are met, growth can be achieved if enough properly balanced nutrients are provided to the calf. Nutrient requirements of the calf have been described in the current Nutrient Requirements of Dairy Cattle (NRC).<sup>35</sup> 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.

The maintenance requirements estimated by the NRC appear to be excellent and reflect our field observations for overcoming the negative energy balance brought about by cold-stress conditions. Example requirements are demonstrated in Table 1 based on body weight and ambient temperature. The user needs to remember that these values are the basal requirements for energy to maintain core body temperature with no growth or with no wind or wet conditions, which would exacerbate the requirements. The long-term consequences of failing to alter these values will be discussed throughout the paper. Our recent data suggests there is a significant lifetime milk loss associated with not meeting these requirements appropriately.

For many years, the National Animal Health Monitoring System (NAHMS)<sup>32,33,34</sup> has published reports describing the morbidity and mortality of calves and heifers on representative US dairy farms. In a recent report, pre-weaning death loss was reported at 8%,<sup>33</sup> whereas the previous survey reported 11%.<sup>32</sup> In a thorough review of calf management practices, Otterby and Linn<sup>37</sup> reported mortality was approximately 11.3%, which indicates we have made little progress over the last 25 years. Also, a previous report indicated that sickness (or the percent of calves treated) ranged between 30 and 40% on most farms.

A study by Godden<sup>20</sup> replicated the mortality and morbidity values from the NAHMS survey, and their data suggested the outcome was a function of the amount

**Table 1.** Amount of milk replacer or milk dry matter (lb) required to meet maintenance requirements of calves at varying temperatures. Calculations assume 2.45 Mcal ME per lb of dry matter.

Bodyweight, lb	Temperature, degrees F						
	68	50	32	15	5	-5	-20
60	0.6	0.8	0.9	1.0	1.1	1.2	1.4
80	0.8	0.9	1.1	1.3	1.4	1.5	1.7
100	1.0	1.1	1.3	1.6	1.7	1.8	2.0
120	1.1	1.3	1.5	1.7	1.9	2.0	2.3

and type of diet fed. In their study, calves were fed either batch pasteurized whole milk at approximately 1 gallon (~4 liters) per day, or 1 lb (0.45 kg) of 20% crude protein (CP), 20% fat milk replacer reconstituted at 12.5% solids. The length of the study encompassed all of the seasons. Calves fed whole milk had significantly less death loss and treatments (Table 2), suggesting the difference in nutrient intake, approximately 18% greater ME intake per day from whole milk compared to the milk replacer, had a profound impact on the survival and disease resistance of the calves. The bottom line is that calves provided more nutrients had less death loss. The morbidity and mortality observed in this study is consistent with the NAHMS data, and suggests we need to do a better job managing cold stress and other stressors in calves. This should not be confused with the notion that milk replacer is not as good as whole milk. It demonstrates that adjustments need to be made when feeding any diet if the calf's requirements change due to the environmental temperature or stress conditions.

Calves are born with about 4% body fat, of which about 50% can be mobilized. Much of that is brown adipose tissue needed for thermogenesis. This gives the calf up to four days of fat reserves, depending on ambient conditions. Once depleted, the calf must rely on either dietary intake or body protein to generate heat and mount an immune response if nutrient intake is below maintenance requirements. This sets up a situation that encourages failure of the immune system unless additional calories from protein, carbohydrates, and fat are provided. Body protein reserves are very low in neonatal calves, and are a poor source of calories for maintaining body heat and mounting immune responses. An additional factor to be considered is what calves use to deposit body fat. Data from several studies demonstrate that calves cannot make fat from carbohydrate very effectively if at all, thus any increase

**Table 2.** Effect of feeding calves one gallon of pasteurized whole milk or one pound of 20:20 milk replacer on morbidity and mortality (Godden, 2005).

	Milk replacer treatment	Pasteurized whole milk treatment
N	215	223
Morbidity, % of calves		
All months	32.1	12.1
Winter	52.4	20.4
Summer	12.7	4.4
Mortality, % of calves		
All months	11.6	2.2
Winter	21.0	2.8
Summer	2.7	1.7

in adiposity must be from dietary fat intake.<sup>25,44</sup> Thus, under cold stress conditions or situations where feed intake is compromised due to illness, the only way to provide greater calories and energy reserves is through the increased intake of dietary fat. Compared to most milk replacers, this is likely why calf managers see significant increases in calf performance when whole milk is fed, especially in cold weather conditions.

### Energy and Protein Requirements

Prior to and since the release of the NRC,<sup>35</sup> new data were being developed and are now available that help us refine those predictions.<sup>3,4,5,6,7,12,26,29,44</sup> Table 3 summarizes the current knowledge about the requirements for growth of the calf based on the body composition data derived since the 2001 NRC was published.

These values are consistent with the NRC current publication,<sup>35</sup> 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 requirements are higher than the NRC publication because of updated data on the efficiency of use of absorbed protein. The 2001 NRC 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 at least 10 to 12% higher than the NRC predictions and very energy dependent, e.g., the more energy they consume, the greater the potential protein synthesis, and the higher the protein requirement.

These requirements reinforce the idea that what the cow would normally provide to the calf is a more 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 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 supply. Moreover, the

feeding of such milk replacers at previously recommended levels might exacerbate the lack of immune system responsiveness and energy reserves needed in support of an illness event. Dietary fat levels will be dependent on the ambient temperatures. The body composition data would indicate that 15% fat is adequate when the calves are not under cold stress conditions, and that as temperatures decrease, fat needs to increase to offset the oxidation for thermogenesis. In addition, attention should be made to the inclusion of essential fatty acids in the diet of neonatal and weaned calves, since it appears traditional calf diets have been deficient in essential fatty acids required for proper growth.<sup>21</sup>

However, to further this idea that calves have "requirements" beyond those for growth and thus need enhanced nutrient intakes, data are available and emerging that suggest factors such as colostrum status, nutrient intake, and growth rates up to at least eight weeks of age have lifetime effects that can be measured in the first lactation. Just like other neonates, it appears that early life events may serve as a catalyst for metabolic programming (or imprinting), generating epigenetic changes in the calves that will remain with them for their entire life. Therefore, "compensatory mechanisms" don't really 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 colostrum handling and management suggests we can still make improvements.<sup>20</sup> A proper discussion of colostrum includes factors other than Ig and

**Table 3.** 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

should include the myriad of other factors in colostrum that have shown to be beneficial to the calf. Factors like insulin, insulin-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.<sup>20,22</sup> 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 that have described decreased growth rate and increased morbidity of calves with low serum immunoglobulin status,<sup>36,40</sup> and some have even indicated that milk yield during first lactation can be affected.<sup>10</sup> Robison *et al*<sup>40</sup> indicated that calves with higher Ig status were 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*<sup>10</sup> demonstrated that for each unit of serum IgG concentration above 12 mg/mL, measured at 24 to 48 hrs after colostrum feeding, there was an 18.7 lb (8.5 kg) 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*<sup>13</sup> 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 more recent study<sup>17</sup> suggested that the impact of serum Ig concentrations was not nearly as great as in the DeNise *et al*<sup>10</sup> study, but did affect milk yield and survival through the second lactation. Brown Swiss calves were provided either two or four liters of colostrum just after birth, with some additional meals over a four-day period. 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 prepubertal 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 four liters of colostrum produced 2,263 lb (1,026 kg) 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. This difference in growth rate has been observed in studies comparing colostrum with colostrum replacement. Calves fed colostrum replacer had nearly identical plasma IgG concentrations, but grew at a rate 30% less than the colostrum fed calves.<sup>31</sup> This would indicate that colostrum contains components important for growth and feed efficiency independent of the Ig content, and understanding which factors are important is an active area of research.

#### *Nutrient Status and Long-Term Productivity*

Several studies in various animal species demonstrate that 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.<sup>14</sup> Aside from the improvement in potential immune competency, there appear to be other factors that are impacted by early-life nutrient status.

Several published studies and studies in progress 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.<sup>2,18,19</sup> 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 (454 to 1361 kg) compared to more restricted fed calves during the same period (Table 4). Although they are suckling studies, nutrient intake in general, rather than milk, is most likely the factor of interest, and this is demonstrated in the more recent data.

In the study conducted at Miner Institute, Ballard *et al*<sup>1</sup> reported that at 200 days-in-milk, the calves fed milk replacer at approximately twice normal feeding rates produced 1,543 lb (700 kg) 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 1,500 lb (680 kg) response to increasing nutrient intake prior to weaning for first-lactation milk yield. The significant observation is that the effect of intake level needs to be accomplished through liquid feed intake.

The responses in the studies of Shamay *et al*<sup>42</sup> and Moallem *et al*<sup>30</sup> are significant, specifically because

**Table 4.** 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, 1994	3,092
Bar-Peled <i>et al</i> , 1998	998
Foldager <i>et al</i> , 1997	1,143
Ballard <i>et al</i> , 2005 (@ 200 DIM)	1,543
Shamay <i>et al</i> , 2005 (post-weaning protein)	2,162
Rincker <i>et al</i> , 2006 (proj. 305@ 150 DIM)	1,100
Drackley <i>et al</i> , 2007	1,841
Chester-Jones <i>et al</i> , 2009	1,800
Morrison <i>et al</i> , 2009 (no diff. calf growth)	0

they suggest 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 some soy protein or whole milk. Further, the calves were fed post-weaning 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 1,700 lb (771 kg) more milk in the first lactation, indicating that the early-life response could be muted by inadequate protein intake post-weaning.

Finally, the data of Drackley *et al*<sup>15</sup> again demonstrate 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; then calves were fed 2.5% of BW from weeks two to five; then systematically weaned by dropping the milk replacer intake to 1.25% of BW for six days; then no milk replacer. All calves were weaned by seven 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 (580 kg). Milk yield on average was 1,841 lb (835 kg) greater for calves fed the higher level of milk replacer prior to weaning.

The Cornell University dairy herd started feeding for greater pre-weaning BW gains many years ago, and we have over 1,200 weaning weights and 3+ lactations with which to make evaluations outside of our ongoing

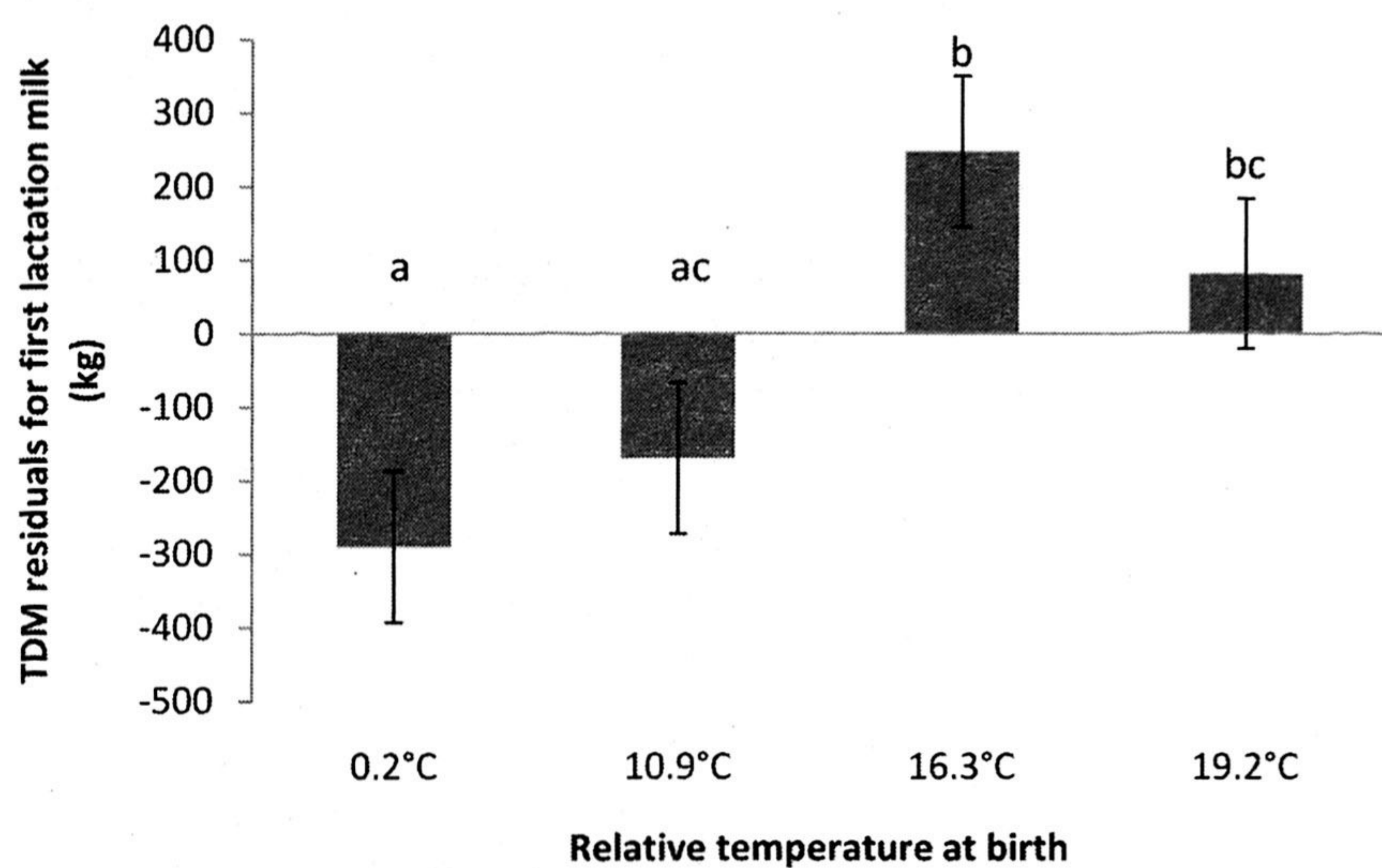
study. What makes our approach unique is the application of a Test Day Model (TDM)<sup>16,46</sup> for the analyses of the data. This approach allows us to statistically control for factors not associated with the variables of interest, and is the same approach that has been used to conduct sire summaries and daughter evaluations and develop heritabilities for genetic traits. Thus, the outcome is mathematically more robust, allows us to look within a herd over time with less bias, and to look at herd responses independent of formal treatments. The resulting residuals are standardized, which makes them additive over the life of the animal, and they can be calculated for individual test days or over the lactation. The power of this type of analysis is much more significant versus comparing daily milk or even ME305 milk, and helps us partition out variance not associated with the variables of interest.

We analyzed the lactation data of the 1,244 heifers with completed lactations using the TDM approach and statistically analyzed several factors related to early-life performance and the TDM milk yield residuals.<sup>43</sup> Factors analyzed were birth weight, weaning weight, height at weaning, BW at four weeks of age, and several other related and farm measurable factors. From a management perspective, the most interesting observation was the relationship among two factors, growth rate prior to weaning, and intake over maintenance and first-lactation milk yield. In these analyses, the strongest relationship associated with first-lactation milk production was growth rate prior to weaning, and the findings are consistent with the data presented in Table 4. In our data set, for every 1 lb (0.45 kg) of average daily gain (ADG) prior to weaning (or at least 42 to 56 days of age), the heifers produced approximately 937 lb (426 kg) more milk ( $P < 0.01$ ). The range in pre-weaning growth rates among the 1,244 animals was 0.52 to 2.76 lb (0.24 to 1.25 kg) per day and the range was actually quite puzzling to us. Our feeding program at the research farm is straightforward: 1.5% of BW dry matter from day 2 to 7 and then 2% of BW dry matter from day 8 to 42 of a 28:15 or 28:20 milk replacer mixed at 15% solids. Free-choice water is offered year round and starter is offered from day 8 onward. At that feeding rate, we are offering twice the industry standard amount and had assumed it was enough for overcoming the maintenance requirement and providing adequate nutrients for growth, even in the winter. However, when we analyzed the TDM residuals by temperature at birth, a very significant observation was made (Figure 1).

These data very much suggest that although we are meeting the maintenance requirements of the calves from a strict requirement calculation, we are not providing enough nutrients above maintenance to optimize first-lactation milk production. We need to remember that the thermoneutral zone for calves is 68 to 82°F (19.8

to 27.5°C), and that when the temperature drops below that level, intake energy will be used to generate heat instead of growth. In addition, when we analyzed the data by lactation, the response increased as the animals matured (Table 5).

These data demonstrate there are metabolic programming events being affected in early life that have a lifetime impact on productivity. When we evaluated the 450 animals that had completed a third lactation, we found a lifetime milk effect of pre-weaning average daily gain of over 6,000 lb (2,722 kg) of milk, depending on pre-weaning growth rates. Further, 22% of the variation in first-lactation milk production could be explained by growth rate prior to weaning. This suggests that colostrum status and nutrient intake and or pre-weaning growth rate have a greater effect on lifetime milk yield, and account for more variation and progress in milk yield associated with management of the calf than genetic



**Figure 1.** Test Day Model residuals in kg of milk, averaged by temperature at time of birth with mean temperature in Celsius. Columns with different superscripts differ ( $P < 0.05$ ).

selection. Generally, milk yield will increase 150 to 300 lb (68 to 136 kg) per lactation due to selection, whereas the effect of management is three to five times that of genetic selection.

In the Cornell herd, the effect of diarrhea or antibiotic treatment on ADG was not significant and ADG differed by approximately 30 grams per day 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 grams per day ( $P < 0.01$ ). 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 TDM residual milk, and calves that were treated with antibiotics produced 693 lb less milk in the first lactation ( $P > 0.01$ ) than calves with no record of being treated. Regardless of antibiotic treatment, the effect of ADG on first-lactation milk yield was significant in all calves ( $P < 0.05$ ). Calves that were treated with antibiotics produced 623 lb more milk per lb of pre-weaning ADG, while calves that did not receive antibiotics produced 1,408 lb more milk per lb 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.<sup>9,24</sup>

An analysis of all the lactation data and the pre-weaning growth rates, when controlled for study, suggests 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 three to four weeks of life in order to achieve this response.

**Table 5.** Predicted differences by TDM residual milk (lb) for 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> lactation as well as cumulative milk from 1<sup>st</sup> through 3<sup>rd</sup> lactation as a function of pre-weaning average daily gain and energy intake over predicted maintenance for the Cornell herd.

Lactation	n	Predicted difference in milk per lb of pre-weaning ADG	P value	Predicted difference in milk (lb) for each additional Mcal intake energy above maintenance	P value
1 <sup>st</sup>	1244	850	< 0.01	519	< 0.01
2 <sup>nd</sup>	826	888	< 0.01	239	0.26
3 <sup>rd</sup>	450	48	0.91	775	< 0.01
1 <sup>st</sup> – 3 <sup>rd</sup>	450	2,280	0.01	1,991	< 0.01

What changes in the animal are allowing for these differences? There is no one answer to that question, but investigators are looking for several factors. Although mammary development as previously measured is probably not the appropriate factor,<sup>27,28</sup> it is intriguing to look at very specific cells within the mammary gland. There are a couple of sets of data that demonstrate increased mammary cell growth based on early-life nutrient intake. Brown *et al*<sup>7</sup> observed a 32 to 47% increase in mammary DNA content of calves fed approximately two versus one lb (0.91 vs 0.45 kg) 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*<sup>27</sup> 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.<sup>27</sup> Sejrsen *et al*<sup>41</sup> 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,<sup>8</sup> and it was hypothesized that the stem cell proliferation might lead to greater secretory cells once the animal becomes pregnant.

### Economics

An in-depth economic analyses of a program designed to double the birth weight and decrease age at first calving by almost three months was conducted by Dr. Mike Overton with input from Dr. Bob Corbett.<sup>38</sup> In his analyses he utilized both research and herd data to characterize the costs and potential income associated with feeding and managing calves in a manner to promote a milk yield response. In his analysis, the first-lactation profit was \$190 per heifer without accounting for the increase in inventory and associated changes in either voluntary culling or heifer sales. The change in profitability was due to the average 1,700 lb (771 kg) milk response observed from the studies described in Table 4, and was adjusted for net present value of the investment today relative to the income two years from now.

We conducted our own analysis of the response using calf and heifer performance data from a herd used in a heifer cost benchmarking study from New York (Table 6). There are many terms for the difference in management of the calves – in this analysis we will call

it intensified, but it really represents more biologically normal growth. Actual health data, feed costs, and total costs of rearing were included in the estimation. Age at first calving (AFC) was a function of getting heifers pregnant at 55% of the mature body weight and then calving at a minimum of 82% in both systems. In our analyses, AFC was reduced by 2.3 months, but the costs associated with achieving the same body weight post-calving were nearly identical due to the higher costs of feeds and the amount of feed consumed to achieve the earlier AFC.

While the cost per heifer completing the system did not change, there are several other areas where decreased calving age and the decrease in non-performance expense impact economic value. If at the start the same number of heifers calve each month, there will be on average two more animals completing the system each year. There is also a decrease in the total number of animals in the replacement program, dropping 8%. This could allow the dairy to grow larger with the same replacement system, or allow the dairy to invest in a replacement program that was 8% smaller than before. The third area to impact profitability is the increased performance of the heifer in the dairy herd.

Using a model that treats the replacement program as a separate enterprise within the dairy, we looked at the combined changes for this herd, decreasing the calving age to 22.2 months, decreasing the non-performance rate to 7.5%, and fully transferring the increased value of production in the lactating herd. The non-completion rate was reduced due to a reduction in death loss with greater nutrient intake prior to weaning with no changes post-weaning, indicating there will be more heifers available to enter lactation. The base replacement enterprise was generating a return of 0.87% on assets invested in the replacement program. With all the changes, the return increased to 7.2%.

The profitability increase is due to the potential decrease in inventory due to calving approximately three months earlier, and the milk yield increase due to improved nutrition and management from birth. The management decisions associated with the inventory change due to AFC are difficult to generalize among all herds, and it is really a one-time adjustment to the cost of production. However, given the potential change in milk yield over the lifetime of the animal, the change in calf management in a program that maintains the targets throughout the growing phase is worth approximately \$211, assuming a discount of 7% per year over the three-year period, a \$15 milk price, and income-over-feed costs of \$10.50. This value is similar to the profit calculation of Overton<sup>38</sup> and an outcome of the average milk response we are using to make the estimation along with the individual assumptions about costs of management.

**Table 6.** Cost assessment of conventional versus intensified calf and heifer programs.

	Conventional	Intensified
Pre-weaning cost per pound gain, \$	2.73	2.91
Total pre-weaning gain, lb	64	102
Age at pregnancy, mo.	15.4	12.2
Age at first calving, mo	24.5	22.2
Overall average daily gain from birth, lb	1.70	1.89
Body weight at calving, lb	1,350	1,350
Percent non-completion rate, % entering replacement program	10.2	7.5
Total cost per heifer, \$	1,738	1,740
Total investment per heifer, \$	1,887	1,890

**Table 7.** Replacement enterprise impact for selected management changes for a 250-cow herd. These values represent the differences in expenses associated with the heifer-rearing enterprise associated with the calf-raising program.

	Base	Lower calving age	Lower non-completion rate	Combined changes
Heifers-to-cows ratio, %	76	68	74	69
Total rearing costs, \$	1,736	1,739	1,701	1,724
Income per animal, \$	1,900	1,900	1,900	2,104
Completing system				
total investment, \$	223,142	202,348	217,508	211,692
% return on capital	0.87%	0.53%	1.75%	7.27%

## Conclusion

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. We have much to learn about the consistency of the response and the mechanisms that are being affected. Given the amount of variation accounted for in first and subsequent lactation milk yield, there is opportunity to enhance the response once we know and understand those factors. The bottom line is that there is a positive economic outcome to improving the management of our calf and heifer programs starting at birth.

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