Does Early Growth Affect Subsequent Health and Performance of Heifers?

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Take Home Messages

- Conventional calf-rearing systems limit nutrient intake from milk or milk replacer during the first 2-3 weeks of life compared with what calves consume if given free access to milk.
- Cold stress increases maintenance energy requirements and further limits nutrient adequacy under conventional feeding programs.
- Accumulated evidence shows no detrimental effects of increasing the amount of milk or milk replacer fed during the preweaning period in calves.
- While few data are available, subsequent milk production generally has been higher for heifers with improved nutrient status as calves. Some of this effect may be mediated by better health.

Introduction

Conventional calf-rearing systems typically restrict the amount of milk or milk replacer fed during the first few weeks of life in an effort to encourage solid feed intake and allow early weaning. Recent demonstrations of the remarkable growth improvements in growth and feed efficiency by feeding greater quantities of milk (Flower and Weary, 2001; Jasper and Weary, 2002) or milk replacer (Bartlett, 2001; Diaz et al., 2001; Tikofsky et al., 2001; Blome et al., 2003) have stimulated renewed interest in early calf nutrition. In evaluating the economic implications of such systems, an important question is whether systems based on greater liquid feed intake early in life have any demonstrable long-term effects on health, reproduction, milk production, and longevity of the animal in production settings. This question is important not only to evaluation of different feeding strategies, but also to potential lasting effects of suboptimal nutrition caused by failure to adjust amounts fed during cold stress.

It must be made clear at the outset that few data are available that directly link nutritional status in young calves with later life health and productivity as cows. Frankly, it appears that this question has rarely been considered in most research conducted over the last half-century. That this question is now being debated seriously reflects in part the growing recognition of, and appreciation for, the considerable body of knowledge gained in other animal species and humans on the impacts of early-life nutrition on growth and health, both during the neonatal period and later in life (e.g., Roberts and McDonald, 1998; Woodward, 1998; Burrin et al., 2001). Available data for calves will be discussed here, but much of the discussion will by necessity be rather speculative. At the very least, consideration of the possible physiological impacts of suboptimal early-life nutrition based on data from other species may help to develop testable hypotheses for dairy calves (Drackley, 2005).

▪ Background

First, what is meant by differences in early nutrition must be established. Current convention of calf rearing in North America is that calves are fed a limited amount of milk or milk replacer, typically 8 to 10% of body weight (BW) as liquid, in an effort to stimulate early consumption of solid feeds (starter). Because volatile fatty acids (particularly butyrate) from fermentation of concentrate-based ingredients are the stimulus for development of the ruminal epithelium, early consumption of starter dry matter (DM) is important for systems in which the goal is early weaning and the lowest cost rearing program (Davis and Drackley, 1998). Consumption of this limited amount of solids from milk or milk replacer (typically 400 to 600 g/d) will support maintenance plus average daily gains (ADG) in the range of 200-300 g/d (for milk replacer) to 300-400 g/d (for whole milk) under thermoneutral conditions (National Research Council, 2001). However, under adverse environmental conditions, increased maintenance requirements for thermogenesis may result in reductions in BW gain or even BW loss. For example, a 45-kg calf consuming 500 g/d of a typical milk replacer powder will lose BW when the effective environmental temperature is below 5°C (National Research Council, 2001).

Restricted-feeding programs differ markedly from the natural feeding behavior of calves allowed to suckle their dams or to consume milk ad libitum. Calves allowed to suckle their mothers typically consume 6 to 10 meals per day, and may consume 16 to 24% of their BW daily as milk after 3 to 4 wk of age (Hafez and Lineweaver, 1968). Recent studies have confirmed these patterns in Holstein calves. Flower and Weary (2001) showed that Holstein calves left with their dams weighed 59.9 kg at 14 d of age compared with 46.9 kg for calves fed milk from a bucket at a rate of 10% of BW. Jasper and Weary (2002) reported mean milk intakes of 8.8 kg/d during the first 35 d of age when Holstein calves had free access to milk via an artificial teat, compared with 4.7

kg/d for calves fed milk at 10% of BW. In that experiment, calves with ad libitum access to milk consumed over 9 kg/d by d 4 of life.

Studies with hand feeding of milk also show that ad libitum intakes of milk are in excess of 18% of BW. For example, Khouri and Pickering (1968) fed a milk replacer twice daily to calves during the first 6 wk of life at rates of 11.3, 13.9, 15.9, or 19.4% of BW (ad libitum). The ADG during weeks 2 to 6 of life were 0.41, 0.50, 0.62, and 0.94 kg/d, respectively. Feed efficiencies (kg milk DM per kg BW gain) were 1.59, 1.47, 1.33, and 1.23, respectively. The latter values are very similar to feed efficiencies for young pigs and lambs (Greenwood et al., 1998; Kim et al., 2001). Consequently, what has been referred to as “accelerated growth” by calves is, in fact, biologically normal growth. It is a management (i.e., economic) decision to feed smaller amounts of milk or milk replacer twice daily to encourage dry feed intake.

As starter intake increases in restricted-milk programs, gains of BW increase and rates of ADG may approach those on more aggressive milk feeding programs (Figure 1). Thus, differences in plane of nutrition are most pronounced during the first 2-3 wk of life when limit-feeding falls far short of meeting nutrient requirements (National Research Council, 2001). Clearly, early growth is limited by restricted-milk feeding programs. Because of the close link between growth and normal developmental processes in animals, it seems wise to ask what other early-life developmental processes might be limited by our conventional feeding programs that limit early growth. Consequently, the frame of reference for the following discussion is the comparison between marginal nutrition during the first 2-3 wk (from conventional feeding systems or from underfeeding during cold stress) with more biologically appropriate early nutrition.

▪ Evidence for Long-Term Effects of Early Life Nutrition

Is Increased Early Nutrition Detrimental?

As those accustomed to limit-feeding calves are exposed to the idea of feeding more milk or milk replacer to young calves, common concerns raised include increased incidence of scouring and other early health problems, overfattening, impaired fertility, decreased milk production (perhaps mediated by impaired mammary development), bone or skeletal abnormalities at maturity, and, as a result of some combination of these factors, decreased herd life.

A common argument in favor of restricted liquid feeding and early weaning has been that scouring is decreased. Fecal consistency becomes less fluid as dry feed is consumed, primarily as a result of the bulking effect of dietary fiber. However, merely feeding more milk or more of a high-quality milk replacer does not cause scouring (Mylrea, 1966; Huber et al., 1984; Nocek and Braund, 1986;

Appleby et al.,, 2001; Diaz et al., 2001). The occurrence of calf scours, unless a poor-quality milk replacer containing damaged ingredients is fed, depends more on the load of pathogenic microorganisms in the calf's environment (Roy, 1980) and the degree of environmental stress on calves (Bagley, 2001). Calves fed larger amounts of milk replacer have softer feces, and that requires a shift of mindset by producers and advisors. Our own experiences with calves fed milk replacer at up to 18% of BW indicated that average fecal scores were not significantly different but that days with elevated fecal score (softer feces) were increased (Bartlett, 2001; Pollard et al., 2003). Feeding milk replacer resulted in softer feces than feeding similar amounts of whole milk, regardless of the macronutrient composition of the milk replacer (Bartlett, 2001).

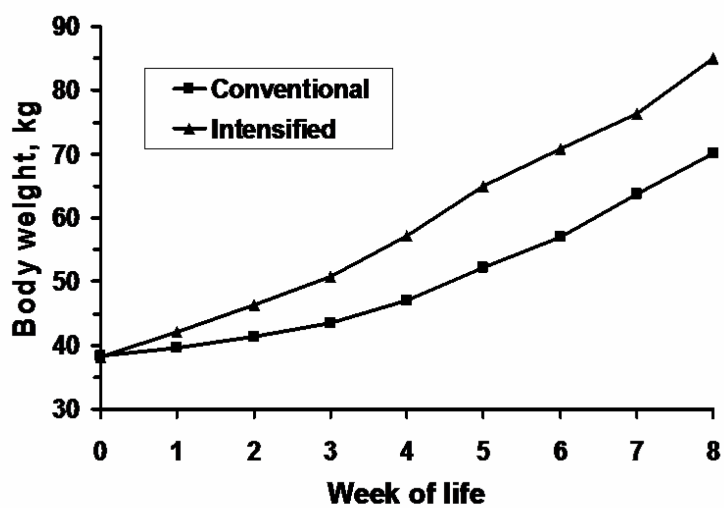

Figure 1. Example of differences in early growth between calves fed on a conventional limit-feeding program (milk replacer powder fed at 1.25% of birth BW; calves weaned at 35 days) or on an intensified program (milk replacer fed at 2% of birth BW for wk 1, then 2.5% of BW at wk 2 during wk 2-5; calves weaned at d 42). Calves had access to starter from wk 1 of life. (B.C. Pollard and J.K. Drackley, unpublished data, 2002)

Given the known adverse effects of allowing heifers to become too fat (Sejrsen et al., 2000), concern exists that increased milk or milk replacer might allow calves to become too fat, in turn impairing subsequent reproduction or milk production. Our recent studies (Bartlett, 2001; Blome et al., 2003) as well as those by Van Amburgh and associates (Diaz et al., 2001; Tikofsky et al., 2001) have shown clearly that body composition can be influenced by dietary composition in young dairy calves. Measurements of stature increase as the content of dietary crude protein (CP) is increased in isocaloric diets (i.e., as the dietary protein to energy ratio is increased; Bartlett, 2001; Blome et al., 2003), indicating stimulation of skeletal growth. Whole-body deposition of protein (i.e., lean tissue) also increases linearly as dietary CP supply increases over a wide range of protein intakes (Figure 2). At the same energy intake for calves fed isocaloric diets, whole-body protein deposition increases linearly while at the same time fat deposition decreases linearly (Figure 3) as the protein to energy ratio increases (Bartlett, 2001). Fat deposition is increased by a greater amount of dietary fat compared with a similar amount of energy from lactose (Bartlett et al., 2001a; Tikofsky et al., 2001). Taken together, these studies indicate that overfattening should not be a concern with higher protein, moderate-fat milk replacers designed for enhanced growth rates; fat deposition may increase with larger amounts of whole milk fed for prolonged periods.

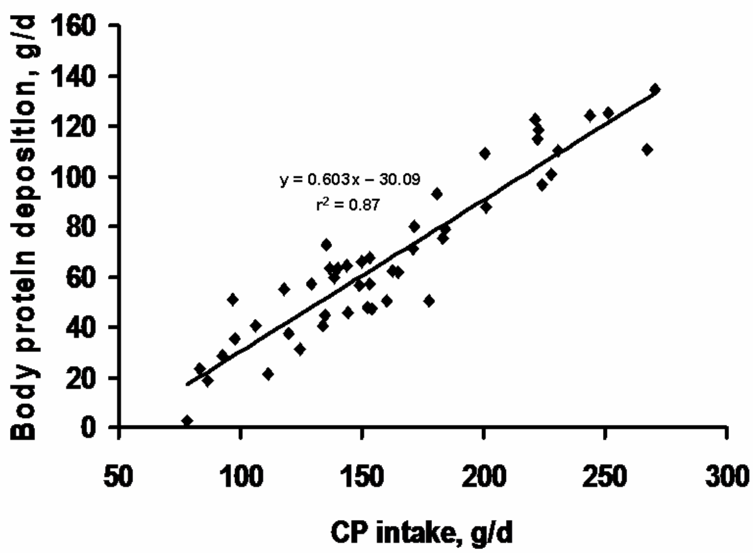

Figure 2. Relationship between dietary crude protein intake in milk replacer and whole-body protein deposition in Holstein calves fed milk replacer. (Drawn from data in Bartlett, 2001)

While controlled studies of subsequent reproductive characteristics as affected by early differences in nutrition have not been performed, field observations to date have indicated no problems. Indeed, there is little biological basis at present to propose that differences in early life nutrition, in the presence of similar growth from weaning to puberty and breeding, would impact fertility.

Over-feeding energy during the period of 3 mo of age to puberty may negatively impact mammary development and milk production (Sejrsen et al., 2000). Although concern has been raised that greater liquid feeding early in life also might impact mammary development, Danish researchers have found no evidence for effects of high growth rate during the first 2 mo on mammary development (Sejrsen et al., 1998, 2000). Recent research from Michigan State University has shown that improved early nutrition actually stimulated mammary tissue development (Brown et al., 2005). Calves fed a milk replacer (28.5% CP, 15.0% fat) for ADG of 666 g/d had 32% more parenchymal mass and 47% more parenchymal DNA than calves fed a conventional milk replacer (20.0% CP, 20.0% fat) for ADG of 379 g/d.

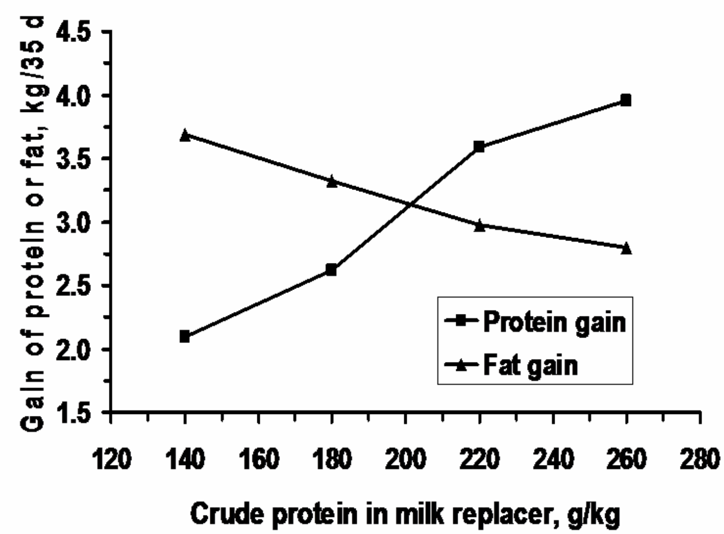

Figure 3. Relationships between whole-body protein deposition and whole-body fat deposition in Holstein calves fed milk replacers with increasing crude protein content. Reconstituted milk replacers were isocaloric and were fed at a rate of 14% of BW, adjusted weekly. The linear effect of crude protein content was significant (*P* < 0.05) for both. (Drawn from data in Bartlett, 2001)

The author is aware of no evidence that might provide a basis for abnormal skeletal development as a result of greater milk intake in cattle, or any other mammalian species, during early life. One only has to consider the fact that beef heifers consume large amounts of milk early in life and live to greater average ages than do dairy cattle, with no evidence of bone problems. Although current biologically appropriate early nutrition programs have not been in existence long enough to make any evaluation of longevity, there is little basis on which to postulate negative effects if properly formulated and balanced diets are fed to meet nutrient requirements.

Is Increased Early Nutrition Beneficial?

As mentioned in the introduction, the possibility that early-life differences in nutrition might impact subsequent productivity or longevity has not been widely considered by researchers in the past. Nevertheless, although data are limited there is more evidence that a higher plane of nutrition during early postnatal life may improve subsequent productivity than evidence for impairment.

Israeli researchers (Bar-Peled et al., 1997) compared calves allowed to suckle nurse cows three times daily for 15 min per feeding during d 5-42 of life with calves fed a milk replacer (23% CP, 18% fat) in restricted amounts. All calves had free access to starter concentrate and hay. Suckled calves were changed to milk replacer at d 43, and the amount fed was decreased to be similar to controls by d 50. From d 51 until calving, management of the two groups was identical. Suckled calves consumed essentially no starter or hay during the treatment period, but consumed on average 14% more energy than calves fed limited amounts of milk replacer. Although ADG were greater during the treatment period (Table 1), suckled calves underwent a pronounced growth slump at weaning. Consequently, suckled calves were actually nearly 10 kg lighter at 12 wk of age. Nevertheless, suckled calves were 5 cm taller, calved 30 d earlier, and produced 453 kg more milk in first lactation than calves fed milk replacer in restricted amounts.

A Danish study compared calves fed 4.6 kg of whole milk from birth to 56 d of life with calves allowed to suckle their dam for 30 min twice daily through 56 d (Foldager and Krohn, 1994). Suckled calves produced over 4.5 kg per day more milk in first lactation than the conventionally fed calves (1403 kg more for a 305-d lactation). A second Danish study compared calves fed 4.6 kg of whole milk for 42 d with calves fed ad libitum amounts of milk twice daily from a bucket through 42 d (Foldager et al., 1997). Calves fed the greater amounts of milk produced 489 kg more milk in first lactation than restricted-fed controls.

We recently compared an intensified milk replacer feeding system with a conventional limit-feeding system with calves born over a two-year period (Pollard et al., 2003). Calves fed the intensified treatments had greater ADG during the milk feeding period, but stalled markedly around weaning. By 12 wk of age, differences in BW and stature had narrowed between groups. Nevertheless, as of this writing, first lactation 305-day mature-equivalent milk yields average over 1100 kg greater ($P = 0.17$) for the heifers that were fed the intensified program as calves; these are preliminary data and calves studied in the second year are early in their first lactation currently.

Table 1. Growth and subsequent production in Holstein heifers fed restricted amounts of milk replacer (conventional) or allowed to suckle cows three times daily during the first 42 d of life (from Bar-Peled et al., 1997).

Variable	Conventional	SEM	Suckled	SEM
n	20		20	
BW, kg				
6 wk	61.9	3.2	73.4	4.7
12wk	98.2	4.2	88.3	5.1
ADG, kg/d				
0 to 6 wk	0.56	0.08	0.85*	0.11
7 to 12 wk	0.86	0.11	0.35*	0.35
0 to 12 wk	0.71	0.10	0.60	0.13
12 wk to conception	0.64	0.08	0.87*	0.09
Conception to calving	0.65	0.06	0.67	0.08
Age at conception, d	426	13	394*	15
Calving age, d	700	15	669*	12
BW at calving, kg	507	24	544	30
Milk (kg/300 d)	9171	306	9624†	374
Wither height, cm	134.4	1.9	139.7*	2.3

* $P < 0.05$
† $P < 0.10$

The magnitude of the differences in first-lactation milk yield due to improved early nutrition is strikingly similar among the few studies that have reported those results. As another example, our research group compared growth responses of Holstein heifer calves to dietary protein concentrations in milk replacer and starter designed for conventional limit-feeding programs. Treatments were two protein contents in milk replacer (18 or 22%) and two protein contents in starter (18 or 22%) in a 2 x 2 factorial arrangement. Calves were assigned randomly to treatments (n = 15) at birth and received colostrum and transition milk for the first 2 d of life. Calves received milk replacer (reconstituted to 12.5% solids) at a fixed allocation of 10% of birth BW divided into two feedings daily. During d 28-35, calves received one feeding of milk replacer; calves were weaned abruptly at d 35. Calves remained in individual hutches until d 49, and then were commingled under common management and feeding until breeding and calving.

Some data from this study are given in Table 2. Few interactions of milk replacer and starter CP content were detected, so only main effects are presented. Milk replacer containing the higher amount of CP resulted in greater ADG and heart girth increase. In contrast, higher starter CP content did not affect ADG, but resulted in greater concentrations of urea-N in plasma. A total of 47 of the original 60 heifers completed first lactations. The BW at calving was 20 kg less for heifers fed the higher CP milk replacer as calves, although this difference was only marginally significant ($P = 0.11$). Despite being smaller on average, these heifers produced 508 kg more milk. It is interesting that this difference is of similar magnitude to the studies reported above, although the difference did not achieve statistical significance ($P = 0.33$). On the other hand, heifers that were fed the higher CP starter as calves produced an average of 540 kg less milk than those fed the lower protein starter; again, the difference was not statistically significant ($P = 0.30$). It is likely that, because of the immature rumen, nitrogen from CP degradation was in excess of available carbohydrate in the higher CP starter, as demonstrated by higher concentrations of urea-N in plasma. One might only speculate, therefore, whether the elevated ammonia or urea somehow resulted in developmental changes unfavorable for subsequent milk production. Larger studies would be needed, of course, to confirm these tendencies. Given the magnitude of the differences between means and the degree of variability present in this experiment, over 200 cows per treatment would be necessary to have a 90% chance of demonstrating statistical significance at a probability of 0.05! While such large numbers of animals per treatment would be required in individual experiments to demonstrate effects in later life, data from smaller experiments might be able to be combined for statistical analysis using techniques such as meta analysis. It is unfortunate, however, that most research studies on early life nutrition in calves have not measured subsequent milk production, reproductive efficiency, or longevity. Several studies are ongoing at the time of this writing to determine longer-term effects of intensified milk replacer programs, but results are not yet available.

Table 2. Effects of crude protein (CP) content in milk replacer and starter on growth and subsequent milk production in Holstein heifers (Drackley, J.K., Blome, R.M., and Bartlett, K.S., unpublished data)

	CP in milk replacer, %		CP in starter, %		
Variable	**18**	**22**	**18**	**22**	**SEM**
d 3-49					
n	30	30	30	30	---
ADG, kg	0.52	0.58†	0.54	0.55	0.03
Wither height gain, cm	18.5	20.3	18.6	19.7	0.9
Heart girth gain, cm	13.5	15.4*	14.2	14.6	0.6
Plasma urea-N, mmol/L	1.13	1.35*	1.09	1.39*	0.05
First lactation					
n	26	21	22	25	---
Calving age, mo	25	26	26	26	---
Calving BW, kg	581	561	570	572	8
Milk yield, kg	11,354	11,862	11,878	11,338	366
Milk fat, kg	410	425	423	412	14
Milk protein, kg	350	362	367	346	12

* $P < 0.05$ within main effects.
† $P < 0.10$ within main effects.

▪ Potential Mechanisms for Long-Term Effects of Early Life Nutrition

If improved early nutritional status were actually to lead to enhanced productivity, health, and longevity, what might be the mechanisms? Given the close association between normal growth and developmental processes, the simple answer may be that more closely meeting early life nutrient requirements may better support early developmental processes that in turn make for a better dairy cow. However, scientists would prefer more defined mechanistic explanations or hypotheses. Based on data obtained in other animal models, theories can be proposed that include 1) improved development or function of the immune system leading to better health status, 2) enhanced early mammary development, 3) altered endocrine development or function, 4) enhanced lean tissue development, and 5) metabolic programming or imprinting. Because this topic is largely beyond the scope of this paper, only the first possibility will be discussed here. A more detailed coverage of potential mechanisms will be found in Drackley (2005).

Improved Health Status

Poor health during early life is believed to have long-lasting effects on production and herd life. Epidemiological studies relating specific neonatal illnesses to later productivity generally have not found strong relationships between any specific illness or condition and subsequent survivability or productivity, although respiratory disease in calves increased the age at first calving (Correa et al., 1988). Perhaps most interesting is the report that early-life “dullness” in calves was a significant risk factor for shorter herd life. Calves that were characterized as having dullness before 90 d of age (defined as dull appearance, listlessness, droopy ears, and off feed) were 4.3 times more likely to die after 90 d of age (Curtis et al., 1989) and 1.3 times more likely to leave the milking herd than herdmates (Warnick et al., 1997). The authors speculated that this condition might reflect the combined effects of poor health and suboptimal nutrition.

Insufficiencies of protein or energy are well known to impair health and immune system function in other species (Woodward, 1998). Is there evidence that inadequate nutrition during early life decreases resistance to disease and compromises health and well being of calves? Williams et al. (1981) compared calves fed two amounts of milk replacer solids (600 g/d and either 300 or 400 g/d) with either ad libitum or restricted access to calf starter. Calves fed the higher amount of milk replacer with ad libitum access to starter had the greatest ADG and least mortality. Other studies have shown that inadequate nutrition results in impaired immune responses in young calves. Griebel et al. (1987) fed neonatal calves either below maintenance or above maintenance intakes of milk replacer. Calves fed below maintenance lost BW and had higher (although nonsignificant) concentrations of cortisol in serum; lymphocytes isolated from these calves had decreased proliferative responses compared with adequately fed calves. Malnourished calves had lower primary antibody response to administration of K99 antigen.

Pollock et al. (1993, 1994) compared effects of weaning age (5, 9, or 13 wk of age) and two levels of nutrition (400 g/d or 1000 g/d of milk replacer powder). Weaning at 5 wk resulted in compromised lymphocyte responses (cellular immunity) at 10 wk of age. The higher plane of nutrition, which was approximately twice maintenance, resulted in improved responses of cell-mediated immunity and decreased skin responses to antigen (Pollock et al., 1993). In contrast, the high plane of nutrition resulted in decreased antibody titres to specific antigens, without changing total immunoglobulin concentration in serum (Pollock et al., 1994). These results are consistent with recent evidence demonstrating that neonatal calves have vigorous antigen-specific cell-mediated immune responses but relatively weak antibody responses compared with adult cattle (Foote et al., 2003; Nonnecke et al., 2003).

Recent research (Nonnecke et al., 2000, 2003) studied immune system characteristics in calves fed a milk replacer for greater rates of early growth (30% CP, 20% fat; DM fed at 2.4% of BW) or in calves fed a conventional milk replacer (20% CP, 20% fat) at slightly greater rates than industry standard (DM fed at 1.4% of BW). Increased plane of nutrition did not affect total numbers of blood leucocytes, composition of the mononuclear leukocyte population, mitogen-stimulated DNA synthesis, or immunoglobulin M secretion. However, mononuclear leukocytes isolated from calves fed on the higher plane of nutrition produced more inducible nitric oxide and less interferon-(than cells from conventionally fed calves. In another study by that research group, calves fed 568 g/d of conventional milk replacer powder (22% CP, 20% fat) had lower antigen-induced proliferation of CD8 lymphocytes than calves fed 1136 g/d of a milk replacer (28% CP, 20% fat) designed for intensified early nutrition (Foote et al., 2003). While effects were relatively small, it must be remembered that control calves received adequate nutrients and were under clean and thermoneutral conditions. Together, available data support a role of nutritional status in at least some aspects of immune system function in young calves.

Improved neonatal nutritional status might be expected to impact the immune system via provision of deficient nutrients or energy, or by altering the endocrine environment that affects the developing immune system. Houdijk et al. (2001) have discussed the partitioning of nutrients among maintenance, immune function, and growth or other productive functions in animals. These authors raise the possibility that inadequate protein supply may limit function of the immune system, through the importance of glutamine (and potentially other amino acids). Amino acid status, as indicated particularly by glutamine availability, might be expected to affect both innate and specific immunity. Glutamine is a major fuel and biosynthetic amino acid for rapidly proliferating cells of the gut (Newsholme et al., 1985b), which might impact barrier function of the intestine in young calves. Glutamine also is a major fuel for lymphocytes (Newsholme et al., 1985a) and other cells of the immune system (Calder and Yaqoob, 1999). Deficiency of glutamine results in immunosuppression in humans (Calder and Yaqoob, 1999) and mice (Kafkewitz and Bendich, 1983). Given the importance of protein intake for growth as demonstrated by our experiments (Bartlett et al., 2001b; Blome et al., 2003) in which increasing protein content of isocaloric milk replacers markedly increased ADG and efficiency of gain at similar overall energy retention, relationships among nutrition, growth, and immune function in calves is an important area.

The anabolic hormones growth hormone (GH) and insulin-like growth factor-1 (IGF-1) play a direct role in integrating the growth, maintenance, repair, and function of the immune system in other species (Clark, 1997). Lymphocytes express receptors for both GH and IGF-1. In rodents, IGF-1 causes growth and maturation of B cells, increases size of the thymus and spleen, and increases antibody production by B cells (Clark, 1997). Consequently, if responses in calves are similar, increased concentrations of IGF-1 resulting from improved nutrition might be expected to enhance immune function in calves.

Smith et al. (2002) recently reported that calves fed for biologically appropriate growth during early life had greater concentrations of IGF-1 than did calves fed milk replacer at a conventional (restricted) rate. Plasma from calves in both groups showed increased IGF-1 concentrations in response to injection of bovine somatotropin at 5 wk of age, but calves on the higher plane of nutrition also responded with increased growth rates. In our experiments (Bartlett, 2001), IGF-1 in plasma was increased by greater feeding rates and by increasing dietary CP. Patterns of plasma IGF-1 were nearly identical to those for ADG and the two variables were highly correlated (r = 0.72). These results clearly show a functional IGF-1 system in young calves that is responsive to early nutritional status, although the relationship of the enhanced IGF-1 status to immune function and health remains to be determined.

The health status of young calves likely is impacted by interactions of early nutrition and the environment. Nutritional insufficiency may be especially problematic for immune function during cold or heat stress, when maintenance requirements for temperature regulation are increased. For example, we conducted an experiment to determine the value of supplementing milk replacer with energy sources for Jersey calves raised in hutches during winter (Drackley et al., 1996). To do so required establishment of an appropriate baseline feeding regimen. Jersey heifer calves fed a conventional milk replacer at 8% of BW did not maintain BW and had a high incidence of health problems. Calves fed the same milk replacer at 10% of BW gained small amounts of BW but still were unhealthy. Only when calves were fed at a rate of 12% of BW were they able to maintain health and BW gains.

A recent study conducted in Minnesota (Godden et al., 2005) compared equal volumes of pasteurized non-saleable milk and a conventional milk replacer. Because whole milk contains about 17% more energy than milk replacer at equal amounts, indirectly these authors were comparing two planes of nutrition. Calves fed the pasteurized non-saleable milk had greater ADG than those fed milk replacer. In summer, mortality of calves did not differ between those fed milk (2.2%) or milk replacer (2.7%). However, for calves born in the winter, mortality was much greater for calves fed milk replacer (21.0%) than for those fed milk (2.8%). Much of this difference is likely attributable to the marginal nutrient status of the calves fed milk replacer because maintenance energy requirements are much greater during cold stress.

■ Concluding remarks

Few data are available to document conclusively what impacts early nutrition might have on later life productivity, health, and longevity. Current conventional systems restrict nutrient intake during the milk feeding period in an effort to encourage early intake of calf starter, allow earlier weaning, and decrease costs of heifer rearing. Programs of more aggressive liquid feeding early in life result in nutrient intakes that more nearly meet the requirements of neonatal calves for normal growth and development. Consequently, from a biological perspective it would be difficult to argue that improving nutritional status of the young calf during the first few weeks of life should be anything but positive for subsequent productivity and longevity.

Malnutrition or suboptimal nutrition has been well documented to impact growth and health status in the young of other species. To what extent can parallels be drawn between early development of dairy heifers and information on early-life events in other mammalian species? Knowledge from other species should be able to be used as the basis for testable hypotheses in dairy cattle; however, experiments to test such hypotheses likely will require very large numbers of animals and will be long, difficult, and expensive to conduct.

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