A Systematic Approach to Calf and Heifer Rearing: "Intensified" Feeding and the Target Growth System

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Growth is an essential component of the dairy enterprise, yet many of us that work in the dairy industry have had little training or background in applied aspects of animal growth. We are more comfortable with concepts involving milk yield and composition primarily because that is where we generate income. However, to improve calf and heifer management, we must understand basic concepts of applied growth so that better recommendations can be developed.

For several years our laboratory has been investigating nutritional and management practices of calves and heifers in an effort to reduce the age at first calving. Interest in this area stems from several factors, primary of which is the economic investment required for the heifer replacement program by the dairy industry which is equivalent to 15 to 20% of the cost to produce milk. Our research group made several observations that precipitated a series of ongoing experiments that will be discussed in this paper.

Those observations were:

1) Studies that have investigated pre-pubertal "accelerated growth" in an effort to lower age at first calving never started treatments earlier than 3 months of age and most were well into the ruminant phase of growth and as late as 8 months of age. Thus, from a systematic perspective we might have lost a significant amount of time and opportunity with regard to lowering the AFC. If we are being systematic, why not start at birth? Further, early postnatal growth is the most efficient time to deposit protein and develop skeletal growth and attain the highest feed efficiencies. What do we do as an industry to capitalize on this capacity for lean growth?

2) Recent evaluations of nutrient requirements for Holstein heifers suggested that the system of equations we use to calculate requirements does not adequately represent the composition of gain and thus the energy and protein requirements for growth during the pre-pubertal phase of life. Further, this inability to meet the "true" requirements might have confounded our expectations and interpretation of accelerated growth studies. Most of the equations we use to derive nutrient requirements for Holstein heifers were derived from Angus and Hereford steers slaughtered in excess of 500 lb bodyweight. Thus little direct data exists for the weight range or cattle type we work with.

3) On farm management of calf rearing typically follows nutrition programs developed for early weaning and thus controlled restricted liquid feeding levels in an effort to encourage dry feed intake. Considering this practice, in light of the 1996 National Animal Health Monitoring Service data indicating that neonatal calf mortality was greater than 10%, we were led to think about calf management from a different perspective. The shift in perspective involved the following questions: 1) do standard calf nutrition programs contribute to the observed morbidity and mortality and 2) is the practice of restricting liquid feed intake the most biologically sound approach to achieving calf growth and health. If milk or milk replacer intake is limited, are there enough nutrients in early life that will allow the calf to develop an adequate immune response?

4) Finally, we know of no other neonatal system that is successful at enhancing future productivity by restricting milk intake in an effort to force weaning, humans included. Compared to every other neonatal management system, dairy calves are the only animals that we purposely restrict milk or milk replacer intake from day of birth (10% body weight intake – fixed over the feeding period). Beef calves, lambs, piglets, dogs, cats, horses and humans, all suckle on demand at least for the first four to six weeks of life. Is there a benefit to increased nutrient intake during the first few weeks of life for normal development and immune system responsiveness?

From the perspective of a nutritionist, one of the most over-looked groups of animals on the dairy farm has been the milk-fed and transitional calf. There are several reasons for the lack of a mechanistic approach to "ration formulation" for the young calf, primary of which has been the unavailability of tools for calculating nutrient requirements and supply. With the release of the 2001 National Research Council Nutrient Requirements of Dairy Cattle, a more useful approach to feeding calves has been developed. The new Dairy NRC (National Research Council, 2001) employs a more mechanistic approach to calf growth and development than previously utilized in the United States, and with adoption of the system the industry will be encouraged to re-evaluate the one-size fits all approach to calf feeding that currently exists.

The objectives of this paper will be 1) to review current feeding recommendations published by manufacturers of milk replacers and evaluated by the new 2001 Dairy NRC and 2) to describe new data that helps us refine our predictions of nutrient requirements for milk fed and transitioning calves, and, 3) to discuss data that suggests increased nutrient intake during early life enhances calf development and milk yield in at least the first lactation.

Milk replacer formulation and feeding guidelines have been developing on a widespread, commercial basis since the 1950s. Roy (1964) examined the origins of commercial milk replacer and clarified the context in which developments like fat concentration, ingredient choices, and feeding practices were made. It is clear from the review of Davis and Drackley (1998) that considerable research has been completed over the last 50 years to elucidate the specific nutrient requirements of the young calf, as well as the potential benefits (or risks) of various feeding practices. It is therefore logical to assume that the advances in this nutrition technology would be subsequently reflected in the feeding instructions used to tag calf milk replacer products developed for and by the dairy industry.

However, the results of this investigation of milk replacer products currently on the market illustrate that technological advances of the last 50 years are not well represented by current industry recommendations. Field observations, as well as the market research results of large milk replacer manufacturers, indicate that calf raisers are unaware of the disconnect in the research and development of a system because while adhering to the old paradigms of minimized liquid feed intake they continue to complain about animal performance, including growth and health.

Likewise, dairy calf raisers should be encouraged to adapt their feeding practices to allow for significant changes in management so that implementation of a more systematic approach may yield economically beneficial results. An assessment of economic feasibility should be based not only on the investment in heifer rearing, but also on the return on that investment. It has been recognized that replacement heifer management decisions interact with the biological aspects of growth, thereby influencing the future profitability of the heifer (Mourits, 2000; Quigley et al., 1996). It is intuitive that the biologically correct growth system is the best method for the rearing of an animal of any species. If "biologically correct" does not equate to "economically optimal", then we would argue that there is a bottleneck in the management system.

Evaluation of Current Feeding Approaches

The following examples are used to demonstrate labeled feeding rates for a group of randomly selected commercially available milk replacers. For this exercise we fed an example calf with the 2001 Dairy NRC Model (National Research Council, 2001) according the feeding instructions provided by the milk replacer manufacturer on the product tag. For this exercise calves were characterized in the following way:

1) Twelve to fourteen days of age - It is reasonable to believe that by this stage of development a calf is more than capable of the dry matter intake specified by label recommendations, but she is not likely be consuming a quantity of starter grain sufficient to contribute to an appreciable amount of metabolizable energy.

2) One hundred pounds body weight - Average Holstein calf birth weights are between 86 and 95 lb (Diaz et al., 2001, Tikofsky et al., 2001), and calves generally do not gain a significant amount of weight in the first two weeks of life due to a variety of challenges including health, environmental change, and feeding management.

All of the milk replacers were made from all milk protein sources. The 2001 Dairy NRC uses metabolizable energy (ME) and apparently digestible protein (ADP) as the respective energy and protein "currencies" which is a welcome departure from previous approaches.

Based on the energy and protein allowable gains presented in Table 1, the goal as described by the feeding instructions of these samples of standard milk replacers (A, B, C, and D) is some production level between a near-maintenance gain of 0.22 lb/d and 0.88 lb/d assuming a thermo-neutral environment. These expected gains are consistent with research observations (Diaz et al., 2001, Bartlett, 2001). Evaluations of milk replacers E and F demonstrate energy and protein allowable gains between 1.65 and 2.00 lb/d, and an acceptable balance between the energy and protein allowable gain, unlike the previous milk replacers.

Table 1. Energy (ME) allowable gain (lb/d) and apparently digestible protein (ADP) allowable gain (lb/d) of example calf fed variety of milk replacer formulations according to labeled instructions as evaluated by the 2001 Nutrient Requirements of Dairy Cattle (National Research Council, 2001).

Milk replacer	Formulation[a] (CP%:fat%)	Gross energy (Mcal/lb)[b]	DMI (lb/day)	Dilution (%)	Energy allowable gain (lb/d)	Protein allowable gain (lb/d)
A	22 : 12	2.14	0.93	10.4	0.22	0.55
B	22 : 20	2.34	1.00	10.4	0.48	0.62
C	18 : 21	2.33	1.25	11.6	0.88	0.64
D	20 : 20	2.32	1.25	11.6	0.79	0.73
E	28 : 20	2.31	1.98	15.3	1.65	1.86
F	28 : 15	2.27	2.25	17.4	2.00	2.20

[a]All milk replacers manufactured with all milk protein sources. The fat source was mostly lard or choice white grease.

[b]Calculated value, assuming gross energy values (kcal/g) for lactose, protein, and fat common to milk replacers are 3.95, 5.86 and 9.21, respectively (Davis and Drackley, 1998). Assuming ash content of all milk replacer is 7% and lactose is calculated by difference (100 – ash – fat – protein).

From a systematic perspective, setting manageable targets for both weaning weight and feed efficiency would indicate that milk replacers E and F are more appropriately labeled and formulated for meeting those goals.

The feeding examples described in Table 1 were according to the labeled feeding rates on the product tag. Many question whether feeding more of a 20% CP, 20% fat milk replacer would allow calves to achieve the same performance as calves fed a higher protein milk replacer. Comparisons of “off-label” feeding rates are found in Table 3.

The requirement for protein is energy driven, subsequently any increase in energy intake will increase the demand for protein and a given product might not provide the best balance of nutrients. This is illuminated in Table 2 by the data summarized by Davis and Drackley (1998) and described by Drackley (2000). The data summarized by Drackley (2000) demonstrate that the protein requirement is a function of the energy allowable gain. As the energy intake increases the protein required to meet the energy allowable gain increases, thus there is no single protein value that meets the nutrient requirement of the calf.

From the data found in Table 3, it is apparent that traditional milk replacer formulations were designed to be fed at close to labeled rates. Exceeding that level of intake in all cases except for milk replacers E and F demonstrates a deficiency in protein allowable gain, which will lead to an accumulation of fat and a reduction in protein deposition and feed efficiency (Bartlett, 2001, Diaz et al., 2001). All of the slaughter work conducted in the last few years (Bartlett, 2001, Diaz, et al., 2001, Tikofsky et al., 2001) supports the predictions of the 2001 NRC calf model.

Table 2. Effect of rate of body weight gain with constant initial body weight (100 lb) on protein requirements of pre-weaned dairy calves (adapted from Davis and Drackley, 1998) (From Drackley, 2000).

Rate of gain (lb/d)	ME, (Mcal/d)	ADP (g/d)	Required DMI[1], (lb/d)	CP required, (% of DM)
0	1.75	28	0.84	8.3
0.50	2.30	82	1.11	18.1
1.00	3.01	136	1.45	22.9
1.50	3.80	189	1.83	25.3
2.00	4.64	243	2.24	26.6
2.50	5.53	297	2.67	27.2
3.00	6.46	350	3.12	27.6

[1]Amount of milk replacer DM containing 2075 kcal ME/lb DM need to meet ME requirements.

Table 3. Nutrient balance as calculated by the 2001 Nutrient Requirements of Dairy Cattle (National Research Council, 2001) based on off-label increased feeding rates of milk replacers.

Milk replacer	Formulation[a] (CP%:fat%)	Gross energy (Mcal/lb)	DMI (kg/day)	Dilution (%)	Energy allowable gain (lb/d)	Protein allowable gain (lb/d)
A	22 : 12	2.14	2.20	10.4	1.85	1.63
B	22 : 20	2.34	2.20	10.4	2.07	1.63
C	18 : 21	2.33	2.20	11.6	2.05	1.28
D	20 : 20	2.32	2.20	11.6	2.07	1.45
E	28 : 20	2.31	3.30	15.3	3.30	3.35
F	28 : 15	2.27	3.30	17.4	3.15	3.35

[a]Same milk replacers as in Table 1.

All of the examples in Tables 1 and 2 assume thermo-neutral conditions. Due to their body weight to surface area ratio, calves become cold stressed at moderate temperatures. Again the 2001 Dairy NRC calf model was employed to evaluate feeding recommendations. The model has an environmental component that allows the user to evaluate the affect of temperature on maintenance requirements. Two milk replacers were used, a 20:20 CP:fat and a 28:20 CP:fat inputted at labeled feeding rates and temperatures were decreased from 68°F to 50°F and to 32°F for a 100 lb calf (Table 4).

Table 4. Effect of cold stress on predicted calf growth using the 2001 Dairy NRC calf model (National Research Council, 2001). A 100 lb calf was used as the model calf.

Temperature, degrees F	Milk replacer formulation and intake, lb/d	Energy allowable gain, lb/d	Protein allowable gain, lb/d
	20:20		
68	1.0	0.46	0.53
50	1.0	0.05	0.53
32	1.0	0.00	0.53
	28:20		
68	2.0	1.96	1.96
50	2.0	1.67	1.96
32	2.0	1.41	1.96

From this exercise it becomes apparent that a calf will be cold stressed at a relatively moderate temperature of 50°F (Table 4). Most 100 lb calves have not begun to develop a rumen and dry matter intakes aside from milk replacer or milk, are usually very limited. The calf fed a traditional amount of the 20:20 CP:fat milk replacer will be very close to negative energy balance at 50°F and will definitely be mobilizing adipose tissue at 32°F. When a calf reaches this point, immune status can be easily compromised and the calf becomes susceptible to factors other than cold. The empty body fat content of 100 lb calves is 3.5 to 4%, (3.5 to 4 lb) of which approximately half can be mobilized to support heat production. The calf fed the 28:20 CP:fat milk replacer will receive enough nutrients to maintain adequate growth through the cold stress conditions and we could expect more immune competence from this calf, assuming an adequate dry cow vaccination and colostrum program was in place. Some milk replacer feeding instructions suggest feeding a supplemental fat during periods of cold stress. Most of those products are 7% CP and 60% fat. Adding 0.25 lb/d of a 7:60 fat source to supplement the intake of the calf fed 1.0 lb of the 20:20 CP:fat milk replacer at a temperature of 32°F increases the energy allowable gain to 0.22 lb/d, just slightly above maintenance. Feeding more of an appropriately balanced diet to meet the requirements for both energy and protein allowable gain would appear to be the most systematic solution to this cold-stress challenge. Incidentally, it is during periods of cold stress that many producers will indicate they notice greater acceptability and intake of starter grain compared to warmer periods – this is most likely in response to a tremendous need for energy to maintain body temperature and survival.

Current Research and Application

Recently, several studies have been conducted to determine the effect of nutrition on body composition changes in milk fed calves (Bartlett, 2001, Blome, 2001, Diaz et al. 2001, Tikofsky et al., 2001). From this work we determined that under normal feeding conditions, maximum protein deposition in the calf would be achieved at a protein content of approximately 28% (Bartlett, 2001; Diaz et al., 2001). This data is consistent with the predictions of the Dairy NRC 2001, although some refinements can be made. In addition, the level of fat in milk replacer was investigated (Bartlett, 2001; Tikofsky et al., 2001) and from the analyses of body composition data and the calf performance data, fat levels of 15% to 20% appeared adequate for normal growth and development in Holstein milk fed calves. Work currently underway at Virginia Tech with Jersey calves suggests higher fat levels might be required (Scott Bascom, personal communication).

A consistent question surrounding this research and that potential application of this research is what is the long-term impact of increased feeding rates of milk fed calves? Several studies exist in the literature, which serve to address that question. Brown et al., 2002 conducted a study to determine if feeding increased amounts of milk replacer decreased mammary development in milk fed calves. The study was conducted in two phases, two to eight weeks and then eight to fourteen weeks. Calves were assigned to a either a high or low rate of gain prior to weaning and then maintained on that level or switched an alternate rate of gain post-weaning (Table 5). The heifer calves were then slaughtered and mammary development determined. During pre-weaning, the high calves were fed a 28.5% CP, 15% fat milk replacer whereas the low calves were fed a 20%CP, 20% fat milk replacer. Mammary parenchyma growth was enhanced by 32% during the high milk feeding phase and mammary DNA and RNA was enhanced by 47% during the high milk feeding phase. 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.

Table 5. Effect of two levels of nutrient intake from 2 to 8 weeks and 9 to 14 wks of age on mammary development in Holstein heifer calves. Data indicates that mammary development was enhanced by liquid feed intake prior to weaning, but the effect was not observed once weaning occurred. (Brown et al., 2002)

	Low-Low	Low-High	High-Low	High-High
Daily gain 2 to 8 wk, lb/d	0.84	0.84	1.47	1.47
Daily gain 9 to 14 wk, lb/d	0.97	2.41	0.97	2.41
Final bodyweight, lb	176	234	192	267
Total mammary wt., g/100 kg bodyweight	253	391	266	512
Parenchymal wt., g/100 kg bodyweight	16	15	22	23
Parenchymal DNA, mg/100kg bodyweight	45	42	79	86
Parenchymal RNA, mg/100kg BW	140	132	194	219

Sejrsen et al., (2000) also reported data supporting this observation and that once the calves were weaned mammary development was decreased by increased nutrient intake. Further, there are three studies that have investigated either the effect of suckling versus controlled intakes or ad-libitum feeding of calves from birth to 42 or 56 days of life (Bar-Peled et al, 1997; Foldager and Krohn, 1994; 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. This data further suggests there is factors not well defined that allow the calf to be more productive throughout her life. Similar responses have been observed in baby pigs that indicate enhanced early nutrition has long-term positive effects on health and productivity. Research is underway in our laboratory to further define these factors.

Cornell Lactation Data. The following data was generated from the Cornell University Dairy Herd. In 1997 all of our herd heifers were moved to an "intensified" feeding management system. The following study data is controlled, therefore it allows us to make a comparison within herd of the first lactation milk yield compared to the mature cattle in the herd that were never on an intensified system of rearing. The study described here was a pre-pubertal fatty acid feeding study and all heifers were fed the intensified system (Smith and Van Amburgh, 2002). Heifers were assigned in a restricted randomization to accommodate pen-feeding conditions at the Cornell Teaching and Research Center Dairy Unit. Calves were fed a 30% CP, 20% fat milk replacer at 2% BW DM intake and were provided a starter grain that was 25.7% CP (DM basis) and contained 1.18 Mcals NEm and 0.47 Mcals NEg per lb. Calves were weaned by eight weeks and were then group fed one of four diets: Control – no fatty acid supplementation; Sunflower oil – sunflower oil added to equal the fat level of the CLA diet; Ener GII – Ener GII added to equal the fat level of the CLA diet; and a calcium salt of conjugated linoleic acid (CLA) – mixed isomers. Heifers were fed treatment diets until they were 630 lb on average and averaged 182 days on treatment. Diets were balanced to be similar in metabolizable energy (ME) and protein (MP) allowable gain (~ 1.0 kg/d ME and MP allowable gain) using the CNCPS (Fox et al., 2000) and the gains were designed to allow for 22 mo age at first calving. Heifers entered the breeding window when they weighed approximately 750 lb BW. The target breeding system described by Fox et al., (1999) and the 2001 Dairy NRC (National Research Council, 2001) was utilized. Based on an average mature weight of 1,476 lb, heifers were targeted to be pregnant by approximately 812 lb (55% of mature weight) independent of age and to weigh 1,210 lb (82% of mature weight) post-calving at first calving. A common post-treatment diet was fed to all heifers after they were removed from treatment and was designed to achieve the target post-calving body weight. During lactation, the heifers were fed a common diet, housed as a group, milked three times per day and given bST per label. Breeding was based on a voluntary weight period of approximately 45 days.

There was no significant difference in 3.5% fat corrected milk among the fatty acid treatments (Table 6); therefore, the heifers were re-stratified independent of the original treatments. The heifers were stratified by age at first calving independent of the original study. Heifers were categorized by those calving less than 21 mo, 22-23 mo. and 24 mo and greater (Table 7). Although there were no heifers fed less to serve as controls for rate of gain effects on lactation performance, the production of the heifers in the first lactation compared with the mature cattle production levels is above average. First lactation heifers should produce at 80% or better of the lactation milk yield of the mature cattle in the herd (82 to 85% is excellent). The third lactation cattle at the Cornell Dairy Unit are currently producing ~ 28,522 lb milk per lactation. Thus, the first lactation heifers are producing at 88% of the mature cattle in the herd. The heifers that calved in early (20 mo) are most likely the smaller mature size cattle within the herd and achieved puberty at an earlier age, whereas the larger mature size cattle (24 mo) achieved puberty at a slightly heavier weight, which lead to a greater AFC. Note, however, there is no difference in milk yield among heifers calving at an average age of 20 mo, compared with the older animals.

This data demonstrates that a systematic approach to calf and heifer management from birth coupled with an appropriate rearing strategy and adherence to a target growth approach will allow heifers to achieve lower ages at first calving without a milk loss or at least reduce the variation in milk yield associated with age at calving. Whether this increase in performance relative to the mature cattle in the herd is due to the more intensive calf rearing system is unknown, and a study to determine this directly is underway.

Table 6. Management and production characteristics of Holstein heifers fed a control diet or diets supplemented with either sunflower oil, a commercially available calcium salt of primarily palm oil (Ener GII), or a calcium salt of conjugated linoleic acid during the prepubertal period. Data are preliminary and are presented as least square means.

	Control	Sunflower oil	Ener GII	Ca CLA	Std. Dev.
N	16	16	17	16	
Pre-pubertal daily gain, lb	1.90	1.92	1.96	1.87	0.15
Age first calving, mo	21.8	21.6	22.3	22.3	1.5
Days in milk	299	294	294	290	10
Body weight at calving, lb	1,228	1,199	1,240	1,267	75
Milk yield, 3.5% FCM, lb	25,057	24,599	25,538	25,344	2,451

Table 7. A post-hoc analysis of the management and production characteristics of Holstein heifers ranked by age at first calving, independent of dietary treatment.
Data are preliminary and are presented as least square means.

Age first calving rank, mo	<21	21 - 23	>23	Std. Dev.	P
N	19	27	19		
Pre-pubertal daily gain, lb	2.16[a]	2.03	1.96[b]	0.2	0.05
Age first calving, mo	20.2[a]	21.8	24.2[b]	0.6	0.001
Days in milk	298	299	285	14.0	0.7
Post -calving weight, lb	1,177[a]	1,218	1,314[b]	42.0	0.001
Milk yield , 3.5% FCM, lb	24,817	25,485	24,976	2,405	0.6

[abc]Values with superscripts within row differ P < 0.05.

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