Feeding Dairy Calves for Performance

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Management programs markedly impact the expression of genetic capabilities in dairy cattle. Poor management conditions may negatively impact dairy cattle performance on a permanent basis. Unfortunately, seemingly trivial mistakes made in the earliest stages of life may manifest themselves in markedly negative fashion throughout the animal's life. More often than not, these performance shortfalls result in premature culling and represent a significant economic loss to the industry. The decision to manage dairy cattle and harvest the productive fruits of their existence brings with it the inherent responsibility to provide a quality life for the animals managed. It is therefore imperative that we study and understand the animals we are managing so that we might continue to improve in meeting their productive requirements.

Growth and development of dairy cattle often become melded together as if they are the same. In reality, growth is a function of development, positive or negative. Growth occurs as tissues develop, with positive growth associated with an increase in cell numbers and/or size. Growth of some tissues may impede the development of others. Typically, development occurs in phases from conception through maturity and is more highly regulated than growth. Growth is typically measured in terms of weight gain or increase in structural size and does not necessarily account for optimal tissue development. Development is the differentiation and maturation of cellular tissues capable of expressing genetic potential of the animal. It is often difficult to measure as it is occurring and may only be qualified and quantified during productive function of the tissue measured.

In dairy replacement heifers, the following critical phases of physiological development can be identified:

- embryonic and fetal,
- birth to 7 d of age,
- 7 d to weaning,
- weaning to 6 mo of age,
- 6 mo to breeding,
- breeding to 8 mo of pregnancy,
- 8 mo of pregnancy to parturition, and
- parturition through a cyclic continuum of lactation, gestation, and dry phases that continue through maturity until the end of their productive life.

The dairy steer undergoes a different pattern of development beginning at weaning and progressing through harvest. It is the accumulation of environmental events (inclusive of all factors influencing development such as nutrition, weather, facility, disease, stressors, etc.) that either advance or impede tissue development and thus genetic expression of performance and productive traits.

While it would take multiple texts to adequately discuss all of the developmental phases and their respective responses to environmental challenges, the following is offered as a reminder of some often neglected issues regarding the feeding of dairy calves in their early stages of development for performance and productivity.

COLOSTRUM

Colostrogenesis begins approximately 3 to 4 wk prior to parturition with the accumulation of hormones, growth factors (IGF-I and IGF-II) and transforming growth factors (TGF-β1 and TGF-β2) which activate mammary secretory cell receptors to facilitate the influx of immunoglobulin G_1 (IgG_1) (Fleet et al., 1975; Tucker, 1981; Larson et al., 1980; Pakkanen and Aalto, 1997). Within 1 to 2 wk, these receptors are fully active and high levels of IgG_1 are now accumulating with some immunoglobulin M and A (Tripathi and Vashishta., 2006). With only 3 to 5 d prior to parturition, additional secretory cell receptors for growth promotors, hormones, and other biologically active substances (IGF-I, IGF-II, cytokines, subunits of thymosin, lactoferrin, transferrin, xanthine oxidase, and lactoperoxidase) are fully active. With approximately 2 d prior to parturition, the hormonal balance shifts towards an increase in prolactin and glucocorticoid, which override the inhibitory influence of progesterone on the secretory cells (Erb, 1976). Thus, copious amounts of milk synthesis and secretion is initiated.

Quality colostrum contains high dry matter (18.5 to 25.0 %), high protein (10.0 to 17.3 %, primarily IgG_1), low lactose (1.7 to 2.7 %), high milk fat (4.1 to 7.6 %), and high concentrations of growth promotors, hormones and biologically active substances as previously listed (Jaster, 2005; Georgiev, 2005; Kehoe et al., 2007; Foley and Otterby, 1978; Blum and Hammon, 2000; Tsioulpas et al., 2007; Zhelev, 2011). Colostrum not harvested in a relatively short period of time will result in a more dilute substance due to increasing milk synthesis and secretion as well as reabsorption of much of the biologically active substances. A marked reduction in colostrum quality can be measured within the first 6 to 10 h postpartum (Moore et al., 2005).

Zhelev (2011) reviewed several variables influencing the quality of colostrum including: harvest time and conditions, storage, handling and packaging prior to feeding, and pasteurization. Feeding practices and use of additives also significantly influence the ability of the calf to absorb antibody and other critical biologically active substances. Biological and environmental contaminants also negatively impact the quality of colostrum available to the newborn calf (McGuirk and Collins, 2004; Stewart et al., 2005).

The scientific community of animal scientists has been expounding the virtues of colostrum quality and its impact on calf survival, morbidity, growth, and productivity since the late 1800s. Timely and adequate colostrum intake significantly improves morbidity, mortality, growth rate, and feed efficiency in pre-weaned dairy calves (Robison et al., 1988). The positive impact of a successful colostrum feeding program has also been measured in the first lactation production of dairy heifers (DeNise et al., 1989; Faber et al., 2005). The impact of colostrum quality and successful transfer to the newborn is so significant that professional careers have been made evaluating its role in production livestock and yet still today, the industry has not mastered the task of harvesting and feeding colostrum to insure adequate transfer of antibody and other critical biological substances in dairy calves. Zhelev (2011) measured colostrum quality in seven Central California dairies over a 1 yr period and found the average colostral IgG_1 to be 35.96 ($\pm$ 16.13) mg/ml. This study further identified a failure to adequately transfer antibody at a rate of 36.26 % in dairy heifers. If the prized replacement heifer calf transfer rates are this low, imagine what the real transfer rates in bull calves are.

What would be the colostrum quality, quantity, and successful transfer rates if dry cows were not overcrowded, they were not housed in poor pen conditions, they were not fed poor quality feed, their diets were nutritionally balanced, they had optimal dry matter intakes (**DMI**) , they were not pathogen laden, and/or they were not over- or under-conditioned? What then would the outcome for performance and productivity be in dairy replacement heifers and feedlot steers? Yet in spite of its failings, the industry has found a way to thrive in successfully raising dairy replacements and feedlot steers. The calf rearing industry has worked extensively to devise management protocols designed to support the neonate through a somewhat difficult transition from *in utero* existence to a successful productive life. While there are many, many variables to consider in successfully raising calves, the following discussion will focus on the nutrient aspects of calf rearing.

NUTRIENT REQUIREMENTS

The primary focus of a successful neonatal calf program after the establishment of circulating antibody and immune system stimulation should be on the establishment of a dietary regime capable of sustaining growth and development. The nutritional inputs must reflect the maintenance and growth and development requirements for energy, protein, vitamins, minerals, and water. In order to attain optimal performance and productivity, this diet must be palatable and must supply these nutrients at levels parallel to the growth and development potential of the calf.

Feeding dairy calves for performance requires that the feeding and management program stay focused on the end goal with a clear understanding of requirements to achieve growth and developmental progress at each phase from beginning to end. For example, the newborn dairy heifer from birth to a mature level of lactation and productive life parallel to its genetic potential. Nutrition and management programs should vary with respect to the expectations of the end goal. For example, growth and development rates for young heifers destined for early age at first freshening would differ from those targeting a more traditional age at first freshening. Likewise, feeding and management of dairy steers for a lighter harvest weight versus a heavier harvest weight would differ.

The calf rearing industry has somewhat successfully invested heavily in strategies designed to keep calves alive and moderately protected against stressors and pathogenic organisms. However, the very foundation for maintaining optimal growth and development, nutrition, has been significantly reduced in its importance and attention. The emphasis has been on establishing immune protection via colostral antibody transfer, vaccination of cows and calves, feeding antibiotics and direct fed microbials to combat the establishment of pathogenic populations, and feeding regimes designed to minimize scouring and digestive upsets. The accelerated programs for feeding have proven to be successful in accomplishing enhanced growth and development and perhaps even knocking on the door of attaining genetic potential. However, as exciting as these accelerated programs are, they have still not been widely accepted commercially. Perhaps the resistance to their acceptance is economic driven.

NRC, 2001 identifies the energy and protein requirements for young dairy calves during the milk feeding program. Table 1 lists the energy and protein requirements as adapted from NRC, 2001. Given the approximate calf weight and expected daily

Table 1. Energy and protein requirements for milk and starter fed calves.

Weight lb	ADG lb / d	DMI lb / d	ME Mcal / d	CP lb / d
65	0.44	0.926	1.77	0.185
	.88	1.235	2.49	0.311
85	0.88	1.455	2.76	0.326
	1.32	1.830	3.44	0.452
110	1.32	2.073	3.89	0.467
	1.76	2.492	4.69	0.595
130	1.32	2.293	4.31	0.478
	1.76	2.734	5.16	0.606

gain, the DMI, daily metabolizable energy (**ME**) in Mcal, and crude protein (**CP**) required is calculated for young calves consuming milk or milk replacer and a starter grain mix. The requirements assume the daily DMI to be a combination of 60 % from milk or milk replacer and 40 % from the starter grain mix. It also assumes the milk replacer to provide 2.111 Mcal/lb DM ME and the starter grain to provide 1.457 Mcal/lb DM ME. While these calculations may reflect the approximate expected daily gains when fed these levels of energy and protein, they do not represent the genetic potential for growth of the calves. Calves fed to attain the lower expected performance levels are often more susceptible to environmental and pathological stressors.

The requirements for CP have been determined based on these diets containing higher digestible milk proteins and caution is given for use of these requirements when feeding alternative proteins which have a lower digestibility (NRC, 2001).

The requirements presented in Table 1 also represent those of calves fed in their thermoneutral zone with no apparent requirement for conserving or dissipating body heat. The effective thermoneutral zone varies with respect to age, DMI, subcutaneous fat, and length and thickness of hair coat. When the ambient temperature drops below or exceeds the thermoneutral zone, maintenance energy requirement is increased (NRC, 2001). Table 2, as adapted from NRC (2001), represents the effect of temperature on the maintenance energy requirement of a 100 lb calf.

NUTRIENT CONTENT

Natural whole milk is the optimal nutrient package for the rearing of young dairy cattle and as such, should be held as the standard in comparing alternative milk feeding programs. The utilization of alternatives to milk in feeding young calves is simply a reflection of the economics of the value of saleable whole milk versus the value of milk alternatives. However, true value often becomes mistakenly reduced to simply the cost of the ingredient and not the actual nutritive economic value of the ingredient.

Table 2. Environmental effect on energy requirement of young calves (100 lb calf).

Environmental Temperature	Maintenance Requirement 0 to 3 Weeks	Increase in ME Required Base = 68 °F	Maintenance Requirement > 3 Weeks	Increase in ME Required Base = 50 °F
°F	Mcal / d	Mcal / d	Mcal / d	Mcal / d
68	1.735	0	1.735	0
59	1.969	0.234	1.735	0
50	2.203	0.468	1.735	0
41	2.437	0.702	1.969	0.234
32	2.671	0.936	2.205	0.468
23	2.905	1.170	2.437	0.702
14	3.1.9	1.404	2.671	0.936
5	3.373	1.638	2.905	1.170
-4	3.607	1.872	3.139	1.404
-13	3.834	2.099	3.373	1.638
-22	4.066	2.331	3.607	1.872

Calf grain mixes are relatively variable as to ingredients and textures. There tends to be more scrutiny given to the nutritive value of grain ingredients than there is to milk ingredients. Much like milk ingredients, there is a somewhat limited list of acceptable feeds utilized in formulating calf grains. Common issues between milk and grain ingredients fed to calves are: limited DMI, palatability, and digestibility in a maturing digestive tract. These factors tend to limit the feeds qualified to be included in calf diets.

The following data and comparisons represent a compilation of results from diets fed to calves over an approximately 12 yr period and are offered to illustrate the point of this discussion. Table 3 is a comparison of the nutrient content of three common milks fed to young calves.

Table 3. Comparative nutrient content of milk ingredients fed to calves (100 % dry basis).

Ingredient	$/lb DM	% DM	% CP	% Fat	% Lactose	ME (Mcal / b)
Whole milk	1.420	12.61	25.693	29.104	37.351	2.367
Waste milk	0.509	10.42	26.488	26.697	33.589	2.243
Milk replacer	1.167	96.00	22.000	20.000	38.000	1.938

While the nutrient profile of the waste milk appears to be similar to that of whole milk, it is important to note a wide variability in DM, CP, fat, and lactose exists with waste milk. In addition, the proteins found in waste milk tend to be more variable with considerably less casein present.

Table 4 is an adaptation of energy, CP, and ether extract values of various milk ingredients as reported in NRC, 2001. Commercial *all milk* milk replacers use various blends of these ingredients depending upon availability and price. It is significant to note the variation in energy values as well as consider the variability in biological value of the proteins.

Table 4. Energy, protein, and ether extract values of common milk ingredients (100 % DM basis).

	GE	DE	ME	NE_m	NE_g	CP	EE
Ingredient	---------	------------	Mcal / lb	-------------	----------	% of	DM--------
Whole milk	2.522	2.447	2.349	2.020	1.622	25.4	30.8
Skim milk, fresh	1.955	1.900	1.823	1.569	1.256	35.5	0.3
Skim milk, powder	1.986	1.927	1.850	1.591	1.279	37.4	1.0
Whey Powder	1.778	1.723	1.655	1.424	1.143	13.5	1.0
Whey Protein Conc	2.032	1.973	1.891	1.628	1.306	37.1	2.2
Casein	2.472	2.399	2.304	1.982	1.587	92.7	0.7

Table 5. Energy and protein intake relative to NRC, 2001 estimated requirements for an 88 lb Holstein calf fed starter grain and whole milk, waste milk, or milk replacer (22/20).

	DMI		ME		CP	
Diet	lbs / d	+ /-	Mcal / d	+ / -	lbs / d	+ / -
NRC est. milk	1.098		2.318		0.320	
NRC est. starter	0.732		1.066		0.132	
Whole milk	1.084	-0.014	2.786	+0.468	0.302	-0.018
Waste milk	0.896	-0.202	1.801	-0.517	0.213	-0.107
Milk replacer (22/20	0.960	-0.138	1.786	-0.532	0.203	-0.117

The information in Table 5 offers a comparison of three milk feeding programs, whole milk, waste milk, and milk replacer fed to an 88 lb calf with expected daily gain of 1.32 lb and within the thermoneutral zone. Milk diets are fed at a rate of 1 gal/d and milk replacer is blended at 1 lb in 1 gal of water, all with a starter grain intake of 0.732 lb DM /d. The nutrient contents for the whole milk, waste milk, and milk replacer are derived from data presented in Table 3. These diets are typical of feeding programs in the industry.

It is difficult to attain a starter grain intake of 0.732 lb DM in 1 to 2 wk old calves on a large commercial basis. Milk replacer will often be fed at a *standardized solids* content of 12 to 14 % which may be beneficial, may disrupt the balance of energy, protein, vitamins, and minerals, and may lead to scouring in very young calves. The waste milk is also typically *standardized* with respect to total solids content and not balanced for nutrient content; and thus may lead to digestive upsets and poor performance.

Table 6 is a compilation of data from diets fed over the previous 12 yr from multiple calf ranches in the Western United States at various times of the year. While it is difficult to make direct comparisons due to the many variables involved in this data set, it is interesting to note the apparent favorable trend towards a combination of waste milk and blended milk ingredients. While not quantified in this data set, the general consensus among calf feeders was that as calves were fed higher amounts of milk nutrients, morbidity and mortality were reduced and antibiotic usage was less.

Table 6. Average dry matter, energy, and protein intakes with performance data for various milk feeding programs of dairy calves compiled over 12 yr

Diet	DMI	ME Mcal/d	CP lb / d	$ / lb	Days on Feed	ADG lb	COG $ / lb
Whole milk	1.209	3.464	0.302	0.179	51		
Calf grain	2.242	3.251	0.404	0.143	65	1.81	0.875
Waste milk	21.048	2.464	0.291	0.053	54		
Calf grain	2.084	3.102	0.375	0.146	68	1.58	0.541
Milk replacer	1.224	2.904	0.292	1.120	56		
Calf grain	1.869	2.718	0.336	0.145	74	1.37	0.921
Custom blend	1.302	3.612	0.359	0.091	52		
Calf grain	2.127	2.829	0.383	0.146	66	1.71	0.595

CONCLUSIONS

The benefits of an excellent colostrum management program are paramount in assisting dairy calves in reaching their genetic potential. However, the reality of managing these calves in an industry with greater than 36 % failure in passive transfer of antibody forces the industry to emphasize those variables that they can control after the first 24 h of life. Nutrient feeding programs can be managed relatively easily and economically. Through a better understanding of the nutrients required and the nutrients available, nutrient management programs can be implemented to more closely reach the desired performance levels of dairy cattle. The focus, must thus remain on the available nutrients and the end results desired. Feeding cheap may be the most expensive way to raise calves.

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