DEVELOPING A QUALITY HEIFER: MANAGEMENT, ECONOMIC AND BIOLOGICAL FACTORS TO CONSIDER

M. E. Van Amburgh and F. Soberon, Department of Animal Science, Cornell University, Ithaca, NY

TAKE HOME MESSAGES

1. The pre-weaning period is a period of life where the calf is undergoing significant developmental changes and this development is directly linked to future productivity in the first and subsequent lactations.
2. Pre-weaning growth rate and primarily protein accretion appears to be a key factor in signaling the tissue or communication process that enhances life-time milk yield.
3. Anything that detracts from feed intake and subsequent pre-weaning growth rate reduces the opportunity for enhanced milk yield as an adult.
4. Nutrient supply, both energy and protein are important and protein quality and digestibility are essential.
5. There are no substitutes for liquid feed prior to weaning that will enhance the effect on long-term productivity.
6. Factors other than immunoglobulins in colostrum modify feed intake, feed efficiency and growth of calves and can enhance the effect of early life nutrient status.
7. As an industry and as nutritionists we need to talk about metabolizable energy and protein intake and status relative to maintenance and stop talking about cups, quarts, gallons, buckets and bottles of dry matter, milk, milk replacer etc. The calf has discrete nutrient requirements not related to dry matter and liquid volume measurements.
8. The effect of nurture is many times greater than nature and the pre-weaning period is a phase of development where the productivity of the calf can be modified to enhance the animal's genetic potential.

LACTOCRINE HYPOTHESIS: COLOSTRUM'S ROLE

It has been well recognized that the phenotypic expression of an individual is affected by both genetic ability as well as environment. The environment contains multiple external signals that affect the development and expression of the genetic composition of an animal. While in the uterus, the mother controls the environment in which the fetus is developing, influencing in this way the expression of the genetic material and there is good evidence that the environment can play a role in long-term productivity in beef cattle (Summers and Funston, 2012). The effect and extent of maternal influence in the offspring's development does not end at parturition, but continues throughout the first weeks of life through the effect of milk-born factors, including colostrum, which have an impact in the physiological development of tissues and functions in the offspring. This concept has been recently described as the "lactocrine hypothesis" (Bartol et al., 2008). Conceptually, this topic is not new but the terminology is useful and the ability of several groups to make a direct connection from a factor in milk to a developmental function at the tissue or behavior level is significant (Nusser and Frawley, 1997; Hinde and Capitanio, 2010). Data relating to this topic has been described and discussed by others in neonatal pigs (Donovan and Odle, 1994; Burrin et al., 1997) and calves (Baumrucker and Blum, 1993; Blum and Hammon, 2000; Rauprich et al. 2000). The implication of this hypothesis and these observations are that the neonate can be programmed maternally and post-natally to alter development of a particular process.

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 suggest we can still make improvements (Godden, 2008). Until recently, the primary reason colostrum has been of interest in neonatal ruminants is due to the

importance of supplying Ig's to calves born without any and lacking a mature immune system (Weaver et al., 2000). Thus, without sufficient levels of Ig's, morbidity and mortality rates are increased. While Ig's are important, colostrum provides the newborn calf with much more than Ig's. There is an abundance of literature describing some of these other factors in colostrum and the role these compounds can have in the development of the calf, especially the role of colostrum components on energy metabolism (Hammon et al. 2012).

Colostrum, in comparison with milk, is known to be rich in immunoglobulins (60x cow), as well as hormones and growth factors such as relaxin (>19x pig), prolactin (18x cow), insulin (65x cow), IGF-1 (155x cow), IGF-2 (7x cow), and leptin (90x humans) (Odle et al., 1996; Blum and Hammon, 2000; Wolinski et al., 2005; Bartol et al., 2008) among many other factors that have biological activity in the neonate. For a long period of time, colostrum has been known to have a major effect on the development of the gastrointestinal tract, but the exact mechanisms are still not well understood. During the first few days of life in neonatal piglets, a notable increase in the length, mass, DNA content, and enzymatic activities of certain enzymes (lactase) occurs in the small intestine for neonates fed colostrum/milk versus a control of water (Widdowson et al. 1976, Burrin et al., 1994). This was originally thought to be mediated by differences in nutrient intake between milk and water (Burrin et al. 1992). However, other studies have demonstrated differences between animals fed colostrum that is rich in growth factors, versus milk with comparable energy values (Burrin et al., 1995).

Of interest are the studies that have described decreased growth rate and increased morbidity of calves with low serum immunoglobulin status (Nocek, et al., 1984; Robinson et al., 1988) and have demonstrated that milk yield during first lactation can be affected (DeNise et al., 1989) by this effect. Robinson et al. (1988) demonstrated 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., (1989) demonstrated that for each unit of serum IgG concentration, measured at 24 to 48 hr after colostrum feeding, above 12 mg/mL, there was an 8.5 kg increase in mature equivalent milk. The implication was that calves with lower IgG concentration in serum were more susceptible to immune challenges which impacted long term performance.

Some of the other components in colostrum, such as insulin, IGF-I, relaxin and other growth factors and hormones, are important factors in developmental processes; likewise, a lack or shortage of them in early life might alter developmental functions, leading to a change in nutrient utilization and efficiency (Hammon et al. 2012). To examine this concept, Soberon and Van Amburgh (2011) examined the effect of colostrum status on pre-weaning ADG and also examined the effects of varying milk replacer intake after colostrum ingestion. Calves were fed either high levels (4 liters) or low levels (2 liters) of colostrum, and then calves from these two groups were subdivided into two more groups being fed milk replacer at limited amounts or ad libitum. In this study, none of the calves exhibited failure of passive transfer. Comparing calves fed 4 liters of colostrum and ad libitum intake of milk replacer versus 2 liters of colostrum and ad libitum intake of milk replacer, calves fed the 4 liters of colostrum demonstrated an 8.5% increase in milk replacer intake, an 18% increase in pre-weaning ADG, a 12% increase in post-weaning feed intake, and a 25% increase in post-weaning ADG through 80 days of life, indicating that colostrum potentially affects appetite regulation, which enhances growth and possibly feed efficiency (Table 1). Therefore, it can be logically concluded that if colostrum induces changes in feed efficiency, then the first feeding can also potentially affect future milk production.

To further this concept, data from Steinhoff-Wagner et al. (2010) examined the effects colostrum has on the ability of neonates to regulate glucose, through both exogenous absorption and endogenous production. The results of this study demonstrated that calves fed colostrum had significantly higher plasma circulating glucose levels in comparison to formula fed calves, however the gluconeogenic ability did not differ between the two groups. This suggests that in colostrum-fed calves glucose absorption capacity are increased in comparison to milk-replacer fed calves, as mentioned above. These results were verified by significantly higher postprandial glucose concentrations, and ensuing higher insulin concentrations, in colostrum fed versus milk replacer fed calves. During post-prandial periods, colostrum-fed calves had higher liver glycogen concentrations and g6pase activities, indicating better glucose and galactose hepatic absorption. This has implications for lactose digestion and absorption. First pass uptake of [U-^{13}C]-glucose, or the glucose utilization in splanchnic tissue (intestine and liver), was lower

in colostrum fed calves than milk replacer fed calves. This indicates that glucose was either less absorbed or more utilized in splanchnic tissue in formula-fed calves, resulting in lower percentage use in colostrum-fed calves. Additionally, [U-13C]-glucose concentration was significantly higher in calves fed colostrum over milk-replacer, similar to the xylose absorption data presented earlier. Again, this supports the idea that glucose absorption is enhanced in colostrum-fed calves versus milk-replacer fed calves. Finally, plasma glucose concentrations were significantly higher in calves fed colostrum during feed deprivation of 15 hours and plasma urea concentrations were significantly higher in formula-fed calves. This suggests that calves fed colostrum had higher glycogen concentrations and did not utilize protein catabolism. If the glucose uptake differences were to persist, it would help us understand the role of factors in colostrum other than Ig's important for long-term productivity.

Table 1. Effect of high (4+2 L) or low (2L) colostrum and ad-lib (H) or restricted (L) milk replacer intake on feed efficiency and feed intake in pre and post-weaned calves (Soberon and Van Amburgh, 2011).

Treatment[1]	HH	HL	LH	LL	Std dev
N	34	38	26	27	
Birth wt, kg	44.0	43.4	41.8	43.3	0.95
Birth hip height, cm	80.5	80.3	80.0	80.9	0.56
IgG concentration, mg/dl*	2,746^{a}	2,480^{b}	1,466^{c}	1,417^{c}	98
Weaning wt, kg	78.2^{a}	63.5^{b}	72.2^{c}	62.4^{b}	1.89
Weaning hip height, cm	93.0^{a}	88.6^{b}	91.5^{a}	89.6^{b}	0.60
ADG pre-weaning, kg	0.79^{a}	0.42^{b}	0.67^{c}	0.39^{b}	0.028
Hip height gain, pre-weaning, cm/d	0.248^{a}	0.158^{b}	0.227^{a}	0.161^{b}	0.009
ADG birth to 80 d, kg	0.78^{a}	0.59^{bc}	0.66^{b}	0.53^{c}	0.034
Hip height gain, birth to 80 d, cm/d	0.214^{a}	0.157^{b}	0.184^{c}	0.148^{b}	0.008
Total milk replacer intake, kg DM	44.4^{a}	20.5^{b}	40.9^{c}	20.0^{b}	1.2
Grain intake pre-weaning, kg	2.5^{a}	12.0^{b}	2.1^{a}	9.7^{b}	1.5
ADG/DMI, pre-weaning	0.60	0.61	0.67	0.61	0.042
ADG post-weaning, kg	1.10^{a}	0.97^{ab}	0.88^{b}	0.92^{b}	0.061
DMI post-weaning, kg/d	2.89^{ab}	2.89^{a}	2.58^{c}	2.66^{bc}	0.104
ADG/DMI post-weaning	0.359	0.345	0.335	0.358	0.020

[1]HH = high colostrum, high feeding level, HL = High colostrum, low feeding level, LH = Low colostrum, high feeding level, LL = Low colostrum, low feeding level. Rows with different superscripts differ P < 0.05.

From an on farm perspective, standardization or evaluation of colostrum with a refractometer to ensure the appropriate solids or protein content is also important. Using a calibrated Brix refractometer, a minimum of 22% Brix provides good sensitivity and specificity for Ig levels for fresh and frozen colostrum above 50 mg/mL (Bielmann et al., 2010). Thus, anything above 22% is adequate for the first feeding for calves and anything below 22% should be reserved for later feedings. Finally, to determine total solids with a Brix refractometer, the Brix value needs to be converted. An equation from Moore et al. (2009) can be used to do this effectively, and the equation is: percent total solids = 0.9984 x (Brix%) + 2.077. Given the regression coefficients, a quick calculation is Brix% + 2 units. An evaluation of the use of a Brix refractometer was recently published by Quigley et al. (2012) and they suggested a cut point of 21% was appropriate for their data.

Also, colostrum is the first meal and accordingly is very important in establishing the nutrient supply needed to maintain the calf over the first day of life. The amount of colostrum is always focused on the idea we are delivering a specific amount of immunoglobulins (Ig's) to the calf, and many times we underestimate the nutrient contribution of colostrum. Further, many times of year, we tend to underestimate the nutrient requirements of the calf, especially for maintenance. For example, a newborn Holstein calf at 85 lbs birth weight has a maintenance requirement of approximately 1.55 Mcals ME at 72 °F. Colostrum contains approximately 2.51 Mcals metabolizable energy (ME)/lb, and a standard feeding rate of 2 quarts of colostrum from a bottle contains about 1.5 Mcals ME. Thus, at thermoneutral conditions, the calf is fed just at or slightly below maintenance requirements at its first feeding. For comparison, if the ambient temperature is 32 °F the ME requirement for maintenance is 2.4 Mcals, which can only be met if the calf is fed approximately 1 lb of DM or about 3.5 quarts of colostrum. This simple example illustrates one of the recurring issues with diagnosing growth and health problems with calves and that is the use of volume measurements to describe nutrient supply instead of discussing energy and nutrient values. Two quarts of colostrum sounds good because that is what the bottle might hold, but it has little to do with the nutrient requirements of the calf.

Managing the calf for greater intake over the first 24 hours of life is important if we want to ensure positive energy balance and provide adequate Ig's and other components from colostrum

for proper development. For the first day, at least 3 Mcals ME (approximately 4 quarts of colostrum) would be necessary to meet the maintenance requirements and also provide some nutrients for growth. On many dairies this is done via an esophageal feeder and the amount dictated by the desire to get adequate passive transfer. Those dairies not tube feeding should be encouraging up to 4 quarts by 10 to 12 hours of life to ensure colostrum is fed not only to meet the Ig needs of the calf, but also to ensure that the nutrient requirements are met for the first day of life.

NUTRIENT STATUS AND LONG-TERM PRODUCTIVITY

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

In the study conducted at Miner Institute, Ballard et al. (2005), reported that at 200 days in milk, the calves fed milk replacer at approximately twice normal feeding rates produced 1,543 pounds milk more than the calves that received one pound of milk replacer powder per day. Calving age in that study was not affected by treatment. Overall, averaging the studies, there is a 1,500 pound 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. (2005) and Moallem et al. (2010) are significant, specifically because 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, post-weaning the calves were fed similarly until 150 days of gain, and the diets were protein deficient (~13.5% CP). Starting at 150 days calves from both pre-weaning treatments were supplemented with 2% fish meal from 150 to 300 days of life. The calves allowed to consume the whole milk (ad libitum for 60 minutes) and supplemented with the additional protein produced approximately 1,700 pounds 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. (2007) 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 and then 2.5% of the BW from week 2 to 5 and then systematically weaned by dropping the milk replacer intake to 1.25% of the BW for 6 days and then no milk replacer. All calves were weaned by 7 weeks of age and after weaning all calves were managed as a single group and bred according to observed heats. The heifers calved between 24 and 26 months of age with no significant difference among treatments. Calving BW were also not different and averaged 1,278 lb. Milk yield on average was 1,841 pounds greater for calves fed the higher level of milk replacer prior to weaning.

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 to this unique is the application of a Test Day Model (TDM) (Everett and Schmitz. 1994; Van Amburgh et al., 1997) for the analyses of the data. This approach allows us to statistically control for factors not associated with the variables of interest and is the same approach that has been used to conduct sire summaries and daughter evaluations and develop heritabilities for genetic traits. Thus, the outcome is mathematically more robust and 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 analyses is much more significant compared to

comparing daily milk or even ME305 milk and helps us partition out variance not associated with the variables of interest.

Table 1. Milk production differences among treatments where calves were allowed to consume more nutrients than the standard feeding rate prior to weaning from milk or milk replacer.

Study	Milk yield, lb
Foldager and Krohn, 1991	3,092
Bar-Peled et al., 1998	998
Foldager et al., 1997	1,143
Ballard et al., 2005 (@ 200 DIM)	1,543
Shamay et al., 2005 (post-weaning protein)	2,162
Rincker et al., 2006 (proj. 305@ 150 DIM)	1,100
Drackley et al., 2007	1,841
Raith-Knight et al., 2009	1,582
Terre et al., 2009	1,375
Morrison et al., 2009 (no diff. calf growth)	0
Moallem et al., 2010	1,600
Soberon et al., 2012	1,217
Margerison et al., 2013	1,311
Kinzelback et al. 2015 (little diff. calf growth through entire phase)	0

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 (Soberon et al., 2012). The factors analyzed were birth weight, weaning weight, height at weaning, BW at 4 weeks of age and several other related and farm measurable factors. 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 1. In our data set, for every 1 pound of average daily gain (ADG) prior to weaning (or at least 42 to 56 days of age), the heifers produced approximately 937 pounds more milk ($P < 0.01$) (Table 2). The range in pre-weaning growth rates among the 1,244 animals were 0.52 to 2.76 pounds per day and the range was actually quite puzzling to us. Our feeding program at the research farm is straightforward: 1.5% 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 around 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 provide adequate nutrients for growth, even in the winter.

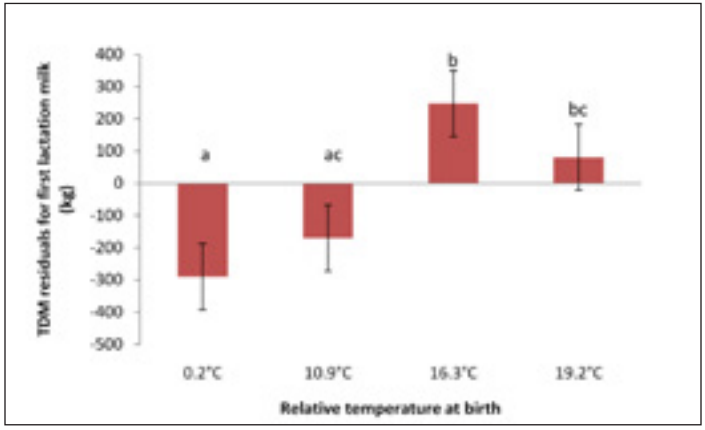


Figure 1. Test Day Model residuals in kg of milk, averaged by temperature at time of birth with mean temperature in Celsius. Columns with different superscripts differ ($P < 0.05$). (Soberon et al. 2012)

However, when we analyzed the TDM residuals by temperature at birth, a very significant observation was made (Figure 1). These data 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 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 2).

These data demonstrate there are programming or developmental 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 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 the management of the calf than genetic selection. Generally, milk yield will increase 150 to 300 lbs per lactation due to selection whereas the effect of management is three to five times that of genetic selection.

Table 2. Predicted differences by TDM residual milk (lb) for 1st, 2nd, and 3rd lactation as well as cumulative milk from 1st through 3rd lactation as a function of pre-weaning average daily gain and energy intake over predicted maintenance for the Cornell herd. (Soberon et al. 2012)

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
1st	1244	850	< 0.01	519	< 0.01
2nd	826	888	< 0.01	239	0.26
3rd	450	48	0.91	775	< 0.01
1st - 3nd	450	2,280	0.01	1,991	< 0.01

In the Cornell herd, the effect of diarrhea or antibiotic treatment on ADG was not significant and ADG differed by approximately 30 g/d 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 g/d ($P < 0.01$). 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 1,086 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 1,373 lb more milk per kg of pre-weaning ADG while calves that did not receive antibiotics produced 3,101 lb more milk per kg 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 (Johnson, 1998; Dantzer, 2006).

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 3 to 4 weeks of life in order to achieve this response.

The papers and data described in Table 1 were analyzed in a meta-analyses to further investigate the impact of nutrient intake and growth rate prior to weaning (Soberon and Van Amburgh, 2012). The analysis excluded Foldager and Krohn, (1991) due to inadequate data and Davis-Rincker et al. (2011) because they did not measure full lactations. The Morrison et al. (2009) study was included in the analysis). The software used was Used Comprehensive Meta Analyses software (www.Meta-Analysis.com) (Borenstein et al. 2005) and the data included were study, treatment size (number of calves) mean milk yield, standard error or deviation, P value and effect direction. The data of Soberon et al. (2012) was initially excluded and then included to test for weighting effects since Soberon et al. contains many hundreds of animals. Inclusion of Soberon et al. did not change the outcome and the data were included in the analyses. The analysis indicated that feeding higher levels of nutrients from milk or milk replacer prior to weaning significantly increased milk yield by 959 ± 258 lb, $P < 0.001$, with a confidence range of 452 to 1,463 lb of milk. Further, if ADG was included as a continuous variable among the data set, the outcome was similar to that of Soberon et al. (2012) where for every pound of pre-weaning ADG, milk yield in the mature animal increased by 1540 lb ($P = 0.001$).

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

this increase in mammary development was not observed once the calves were weaned, indicating the calf is more sensitive to level of nutrition prior to weaning and that the enhancement mammary development cannot be "recovered" once we wean the animal.

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

SUMMARY

Early life events 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 are opportunities to enhance the response once we know and understand those factors. The bottom line is there is a positive economic outcome to improving the management of our calf and heifer programs starting at birth.

REFERENCES

Ballard, C., H. Wolford, T. Sato, K., Uchida, M. Suekawa, Y. Yabuuchi, and K. Kobayashi. 2005. The effect of feeding three milk replacer regimens preweaning on first lactation performance of Holstein cattle. J. Dairy Sci. 88:22 (abstr.)

Bar-Peled, U., B. Robinzon, E. Maltz, H. Tagari, Y. Folman, I. Bruckental, H. Voet, H. Gacitua, and A. R. Lehrer. 1997. Increased weight gain and effects on production parameters of Holstein heifers that were allowed to suckle. J. Dairy Sci. 80:2523-2528.

Bartol, F. F., A. A. Wiley, and C. A. Bagnell. 2008. Epigenetic programming of porcine endometrial function and the lactocrine hypothesis. Reprod. Domest. Anim. 43:273-279.

Baumrucker, C. R., and J. W. Blum. 1993. Secretion of insulin-like growth factors in milk and their effect on the neonate. Livest. Prod. Sci. 35:49-72.

Bielmann V, Gillan J, Perkins NR, Skidmore AL, Godden S, Leslie KE: An evaluation of

Brix refractometry instruments for measurement of colostrum quality in dairy

cattle. J Dairy Sci 2010, 93:3713-3721.

Blum, J. W., and H. Hammon. 2000. Colostrum effects on the gastrointestinal tract, and on nutritional, endocrine and metabolic parameters in neonatal calves. Livest. Prod. Sci. 66:151-159.

Borenstein M, Hedges L, Higgins J, Rothstein H. Comprehensive Meta-analysis Version 2, Biostat, Englewood NJ. 2005)

Brown EG, VandeHaar MJ, Daniels KM, Liesman JS, Chapin LT, Forrest JW, Akers RM,

Pearson RE, Weber Nielsen MS. Effect of increasing energy and protein intake on mammary development in heifer calves.`J Dairy Sci.`2005a;88:595–603

Burrin, D. G., R. J. Shulman, R. J. Reeds, T. A. Davis, and K. R. Gravitt. 1992. Porcine colostrum and milk stimulate visceral organ and skeletal muscle protein synthesis in neonatal piglets. J. Nutr. 122:1205-1213.

Burrin, D. G., M. A. Dudley, P.J. Reeds, R. J. Shulman, S. Perkinson, and J. Rosenberger. 1994. Feeding colostrum rapidly alters enzymatic activity and the relative isoform abundance of jejunal lactase in neonatal pigs. J. Nutr. 124:2350-2357.

Burrin, D. G., T. A. Davis, S. Ebner, P. A. Schoknect, M. L. Fiorotto, P. J. Reeds, and S. McAvoy. 1995. Nutrient-independent and nutrient-dependent factors stimulate protein synthesis in colostrum-fed newborn pigs. Pediatr. Res. 37:593-599.

Burrin, D.D., T.A. Davis, S. Ebner, P.A. Schoknecht, M.L. Fiorotto, and P.J. Reeds. 1997. Colostrum enhances the nutritional stimulation of vital organ protein synthesis in neonatal pigs. J. Nutr. 127:1284-1289.

Daniels, K. M., A. V. Capuco, R. E. James, M. L. McGilliard, and R. M. Akers. 2008. Diet does not affect putative stem cells in pre-weaned Holstein heifers. J. Dairy Sci. 91 (E-Suppl. 1): 121 (Abstr.)

DeNise, S. K., J. D. Robison, G. H. Stott and D. V. Armstrong. 1989. Effects of passive immunity on subsequent production in dairy heifers. J. Dairy Sci. 72:552-554.

Donovan, S. M., and J. Odle. 1994. Growth factors in milk as mediators of infant development. Annu. Rev. Nutr. 14:147-167.

Dantzer, R. 2006. Cytokine, sickness behavior, and depression. Neurol. Clin. 24:441 460.

Drackley, J.K., B. C. Pollard, H. M. Dann and J. A. Stamey. 2007. First lactation milk production for cows fed control or intensified milk replacer programs as calves. J. Dairy Sci. 90:614. (Abstr.)

Everett, R. W., and F. Schmitz. 1994. Dairy genetics in 1994 and beyond. Cow and sire evaluation using test-day records, DairyGene, and DairyView for farm management. Pages 4–39 in Mimeo Ser. No. 170, Cornell Coop. Ext., Cornell Univ., Ithaca, NY.

Foldager, J. and C.C. Krohn. 1994. Heifer calves reared on very high or normal levels of whole milk from birth to 6-8 weeks of age and their subsequent milk production. Proc. Soc. Nutr. Physiol. 3. (Abstr.)

Foldager, J., C.C. Krohn and Lisbeth Morgensen. 1997. Level of milk for female calves affects their milk production in first lactation. Proc. European Assoc. Animal Prod. 48th Annual Meeting. (Abstr.)

Godden, S. 2008. Colostrum management for dairy calves. Vet. Clin. Food Anim. 24:19

-39.

Hammon, H.M., J. Steinhoff-Wagner, U. Schonhusen, C.C. Metges, J.W. Blum. 2012.

Energy metabolism in the newborn farm animal with emphasis on the calf: endocrine changes and responses to milk-born and systemic hormones. Dom. Anim. Endo. 43:171-185.

Hinde, K., and J. P. Capitanio. 2010. Lactational Programming? Mother's milk energy predicts infant behavior and temperament in rhesus macaques (Macaca mulatta). Amer. J. of Primatology. 72:522-529.

Johnson, R. W. 1998. Immune and endocrine regulation of food intake in sick animals. Domest Anim. Endocrinol. 15:309–319.

Jones, C. M., R. E. James, J. D. Quigley, III, and M. L. McGilliard. 2004. Influence of pooled colostrum or colostrum replacement on IgG and evaluation of animal plasma in milk replacer. J. Dairy Sci. 87:1806-1814.

Meyer, M. J., A. V. Capuco, D. A. Ross, L. M. Lintault, and M. E. Van Amburgh. 2006a.

Developmental and nutritional regulation of the prepubertal heifer mammary gland: I. Parenchyma and fat pad mass and composition. J Dairy Sci. 89: 4289-4297.

Meyer, M. J., A. V. Capuco, D. A. Ross, L. M. Lintault, and M. E. Van Amburgh. 2006b. Developmental and nutritional regulation of the prepubertal bovine mammary gland: II. epithelial cell proliferation, parenchymal accretion rate, and allometric growth. J. Dairy Sci. 89:4298–4304

Moallem, U., D. Werner, H. Lehrer, M. Kachut, L. Livshitz, S. Yakoby and A. Shamay. 2010. Long-term effects of feeding ad-libitum whole milk prior to weaning and prepubertal protein supplementation on skeletal growth rate and first-lactation milk production. J. Dairy Sci. 93:2639-2650.

Moore, D. A., J. Taylor, M. L. Harman, and W. M. Sischo. 2009. Quality assessments of waste milk at a calf ranch. J. Dairy Sci. 92:3503–3509

Nocek, J. E., D. G. Braund, and R. G Warner. 1984. Influence of neonatal colostrum

administration, immunoglobulin, and continued feeding of colostrum on calf gain, health and serum protein. J. Dairy Sci. 67:319-333.

Nusser, K. D., and S. Frawley. 1997. Depriving neonatal rats of milk from early lactation has long-term consequences on mammotrope development. Endocrine 7:319-323.

Odle, J., R. T. Zijlstra, and S. M. Donovan. 1996. Intestinal effects of milkborne growth factors in neonates of agricultural importance. J. Anim. Sci. 74:2509-2522.

Overton, M. 2010. Economic comparison of conventional vs. intensive heifer rearing systems. American Association of Bovine Practitioners Pre-Conference Seminar 10, Albuquerque, NM.

Quigley , J. D., A. Lago , C. Chapman , P. Erickson , and J. Polo. 2013. Evaluation of the Brix refractometer to estimate immunoglobulin G concentration in bovine colostrum. J. Dairy Sci. 96:1148–1155.

Rauprich, A. B., H. M. Hammon, and J. W. Blum. 2000. Influence of feeding different amounts of first colostrum on metabolic, endocrine, and health status and on growth performance of neonatal calves. J. Anim. Sci. 78:896-908.

Rincker, L. Davis, M. VandeHaar, C. Wolf, J. Liesman, L. Chapin, and M. Weber Nielson. 2006. Effects of an intensified compared to a moderate feeding program during the preweaning phase on long-term growth, age at calving, and first lactation milk production. J. Dairy Sci. 89:438 (Abstr.)

Robinson, J. D., G. H. Stott and S. K. DeNise. 1988. Effects of passive immunity on growth and survival in the dairy heifer. J. Dairy Sci. 71:1283-1287.

Sejrsen, K., S. Purup, M. Vestergaard, and J. Fodager. 2000. High body weight gain and reduced bovine mammary growth: physiological basis and implications for milk yield. Domes. Anim. Endo. 19:93-104.

Shamay, A., D. Werner, U. Moallem, H. Barash, and I. Bruckental. 2005. Effect of nursing management and skeletal size at weaningon puberty, skeletal growth rate, and milk production during first lactation of dairy heifers. J. Dairy Sci. 88:1460–1469.

Soberon F, E. Raffrenato, R.W. Everett and M.E. Van Amburgh. 2012. Early life milk replacer intake and effects on long term productivity of dairy calves. J. Dairy Sci. 95:783–793.

Soberon, F. and M. E. Van Amburgh. 2011. Effects of colostrum intake and pre-weaning nutrient intake on post-weaning feed efficiency and voluntary feed intake. J. Dairy Sci. 94:E suppl. 1:69. (abstr.)

Steinhoff-Wagner, J., S. Görs, P. Junghans, R. M. Bruckmaier, E. Kanitz, C. C. Metges, and H. M. Hammon. 2011. Intestinal glucose absorption but not endogenous glucose production differs between colostrum- and formula-fed neonatal calves. J. Nutr. 141:48-55.

Summers, A. F. and R. N. Funston. 2012. Fetal programming: implications for beef cattle production. University of Nebraska, West Central Research and Extension Center, North Platte. www.bifconference.com/bif2012/proceedings-pdf/07funston.pdf

Terré, M., C. Tejero, and A. Bach. 2009. Long-term effects on heifer performance of an enhanced growth feeding programme applied during the pre-weaning period. J. Dairy Res. 76:331–339.

Van Amburgh, M. E., D. M. Galton, D. E. Bauman, and R. W. Everett. 1997. Management and economics of extended calving intervals with use of bovine somatotropin. Livest. Prod. Sci. 50:15–28.

Weaver, D. M., J. W. Tyler, D. C. VanMetre, D. E. Hostetler, and G. M. Barrington. 2000. Passive transfer of colostral immunoglobulins in calves. J. Vet. Intern. Med. 14:569-577.

Wolinski, J., M. Biernat, P. Guilloteau, B. R. Weström. 2003. Exogenous leptin controls the development of the small intestine in neonatal piglets. J. Endo. 177:215-222. Widdowson, E. M., V. E. Colombo, and C. A. Artavanis. 1976. Changes in the organs of pigs in response to feeding for the first 24 h after birth. II. The digestive tract. Biol. Neonate 28:272-281.

NUTRITION IN THE POST-WEANED CALF

Tamilee D. Nennich, Ph.D., Dairy Nutrition Specialist, Famo Feeds, Inc.
Tana S. Dennis, Calf and Heifer Specialist, Provimi and Ph.D. Candidate, Purdue University

TAKE-HOME MESSAGES

Proper nutrition of post-weaned heifers is necessary for the continued growth and development of heifers. At young ages, heifers appear to continue to need readily available energy sources as their rumen continues to develop. Realizing that post-weaned heifers are still developing and are not yet ready to be fed like cows facilitates an understanding that specific feeding strategies need to be developed to allow for optimal growth and development of these heifers. Using specific feeding strategies for post-weaned dairy heifers allows them to continue to meet their growth potential while reducing costs per pound of gain and reducing the overall costs of raising dairy heifers.

INTRODUCTION

Nutrition of dairy heifers is often talked about as a whole without referring to the age and growth stage of the heifer. Even though there is a lot of focus placed on feeding milk-fed calves, little research information is available regarding the best strategies for feeding post-weaned dairy heifers. Paying close attending to the diets of post-weaned heifers helps to make sure they are growing at a rate to make sure that they will be ready for breeding and that they are efficiently utilizing the diets they are fed. As feed costs are the greatest expense for raising dairy heifers, nutritional strategies to encourage growth and development while improving feed efficiency will be beneficial for both the animals and heifer raisers.

Nutrition of dairy heifers is often talked about as a whole without referring to the age and growth stage of the heifer. Similar to lactating cows in various stages of lactation, the nutrient requirements of dairy heifers vary substantially during their 2 years of development. Although milk-fed calves have obviously different feed requirements, the nutrient requirements of heifers continue to change, especially over the 6 months after weaning. It is important to keep in mind calves that were recently weaned have different nutrient requirements from year old heifers and, thus, need to be fed differently. Starter intake does help to promote the growth and development of the rumen in calves, but making the assumption that weaned calves are fully functional ruminants is not correct. Therefore, continuing to pay close attention to how post-weaned heifers are fed will allow for the rumen to continue to develop and will maximize the growth and development of these heifers.

FEEDING STRATEGIES FOR POST-WEANED HEIFERS

Feed Delivery Methods for Post-Weaned Heifers

Dietary composition is an important aspect of feeding heifers, but the delivery method can also have an impact when feeding heifers. A study was conducted to evaluate the effects of feeding heifers a total mixed ration (TMR), feeding them concentrate and hay side-by-side in a feed bunk (SBS), or feeding grain in a bunk and hay in a feeder (HF) on growth and intake of post-weaned heifers (Table 1). In this study, heifers fed using HF were significantly heavier ($P \leq 0.05$) than heifers fed using SBS from d 49 throughout the end of the study. Delivering feed using HF resulted in heifers that were, on average, 12.1 lbs and 7.3 lbs heavier than heifers fed using SBS and TMR, respectively, over the course of the study.

Average daily gains varied depending on the time period of the study, as heifers fed using a TMR had lower ADG from d 7 to 14 ($P = 0.05$) and d 14 to 21 ($P = 0.07$) compared with HF and SBS, but higher ADG compared to SBS from d 21 to 28 ($P = 0.03$). These results suggest that post-weaned heifers require more time to adjust to new diets when feeding a TMR compared with component-feeding.

During the grower period, heifers fed using HF averaged 1.1 lbs/d more DMI compared with SBS and TMR ($P < 0.01$). However, heifers fed using a TMR consumed more DMI daily from d 63 to the conclusion of the study. The results of this study suggest that, along with responses in ADG, component-fed heifers maintained intake and weight gains when transitioning to a new diet, while TMR-fed heifers caught up in terms of ADG and efficiency towards the end of the transition period and throughout the grower period. This study indicates that there may be a certain point during the growth of a heifer when it is ideal to be able to switch over to feeding a TMR.

Table 1. Body weight, intake, and skeletal measurements of prepubertal dairy heifers fed common diets using different feed delivery methods.

Item[1]	HF	SBS	TMR	SEM	P-value
Body weight, lb					
d 28[2]	396.5	391.6	387.6	4.45	0.37
d 133	605.3[a]	575.7[b]	575.1[b]	4.45	<0.01
ADG[3], lb/d					
d 0 to 28	2.29	2.09	1.96	0.121	0.21
d 29 to 133	2.05[a]	1.83[b]	1.85[b]	0.064	0.06
d 0 to 133	2.09[a]	1.90[b]	1.87[b]	0.055	0.02
DMI[4], lb/d					
d 0 to 28	9.57	9.08	9.72	0.223	0.15
d 29 to 133	18.04[a]	17.00[b]	16.96[b]	0.209	<0.01
d 0 to 133	16.16[a]	15.26[b]	15.34[b]	0.176	<0.01
Feed efficiency[5]					
d 0 to 28	0.224[a]	0.228[a]	0.188[b]	0.010	0.03
d 29 to 133	0.114	0.111	0.109	0.003	0.58
d 0 to 133	0.124[ab]	0.127[a]	0.115[b]	0.004	0.10

[1]HF = hay feeder; SBS = side-by-side; TMR = total mixed ration; SEM = standard error of the mean.
[2] Day of study.
[3]Average daily gain.
[4]Dry matter intake.
[5]Feed efficiency expressed as lb of ADG per lb of daily DMI.
[ab]Means differ at P < 0.05 level.

Feeding Hay or Ensiled Forages

Forages are an important component of heifer diets. However, little research has looked at how well post-weaned dairy heifers are able to utilize ensiled forages as compared to dry forages. A study was done to evaluate the performance of post-weaned dairy heifers that were fed either dry hay or baleage. In this study (Dennis et al., 2012), heifers fed a diet containing either 40% of their dietary DM as hay or baleage for a 28 d transition period had improved ADG, and the increase in ADG continued when heifers were fed the dry hay at 60% of the dietary DM for an additional 56 d grower period (Table 2). Interestingly, the DMI of the heifers during the transition period was not decreased; thus, the decreased gain was not a result of lesser intakes. During the grower period, the DMI was decreased for heifers fed baleage though there was still an overall tendency for improved feed efficiency for heifers fed dry hay.

Table 2. Body weight, intake, and feed efficiency of prepubertal dairy heifers fed either Hay or Baleage for 28 d Transition Period followed by a 56 d Grower Period (Dennis et al., 2012).

Item[1]	Hay	Baleage	SEM	P-value
Grower Period				
Initial BW, lb	373.5	369.6	3.99	0.47
Final BW, lb	482.2	467.5	4.37	0.02
ADG[3], lb/d	1.39	1.23	0.044	0.04
DMI[4], lb/d	12.5	11.9	0.15	<0.01
NDF Intake,	5.78	5.71	0.035	0.25
Feed efficiency[5]	0.113	0.107	0.002	0.06

[1]Hay or Baleage fed at 40% of diet DM in the Transition Period and 60% of diet DM in the Grower Period.
[2]Body weight.
[3]Average daily gain.
[4]Dry matter intake.
[5]Feed efficiency expressed as lb of ADG per lb of daily DMI.

The results of this study indicate that feeding ensiled forages to post-weaned dairy heifers may result in decreased feed efficiency. In this study, the heifers fed hay were apparently able to better utilize the forage in their diet. Although measurements of rumen development were not determined in this study, it may be possible that the rumen of the post-weaned heifers was still undergoing development and the ensiled forage was not able to be fully utilized at that point in their development.

Grain and Forage Ratios

In most dairy systems today, calves are fed ad libitum amounts of palatable grain-based starters within a few days of birth. As calves grow, they continue to increase their starter intake until they are to the point where they are able to consume enough nutrients from the starter to support their growth without consuming milk. Once calves are weaned, their starter intake continues to increase substantially to make up for the nutrients that are no longer being consumed through milk and to cover the increased nutrient needs of the calf as they continue to grow. The timing as to when calves should begin to receive forage, the type of forage they should receive, and how much of that forage they should be given is still of some debate.

Research was conducted at Purdue University to look at different grain to forage ratios to help determine the best strategy for feeding post-weaned dairy heifers. Heifers began the study when they were approximately 330 lbs and 4.5 months of age and were assigned to diets containing either 80, 60, or 40% concentrate (on a DM basis) for 56 days before abruptly being switched to a common diet that was 40% concentrate.

In this study, increasing grain inclusion from 40 to 80% of the dietary DM resulted in a linear increase in BW and greater overall ADG (Table 3). Frame growth exhibited similar responses to those observed for BW and ADG. Hip heights, heart girth circumference, and body condition score linearly increased with increasing grain inclusion ($P < 0.01$) during the treatment period, resulting in higher growth overall during the study for heifers fed 80% grain during the treatment period.

Feed costs per lb of DMI averaged $0.11, $0.12, and $0.13 for heifers fed 40:60, 60:40, and 80:20, respectively, during the treatment period. Feed costs per lb of ADG were lowest for 60:40 heifers over the duration of the study compared to heifers fed 40:60, though they were statistically similar to the feed costs for the 80:20 heifers. When heifers were fed 60:40 or 80:20 during the treatment period, savings were $0.24 and $0.22 per lb of ADG compared to heifers fed 40:60.

This study demonstrated that feeding higher grain levels to post-weaned dairy heifers can improve growth and can actually decrease the cost of gain over higher forage diets. In addition, it reinforced that heifers fed high grain levels can be negatively impacted by abrupt changes to higher forages diets, with the heifers on the 80:20 treatment showing a definite decline in intake when they were switched to a 40:60 diet that took some time to recover from.

Table 3. Weight, skeletal measurements, and intake responses of prepubertal dairy heifers fed increasing levels of grain during the treatment period then switched to a common diet.

Item[1]	40:60	60:40	80:20	SEM	P-value
Body weight, lb					
d 57[2]	369.2[c]	398.6[b]	428.8[a]	6.01	< 0.01
d 112	476.1[c]	504.7[b]	524.9[a]	6.03	< 0.01
ADG[3], lb/d					
d 0 to 56	1.37[c]	1.87[b]	2.29[c]	0.088	< 0.01
d 57 to 112	1.94[a]	1.92[a]	1.72[b]	0.064	0.07
d 0 to 112	1.65[c]	1.90[b]	2.07[a]	0.042	< 0.01
DM intake, lb/d					
d 0 to 56	9.3[c]	10.7[b]	12.7[a]	0.198	< 0.01
d 57 to 112	14.3	14.1	13.7	0.291	0.31
d 0 to 112	11.8[c]	12.4[b]	13.2[a]	0.165	< 0.01
Feed efficiency[4]					
d 0 to 56	0.147[c]	0.178[b]	0.196[a]	0.008	< 0.01
d 57 to 112	0.136	0.139	0.128	0.005	0.31
d 0 to 112	0.142[b]	0.158[a]	0.161[a]	0.004	0.02
Hip height, in					
d 56	43.7[c]	44.4[b]	45.1[a]	0.13	< 0.01
d 112	45.8[c]	46.8[b]	47.2[a]	0.13	< 0.01

[1]Grain:forage ratio.

[2]Day of study.

[3]Average daily gain.

[4]Feed efficiency expressed as lb of ADG per lb of daily DM intake.

[abc]Means with differing superscripts are significantly different at $P \leq 0.05$ level.

[xy]Means tend to differ at $0.10 \geq P > 0.05$ level.

Non-Fiber Carbohydrates in Heifer Diets

Even though previous research found that feeding higher concentrate diets improved gain and feed efficiency, the concentrate portion of the diet may be made up of a wide variety of different ingredients and nutrient compositions. Understanding the best strategies for designing the concentrate portion of the diet could further help to improve the gains and feed efficiency of dairy heifers.

In order to evaluate the effects of the composition of the concentrate portion of the diet on heifer growth, intake, and feed efficiency, studies were conducted to look at the effects of feeding concentrates that were formulated to provide either high or low levels of non-fiber carbohydrates (NFC). In the first study, heifers (averaging 320 lbs and 4.8 months of age at the start of the study) were fed a low NDF diet (LNFC), a high NFC diet (HNFC), and a low NFC diet with added fat (LNFC+) formulated to provide the same amount of Mcals of energy as the HNFC diet.

Heifers fed LNFC+ were heavier on d 56 and d 112 of the study compared to heifers fed LNFC. Heifers on the HNFC diet were intermediate and tended to be lighter on d 56 and d 112 compared to heifers fed LNFC+. Overall, heifers fed LNFC+ gained 19.4 lbs more BW than heifers fed LNFC during the study ($P = 0.05$). Average daily gain in the first 56 d was 14.9% and 8.9% greater for heifers fed LNFC+ compared to heifers fed LNFC ($P < 0.01$) or HNFC ($P = 0.05$), respectively. During the first 56 d, treatment tended to affect feed efficiency (FE), as heifers fed LNFC+ were 12.7% more efficient than heifers fed LNFC and 9.3% more efficient than heifers fed HNFC, with a trend ($P = 0.07$) towards improved feed efficiency for LFC+ from d 0 to d 112 as compared to HNFC.

During the NFC study, heifers fed LNFC maintained the lowest cost per heifer/d throughout the study as was expected due to the high inclusion rates of by-product feeds. However, feed costs per lb of ADG were lowest for heifers fed LNFC+ compared to HNFC, resulting in a cost savings of $0.12 per lb of gain. However, feed costs per lb of ADG were similar among treatments overall. In our study, a larger proportion of the HNFC diet included

corn and DDGS, resulting in greater costs per ton for the grain mix, especially due to higher corn prices from the 2012 crop year. Paired with increased DMI for heifers fed HNFC, our data suggests that alternative energy sources, such as supplemental fat, may be more cost-effective for feeding growing heifers.

A second study was conducted to evaluate the effect of NFC level in the diets of post-weaned heifers after being started on either a conventional (22:20) or higher plane of nutrition (28:20) milk replacer. One of the goals of this study was to determine if how a calf was raised pre-weaning affects subsequent heifer growth and performance. In this study, animal receiving the HNFC diet had greater weight gain during the growing period from 12 to 28 weeks. Interestingly, when the animals were started on a higher plane of nutrition during the milk feeding period and subsequently fed LNFC diets, their body weight gain was significantly decreased as compared to animals that were started with a convention milk replacer program (Table 4). This study indicates that when calves are started on diets with a higher level of nutrition, maintaining a greater level of nutrition into the growing period may be even more important than when calves are started on a conventional milk feeding program.

CONCLUSIONS

Using the best feeding strategies for post-weaned dairy heifers allows heifers to continue to meet their growth potential while reducing costs per lb of gain and reducing the overall costs of raising dairy heifers. Numerous recently conducted research studies continue to show the importance of feeding post-weaned heifers quality, grain-based diets as a way to increase growth and improve feed efficiency. Continuing to component feed heifers as they entered the growing phase was found to be advantageous as compared to switching young heifers (~300 lbs) onto a TMR feeding system. In addition, continuing to feed diets containing a higher level of grain and concentrates (60:40 grain to forage ratio) was found to improve ADG and growth, while decreasing the costs per pound of gain. Further research has shown that the nutritional program of calves was found to impact the growth and development of heifers after weaning. Paying close attention to the diets of post-weaned heifers helps to ensure that the diets they are fed are being utilized efficiently and their growth rates are preparing them for breeding at an early age.

REFERENCES

Dennis, T. S., J. E. Tower, and T. D. Nennich. 2012. Effects of feeding hay and baleage to prepubertal dairy heifers during the grower period. Prof. Anim. Sci. 28:648-656.

Table 4. Weight and skeletal growth responses of dairy heifers and steers at 28 wks of age fed a milk treatment (MILK) of either conventional milk replacer (CONV) or high nutrition plane milk replacer (HIGH) and fed a grower diet (GRWR) of high non-fiber carbohydrate (HNFC) or low NFC (LNFC) post-weaning grower diets from 12 to 28 wk of age.

	CONV		HIGH			P-value[1]		
Item	HNFC	LNFC	HNFC	LNFC	SEM	MILK	GRWR	MILK × GRWR
BW[2], lb								
28 wk[3]	516.4[a]	503.0[ab]	522.1[a]	494.8[b]	7.98	0.88	< 0.01	0.04
ADG[4], lb/d								
0 to 28 wk	2.12	2.03	2.14	1.98	0.053	0.95	0.01	0.49
Hip height, in								
28 wk	47.6	47.2	47.4	47.3	0.22	0.91	0.24	0.60
Hip width, in								
28 wk	13.9[ab]	13.9[ab,x]	14.1[a]	13.7[b,y]	0.10	0.85	0.15	0.08

[1]MILK = effect of pre-weaning milk treatment; GRWR = effect of post-weaning diet; MILK × GRWR = interaction of milk treatment vs. post-weaning diet effects.

[2]Body weight.

[3]Weeks of age.

[4]Average daily gain.

[ab]Means with differing superscripts significantly differ at P ≤ 0.05 level.

[xy]Means with differing superscripts tend to differ at 0.10 ≥ P > 0.05 level.

IMPORTANCE OF PRODUCING A QUALITY DAIRY REPLACEMENT HEIFER

Michael W. Overton, Elanco Animal Health

INTRODUCTION

Dairy replacement heifers, much like dry cows, are often overlooked, undermanaged, and simply viewed as a large source of cost since there is little to no income generated from them until they enter the milking herd. While it is true that replacement heifer programs usually rank as the second or third largest cost of producing milk (trailing only feed costs and perhaps labor), the costs should more properly be viewed as an investment towards the future. Much like any other investment, money is spent up front for a return that will not be realized until much later, i.e., after the heifer calves and enters lactation; and careful attention to the correct kind and approach to this investing can influence the anticipated future returns.

Broadly speaking, there are two basic approaches towards replacement heifer rearing – a conventional, low cost approach and a more intensive feeding and management approach. The conventional approach is founded on the primary principle of keeping costs, especially feed, as low as possible. One means to accomplish this goal is to minimize the amount of liquid feed provided in order to wean calves earlier in the rearing process. Consequently, dairy calves in these conventional systems are often fed limited amounts (usually about 9-10% of body weight or about 3.8 L (4 qt) per day divided into two feedings) of waste milk or a very basic milk replacer, typically about 20% crude protein and 20% crude fat, that is mixed to deliver about 12% solids. Calf starter that is usually fed ad libitum commonly contains 16-18% crude protein on a dry matter basis (Drackley, 2008). This feeding approach encourages earlier and higher levels of calf starter grain intake, therefore reducing the total amount and cost of liquid feed provided. As expected, this results in a lower daily feed cost but requires a longer total rearing time due to a slower rate of gain in height and weight and a resulting delay in reaching breeding size.

Under thermoneutral conditions, the provision of 0.45 kg (1 lb) of the aforementioned milk replacer powder per day to a typical 88 lb Holstein calf usually yields only about 0.22 kg (0.48 lb) of energy allowable gain or 0.25 kg (0.55 lb) of protein allowable gain (NRC, 2001). If environmental temperatures are lower than thermoneutral, maintenance requirements increase significantly, and this level of feeding fails to support body weight maintenance. As a result, calves fed these traditional diets often suffer from periods of weight loss or stunted growth. Additionally, outbreaks of diarrhea at 7-10 days of age along with increased incidence of preweaning respiratory disease are commonly observed. These health issues are caused (or at least worsened) by a compromised immune system and inadequate caloric and protein intake. A major complicating issue to this conventional feeding approach is the low protein content of the calf starter. The marginal level of calories serves to stimulate earlier and higher levels of starter grain consumption and can allow producers to wean calves at an earlier age, but these calves often fail to grow as desired due to the low metabolizable protein levels.

Assuming that a conventionally reared calf increases its consumption of starter grain and is consuming the identical level of crude protein as a calf on a diet that provides a higher level of milk volume and/or solids, the digestibility of the two diets is not comparable. Milk and milk replacer are generally more digestible than the proteins commonly found in most calf starters. Calves on a conventional diet usually have smaller frames and often have health issues that follow them through the remainder of the growing phase and into lactation. Also, with conventional rearing systems, typical age at first calving is usually between 25 and 27 months and the impact is a large delay in positive cash flow (milk production) and requires a greater number of youngstock to fill the gaps created by culling poor producing animals.

Conversely, the intensive rearing approach achieves higher daily gains preweaning via the provision of a more nutrient dense liquid diet that is usually fed in larger volumes. Increasing the volume provided and increasing the percent solids to feed a more nutrient dense milk offers improved protection against environmental challenges and supports much greater levels of growth as well as reduced morbidity and mortality risks. Milk-fed calves can safely consume 20% of body weight in liquid feed provided it is good quality milk or milk replacer, and the added benefits include greater rates of gain, improved feed efficiency, and reduced risk of typical calfhood disease (Khan et al., 2016; Khan et al., 2012; Khan et al., 2011). This increased rate and efficiency of

gain continues throughout the rearing period if appropriate diets containing adequate levels of metabolizable protein are provided.

Intensive feeding and management programs have received a lot of attention in the last decade or so with a number of studies showing that delivering more nutrients preweaning has been associated with improved health via reduced morbidity and mortality, greater weight and frame growth, earlier age at first service, earlier age at first calving, and increased milk yield during the first lactation (Davis Rincker et al., 2011; Jasper et al., 2002; Moallem et al., 2010; Raeth-Knight et al., 2009; Soberon et al., 2012; Soberon et al., 2013). Consequently, many farms have begun more aggressive nutritional approaches by providing more volume and/or more nutrient dense liquid feed, whether by providing more saleable whole milk, pasteurized waste milk, or higher volumes of milk replacer mixed at higher solids levels. Typical milk replacers used in these intensive programs are 25-28% protein and 15-20% fat and are fed at 12-15% milk solids with a total of 4-10 liters of fluid volume per day, depending upon the size and age of the calf, but pasteurized waste milk or saleable whole milk also work well to improve calf health and growth. Feeding higher levels of nutrients will allow 0.8 – 1.1 kg/d (1.7 to 2.5 lb /d) or more of body weight gain, depending on environmental conditions, volume of milk provided, and on the quality and intake of the calf starter grain mix. In addition, the higher level of nutrients can allow calves to withstand more environmental stressors without resulting in weight loss or spikes in morbidity. Of course, farms often fall somewhere in between a completely conventional approach and a fully intensive one. The most successful programs that have carryover impact well beyond weaning usually feed starter grains, grower grains and subsequent rations that provide higher levels of metabolizable protein without enough extra energy to promote fattening (Corbett, 2010; Soberon et al., 2012; Stamey et al., 2012; Van Amburgh et al., 2008, 2009; Van Amburgh et al., 2011).

A strong positive relationship between preweaning daily gain and first lactation milk production has been shown by a variety of researchers, specifically when the focus was on frame growth and not simply body weight change (Bach et al., 2008; Sadek et al., 2014; Soberon et al., 2012; Soberon et al., 2013; Van Amburgh et al., 2008, 2009; Van Amburgh et al., 2011). Generally, the relationship between preweaning gain and first lactation performance has been in the range of 850-1551 kg more first lactation milk for every 1 kg of preweaning average daily gain.

When examining these impacts of improved nutritional management, there is confusion over how much of the associated impact is a direct consequence of the potential epigenetic effects of improved nutrition and how much is due to the reduction in calfhood disease challenges. Preweaning bovine respiratory disease (BRD) has been shown to have significant long-term costs including increased mortality, increased treatment costs, decreased rate of gain, delayed time to first calving, greater culling risk prior to first calving, and lower likelihood of survival through the first lactation (Bach, 2011; Donovan et al., 1998; Stanton et al., 2012; Waltner-Toews et al., 1986). The true effect of preweaning BRD on first lactation production is likely greatly underestimated due to survivorship bias (affected animals more likely to be culled prior to first calving) and the inconsistent detection, treatment and underreporting of BRD in many commercial dairy operations.

PROJECT DESCRIPTION AND RESULTS

The objective of this project was to examine commercial dairy data to evaluate the potential association between preweaning weight gain as recorded in the on-farm record system (DairyComp305) and performance of both heifers and first lactation animals, while controlling for a variety of potential confounders including genetics, season, and herd. In order to complete this task, herds had to have recorded birth weights, postweaning weights, genetic values (predicted transmitting ability or PTAM, in this case) and disease information (pneumonia and scours events) for animals that had already calved and entered lactation. Many herds have begun recording heifer growth information, but very few have been doing it long enough to generate lactation information, and fewer still have the full historical growth information and all of the other requirements for this retrospective analysis. Two herds were identified that met the above criteria. One herd was from the upper Midwest and one herd was from the West. Both herds milk Holsteins with a few crossbreds or Jerseys present, but only the Holsteins were used in this project. Pneumonia and scours were defined and recorded in each herd and the average incidence was 13 and 41%, respectively.

Birth dates for animals used in this project ranged from December 1, 2012 through December 1, 2013. A total of 3043 Holstein heifers were in the initial data extraction. The DairyComp305 data were imported into a spreadsheet and then moved into a statistical package for analyses (JMP 12.1.0). Birthweights (BWT) ranged from 52-133 lb with a mean of 84 lb. For both dairies, the majority of weights captured after birth were for ages 73-109 days. DairyComp305

software takes the recorded weight and reports an adjusted weight and an adjusted current daily gain for the period in question, in this case, 3 month age adjusted weights and 3 month calculated daily gains, hereafter referred to as WT3M and CDG3, respectively. The WT3M ranged from 141-335 with a mean of 227, and the CDG3 ranged from 0.7-2.39 with a mean of 1.56. Categorical variables, Early Pneumonia and Early Scours, were created based upon the presence or absence of pneumonia or scours occurring within the first 70 days of age. Birth month and calving month were used to create Season of Birth and Season of Calving variables where Dec, Jan and Feb = Winter; March, April and May = Spring; June, July and August = Summer; and Sept, Oct, and Nov = Fall.

The first step was to create multivariate regression models to fit least square means to examine the relationship between a number of variables and either WT3M or CDG3. Variables that might be biologically important were offered to the model as well as relevant two-way interactions. Due to the potential impact of both light birth weight and very large birth weights, BWT was also added as a squared term. Herd, Early Pneumonia, Early Scours, BWT, BWT^2, PTAM, and Season of Birth were each significantly associated with both WT3M and CDG3, as was the interaction of Herd x Season Born. Adjusting for the effects of the other significant variables in the model, Early Pneumonia and Early Scours were associated with 12.7 and 3.1 lb less WT3M and 0.14 and 0.034 lb less CDG3, respectively. The interaction of Herd x Season was significant most likely due to the vastly different environment of each herd with one located in a very cold climate and one in an area with greater heat stress issues.

A Cox Proportional Hazards model was created to examine the relationship between the same previously mentioned variables and time to pregnancy for the nulliparous animals. Across the two herds, neither WT3M or CDG3 was significantly associated with time to pregnancy. The only significant variables were BWT, BWT^2, Herd, Season Born, and the interaction of Herd x Season Born.

A Cox Proportional Hazards model was also created to examine the association between biologically relevant variables and time to culling prior to first calving. Early Pneumonia, CDG3 and Season Born were all significantly associated with time to removal. Heifers that experienced Early Pneumonia were 2.8 X more likely to be culled as compared to those heifers that did not. Heifers born during the Summer or Fall were 2.3 and 2.4 X more likely to be culled as compared to those born during the

winter. A higher CDG3 was actually protective against culling.

To examine the relationships between preweaning performance and first lactation production, a multivariate regression model was built using plausible biological or management variables and first lactation projected 305ME milk production. Season Born, BWT, Early Pneumonia, Age at first Calving (AGEFR), AGEFR^2, Season Calved, CDG3, PTAM, Herd and Herd x Season Born were all significantly associated with Projected 305ME milk production, but Early Scours was not. Adjusting statistically for each of the aforementioned variables, Early Pneumonia was associated with 649 lb less 305me milk and each additional lb of CDG3 was associated with 1728 lb more Projected 305ME milk in the first lactation. Since the expected range of CDG3 is relatively small, perhaps a more useful interpretation is that each additional 0.1 lb of CDG3 was associated with 173 lb more Projected 305ME milk in first lactation.

Similar to before, a Cox Proportional Hazards model was created to examine the association between biologically relevant variables and time to culling following first calving. Culling was followed only until 150 DIM since many of the cows had calved during mid to late 2015. The only variables that were significantly associated with time to culling within the first 150 DIM were Herd and Projected 305ME milk, which was protective. There was a tendency for an association between Early Pneumonia and culling (p=0.09). Calves that experienced Early Pneumonia as a calf were 1.4X more likely to be culled by 150 DIM, but the p-value did not quite meet the selected 0.05 threshold used in this analyis.

CONCLUSION

As previously described, the management of young calves is strongly associated with future productivity well into and beyond the first lactation. In this retrospective evaluation, the associations and interactions between key biological and management variables were examined using a convenience sampling of two commercial dairy herds. The presence of Early Pneumonia was associated with 12.7 lb less WT3M, 0.14 lb less CDG3, a 2.8X higher risk of being culled prior to 600 days of age, and 649 lb less Projected 305ME milk production during the first lactation. There was also a tendency for a 1.4X increased risk of culling from calving to 150 DIM. Early Scours was also associated with losses but much less so than with Early Pneumonia. Early Scours was associated with 3.1 lb less WT3M and 0.034 lb less CDG3 but no quantifiable impact on culling or reproductive performance nor with first lactation milk production. As expected, PTAM was significantly associated with milk production during the first lactation, but this genetic prediction was also positively associated with both WT3M and CDG3. Similarly to the published results, rate of gain during the early growth period was positively associated with first lactation milk production, even after adjusting for the impact of PTAM and other variables. Each additional lb of CDG3 was associated with 1728 lb more Projected 305ME milk in the first lactation, while adjusting for genetics (PTAM), Herd, Season, Early Pneumonia, Early Scours, and other important variables. The consistency of this finding relative to the published estimates is very significant and should provide additional confidence that excellent management coupled with good genetics is key to achieving higher levels of productivity and lowering disease risk.

The impact of both Early Pneumonia and Early Scours was less than expected. Prior unpublished analyses by the author has identified larger impacts of these two diseases on early growth and culling. The reasons for the lower impact identified here are unknown but are likely related to the definition used on each farm, the detection approach employed, the completeness of the record system, therapeutic approach used, and on overall farm management factors. In general, underreporting of any disease usually leads to an underestimation of its impact due to misclassification of affected animals in the "non-affected" group. The best approach to correct for this problem would be to conduct a long term prospective study with careful screening for disease by trained staff. However, much improved information could be gleaned from herds such as the two used in this project if time was taken to carefully define each disease, thoroughly train each employee working with the heifers, and then to consistently record all disease information. With improved records such as this, more accurate and complete evaluation of the impact of disease on livestock would be possible.

REFERENCES

Bach, A. 2011. Associations between several aspects of heifer development and dairy cow survivability to second lactation. J Dairy Sci, 94(2): 1052-1057.

Bach, A., Ahedo, J., & Kertz, A. 2008. Using growth monitoring in heifer management and research. J. Dairy Sci, E-Suppl Vol 1, #602.

Corbett, R. 2010. The replacement heifer, from birth to pre-calving American Association of Bovine Practitioners preconference symposium.

Davis Rincker, L. E., VandeHaar, M. J., Wolf, C. A., Liesman, J. S., Chapin, L. T., & Weber Nielsen, M. S. 2011. Effect of intensified feeding of heifer calves on growth, pubertal age, calving age, milk yield, and economics. J Dairy Sci, 94(7): 3554-3567.

Donovan, G. A., Dohoo, I. R., Montgomery, D. M., & Bennett, F. L. 1998. Calf and disease factors affecting growth in female holstein calves in Florida, USA. Prev Vet Med, 33(1–4): 1-10.

Drackley, J. K. 2008. Calf Nutrition from Birth to Breeding. Vet Clinics of NA: Food Animal Practice, 24(1): 55-86.

Jasper, J., & Weary, D. M. 2002. Effects of Ad Libitum Milk Intake on Dairy Calves. J Dairy Sci, 85(11): 3054-3058.

Khan, M. A., Bach, A., Weary, D. M., & von Keyserlingk, M. A. G. 2016. Invited review:Transitioning from milk to solid feed in dairy heifers. J Dairy Sci, 99(2): 885-902.

Khan, M. A., Weary, D. M., Veira, D. M., & von Keyserlingk, M. A. G. 2012. Postweaning performance of heifers fed starter with and without hay during the milk-feeding period. J Dairy Sci, 95(7): 3970-3976.

Khan, M. A., Weary, D. M., & von Keyserlingk, M. A. G. 2011. Invited review: Effects of milk ration on solid feed intake, weaning, and performance in dairy heifers. J Dairy Sci, 94(3): 1071-1081.

Moallem, U., Werner, D., Lehrer, H., Zachut, M., Livshitz, L., Yakoby, S., & Shamay, A. 2010. Long-term effects of ad libitum whole milk prior to weaning and prepubertal protein supplementation on skeletal growth rate and first-lactation milk production. J Dairy Sci, 93(6): 2639-2650.

NRC. 2001. Nutrient requirements of dairy cattle, 7th ed. Washington: National Academy Press.

Raeth-Knight, M., Chester-Jones, H., Hayes, S., Linn, J., Larson, R., Ziegler, D., Ziegler, B., & Broadwater, N. 2009. Impact of conventional or intensive milk replacer programs on Holstein heifer performance through six months of age and during first lactation. J. Dairy Sci, 92(2): 799.

Sadek, R., Ashour, G., Ibrahim, M., & Samoul, A. 2014. Effect of dairy weight gain on age at first calving and subsequent milk yield of holstein heifers in Egypt. Egyptian J. Anim. Prod, 51(3): 164-171.

Soberon, F., Raffrenato, E., Everett, R. W., & Van Amburgh, M. E. 2012. Preweaning milk replacer intake and effects on long-term productivity of dairy calves. J Dairy Sci, 95(2): 783-793.

Soberon, F., & Van Amburgh, M. E. 2013. LACTATION BIOLOGY SYMPOSIUM: The effect of nutrient intake from milk or milk replacer of preweaned dairy calves on lactation milk yield as adults: A meta-analysis of current data. J Animal Sci, 91(2): 706-712.

Stamey, J. A., Janovick, N. A., Kertz, A. F., & Drackley, J. K. 2012. Influence of starter protein content on growth of dairy calves in an enhanced early nutrition program. J Dairy Sci, 95(6): 3327-3336.

Stanton, A. L., Kelton, D. F., LeBlanc, S. J., Wormuth, J., & Leslie, K. E. 2012. The effect of respiratory disease and a preventative antibiotic treatment on growth, survival, age at first calving, and milk production of dairy heifers. J Dairy Sci, 95(9): 4950-4960.

Van Amburgh, M., Raffrenato, E., Soberon, F., & Everett, R. W. 2008. Early Life Management and Long-term productivity of Dairy Calves. Paper presented at the Cornell Nutrition Conference, Ithaca, NY.

Van Amburgh, M., Raffrenato, E., Soberon, F., & Everett, R. W. 2009. Early Life Management and Long-term Productivity of Dairy Calves. Paper presented at the University of Florida Dairy Extension 20th Symposium, Gainesville, Fl.

Van Amburgh, M. E., Soberon, F., Karzses, J., & Everett, R. W. 2011. Taking the Long View: Treat Them Nice As Babies and They Will Be Better Adults. Paper presented at the Western Dairy Management Conference, Reno, NV.

Waltner-Toews, D., Martin, S. W., & Meek, A. H. 1986. The effect of early calfhood health status on survivorship and age at first calving. Can J Vet Res, 50(3): 314-317.

OPPORTUNITIES AND CHALLENGES IN HEIFER REPRODUCTION AND MONITORING

Michael W. Overton, Elanco Animal Health

One of the largest contributors to the cost of production on a dairy, usually ranking behind only feed and sometimes labor, is the replacement heifer program. Considerable time, effort and expense is incurred to produce sufficient replacement heifers to meet a dairy's needs. While costly, the expense associated with feeding and rearing heifers should be more properly viewed as an investment towards the future, and bringing replacement heifers into the herd at an earlier age, yet well grown and free of lingering disease issues, helps to secure a greater return. There are three key drivers for achieving a more efficient and profitable earlier age at first calving: nutritional management, health management, and reproductive management. This paper will describe some opportunities to improve performance and offer a few suggestions on how to better monitor the process and performance.

Nutritional management is the cornerstone for a successful replacement heifer program. Proper nutrition is key to achieving the most optimal rates of growth and also helps to reduce the risk of disease by enhancing the immune system and reducing nutrition-related stresses. For a dairy replacement heifer, proper nutrition begins with the timely and appropriate administration of colostrum. For a typical Holstein heifer, four quarts fed as soon as possible following birth is likely to provide sufficient levels of immunoglobulins (Godden, 2008). Alternatively, some provide 3 quarts immediately after birth and another 3 quarts within 12 h for an even greater level of risk reduction and improved nutritional support. But, the value of colostrum goes well beyond the immunoglobulins provided by the calf. Colostrum contains higher protein, fat, vitamins and minerals than milk and is in an easier form to digest as well.

Classically, calves have been intentionally underfed or at least limit fed milk or milk replacer in an attempt to lower cost and promote a more rapid transition from liquid diet to a grain-based diet. However, this approach has often led to issues with gastrointestinal disease, respiratory disease, and less than optimal rates of gain or even stunted growth. There is also greater risk of disease in this conventional feeding approach, especially during periods of environmental stress such as cold, wet weather due to the greater maintenance requirements that are present.

Alternatively, higher daily gains are possible preweaning via the provision of a more nutrient dense liquid diet that is usually fed in larger volumes. Increasing the volume provided and increasing the percent solids to provide a more nutrient dense milk offers improved protection against environmental challenges and supports much greater levels of growth as well as reduced morbidity and mortality risks. Milk-fed calves can safely consume 20% of body weight in liquid feed provided it is good quality milk or milk replacer. The added benefits include greater rates of gain, improved feed efficiency, and reduced risk of typical calfhood disease (Khan et al., 2016; Khan et al., 2012; Khan et al., 2011). When also provided with a highly digestible starter grain containing 20-24% crude protein on a dry matter basis and weaned in a progressive manner, high rates of gain with lower risks of neonatal disease challenges and stunted growth is possible.

This more intensive feeding approach should be continued throughout the entire rearing program for optimal results. Feeding rations postweaning that achieve a greater protein-allowable growth than energy-allowable growth helps to promote greater lean tissue accretion, improved frame growth, and less risk for excessive body condition. Modeling work by the author has demonstrated that this feeding approach costs more per day but results in significantly fewer total days on feed, less total feed consumed over the heifer's growth and development, and actually results in a lower total cost of production (Overton et al., 2012).

Another critical component for achieving more efficient, profitable and earlier age at first calving is health management and monitoring. Health management is a very broad term, but for the purposes of this paper refers to the appropriate housing, vaccination, therapeutic strategies, and culling decisions for replacement heifers. "Appropriate" housing depends on the geographic location in which the heifers are reared and the prevailing weather conditions, but at a minimum, should provide a clean, dry area for animals to lie upon, provide ample access to a balanced diet and clean, readily available water,

and allow animals to move about freely without undue stress.

Along with the provision of appropriate housing is the need for the administration of the proper vaccines at the correct time. This will provide the desired level of acquired immunity to help diminish the risk of morbidity and mortality. There is not a universally appropriate vaccination protocol that fits the needs of all heifers. Instead, each farm manager/owner should work with his or her own veterinary consultant to customize a protocol specifically for the needs of the individual farm.

Similarly, each farm should have predefined treatment protocols designed in collaboration with the veterinarian. The protocols should be developed for specific disease issues that have been clearly defined so that everyone working with the animals on that farm has a clear understanding of what each disease represents and its most appropriate therapeutic option.

An essential component of health management that is frequently overlooked is the area of culling management. Dairy managers rarely consider the economic impact of rearing poorly performing heifers or the risk that heifer diseases create for very poor lactation and early removal. Prevention of disease is the absolute best approach. Once an animal has developed lung damage due to bovine respiratory disease and has experienced stunted growth and development, much of the potential future productivity value of that animal has already been lost. The best decision may be to promptly cull such an animal instead of continuing to invest more time, effort and resources into its rearing and development.

A key component of replacement heifer management is the monitoring of both disease and growth and recording this information into the on-farm record system on an individual animal basis. Frequently, producers estimate the birth weight and then weigh trailer loads of heifers while moving them from one pen to another. While this approach can provide some basic information regarding how the group has performed, it actually provides very little useful information upon which individual animal decisions can be made. For example, the average birth weight of Holstein heifers tends to be about 84-90 lb. The standard deviation for birth weight may be 10 lb or more. If a herd used 86 lb as the estimated mean, with a standard deviation of 10 lb, this estimate would be expected to represent, within a range of +/- 10 lb, the birth weight for 68% of the population. What about the remaining 32%? How can one even begin to detect any impact of pneumonia or scours on weaning weight? Based on modeling work by the author, pneumonia likely impacts the adjusted weaning weight by 10-15 lb or more after adjusting for other variables. Imagine for a moment a group's mean weaning weight is 195 lb. The standard deviation of this weight may be 20 lb. If we take the birth weight range of 76 to 96 lb and subtract it from the weaning weight range of 175-215 lb (expected for 68% of the population), what information can truly be gleaned from this result? The potential expected impact of a disease such as scours or pneumonia is completely lost in the variation that is part of the reported group mean; there is too much variation to truly gather any reliable information relative to how disease might be impacting performance or whether a feeding change has truly had any effect. The monitoring of growth at the individual animal level can help to identify hiccups in the feeding and/or management approach that can be corrected earlier in the process. Monitoring can also help identify individual heifers with lower than expected performance to date that might be considered at risk for poor lactation performance in the future.

In setting up a health and growth monitoring program, there are a few critical time points and disease events for consideration. Throughout the following description of times for data recording, though not explicitly stated, animal height should be recorded as well as weight to ensure not only that animals are gaining total body mass at an acceptable rate but that frame is increasing as desired as well. First, the individual birth weight should be recorded for each calf. Next, an adjusted weaning weight, representing a weight at approximately 60 d of age is important to be able to assess preweaning growth. Almost equally important would be the gain from 60 d until 3-4 months in order to assess how well calves are performing immediately postweaning. Ideally, another data point to capture would be a prebreeding measurement at 10-12 months of age followed by a weight at the time of entry into the springer pen. With these multiple data points, estimated current daily gain between each time point can be calculated to assess individual animal growth.

From a disease perspective, the two critical events that should be consistently defined, detected and recorded are respiratory disease and scours, along with the treatment protocol used for each. From this information, the cumulative incidence for each disease, disease risk by age category, time to first event, and number of total cases per animal can be calculated. Consistent disease recording can help detect trends in disease risk and can be used to help identify animals that should be considered for culling.

The final critical component for achieving a more efficient and profitable

earlier age at first calving is reproductive management. The time from birth until entry into the breeding pen is dependent on the feeding, housing and general management. All of these areas could be excellent and still result in less than optimal age at first calving if reproductive management is not excellent. Once an animal becomes pregnant, her remaining time in the replacement program is now set. Thus, it is critical to present animals for breeding management at the appropriate size and age, to manage the reproductive program to achieve a high 21-d pregnancy rate, and then to continue the nutritional management to facilitate the ongoing growth and development necessary to produce a high quality heifer at first calving.

There are a variety of reproductive management approaches including estrus detection based breeding programs, programs that rely heavily on timed AI (TAI), and natural service. Natural service should be discourage from use, especially in virgin heifers since these animals represent the most current, highest level of genetic potential and due to the increased concern of dystocia. From an AI perspective, heifer programs are usually managed either via direct observation of estrus or by use of estrus detection aids such as tailhead paint, Kamars, or other heatmount detection devices. Activity systems may be used as well, but due to the relative ease of detection estrus in heifers, these are less frequently used. One inexpensive technology that is often overlooked is the use of prostaglandin (PGF2α) injections to aid in the synchronization of estrus. One common and very successful approach is to administer a dose to each heifer as she enters the breeding pen. Evaluate for estrus expression for the next 1-2 weeks and repeat the injection for any animal not yet observed and inseminated.

Another approach that could be used either at the initiation of the breeding period or as a safety net for those not yet inseminated following two injections of PGF2α is a TAI protocol. A traditional Ovsynch program can work on virgin heifers but is not advised due to the following factors: heifers have a faster rate of follicular growth than lactating cows, heifers are more likely to have three-wave follicular cycles, and heifers are less likely to ovulate a dominant follicle in response to the first GnRH (Pursley et al., 1997; Sartori et al., 2004). Instead, a modification of the traditional Ovsynch program has most often been recommended for virgin heifers with expected pregnancy per AI of approximately 50-60% (Bridges et al., 2008;

Lima et al., 2011; Lima et al., 2013; Silva et al., 2015). This program has several slight variations but the most successful approach utilizes an IM injection of GnRH and the placement of a CIDR device intravaginally. In five days, the CIDR is removed and an injection of PGF2α is administered. Twenty-four h later, a second PGF2α is administered. After 48 h, another injection of GnRH is administered and the heifer is inseminated at the same time (Lima et al., 2013). This TAI approach has been shown to reduce the median days to pregnancy, to increase the proportion of pregnant heifers by d-84 of the study, and to be more advantageous economically as compared to a traditional estrus detection based program (Silva et al., 2015).

In general, there are a few major points to be followed to achieve optimal reproductive performance in dairy replacement heifers. Heifers should be moved into the breeding pens weekly, once reaching the appropriate height/weight/age. How early heifers achieve the desired size and age is largely a function of the feeding and care delivered to them as calves and growing heifers, and the management preferences of the farm. For Holstein heifers, 850 lb by 11-12 months of age is very achievable. Once heifers are in the breeding pens, exceptional estrus detection and/or the use of TAI protocols can help to drive a high insemination risk. Finally, the heifer group should be evaluated for pregnancy frequently and as early as the attending veterinarian is comfortable with making the diagnosis. Usually, on larger farms, heifer pens are checked weekly beginning at 28-35 d depending on the diagnostic approach preferred. The key is to promptly identify non-pregnant heifers and then to re-enroll them back into a PGF2α-based program or a TAI program to efficiently deliver the next service. Also important is to move pregnant heifers out of the breeding pens to reduce the issues caused by maintaining high stocking densities.

In summary, properly run replacement heifer programs offer tremendous opportunity to improve growth rates, decrease morbidity and mortality and to improve future milk production potential while simultaneously achieving an earlier, more cost effective age at first calving. Appropriate monitoring includes growth, morbidity, mortality and reproduction, all on an individual heifer basis in order to improve the decision making value of the data. Heifer reproductive management is often a hidden economic opportunity and is a key component to getting the full benefit from an intensive heifer rearing program.

REFERENCES

Bridges, G., Helser, L., Grum, D., Mussard, M., Gasser, C., & Day, M. 2008. Decreasing the interval between GnRH and PGF2 [alpha] from 7 to 5 days and lengthening proestrus increases timed-AI pregnancy rates in beef cows. Theriogenology, 69(7): 843-851.

Godden, S. 2008. Colostrum Management for Dairy Calves. Vet Clin North America: Food Animal Practice, 24(1): 19-39.

Khan, M. A., Bach, A., Weary, D. M., & von Keyserlingk, M. A. G. 2016. Invited review:Transitioning from milk to solid feed in dairy heifers. J Dairy Sci, 99(2): 885-902.

Khan, M. A., Weary, D. M., Veira, D. M., & von Keyserlingk, M. A. G. 2012. Postweaning performance of heifers fed starter with and without hay during the milk-feeding period. J Dairy Sci, 95(7): 3970-3976.

Khan, M. A., Weary, D. M., & von Keyserlingk, M. A. G. 2011. Invited review: Effects of milk ration on solid feed intake, weaning, and performance in dairy heifers. J Dairy Sci, 94(3): 1071-1081.

Lima, F. S., Ayres, H., Favoreto, M. G., Bisinotto, R. S., Greco, L. F., Ribeiro, E. S., Baruselli, P. S., Risco, C. A., Thatcher, W. W., & Santos, J. E. 2011. Effects of gonadotropin-releasing hormone at initiation of the 5-d timed artificial insemination (AI) program and timing of induction of ovulation relative to AI on ovarian dynamics and fertility of dairy heifers. J Dairy Sci, 94(10): 4997-5004.

Lima, F. S., Ribeiro, E. S., Bisinotto, R. S., Greco, L. F., Martinez, N., Amstalden, M., Thatcher, W. W., & Santos, J. E. P. 2013. Hormonal manipulations in the 5-day timed artificial insemination protocol to optimize estrous cycle synchrony and fertility in dairy heifers. Journal of dairy science, 96(11): 7054-7065.

Overton, M. W., Heins, B. D., & Corbett, R. B. 2012. An economic comparison of conventional vs. intensive rearing approaches for dairy replacement heifers. Paper presented at the Dairy Calf and Heifer Conference, Visalia, CA.

Pursley, J. R., Kosorok, M. R., & Wiltbank, M. C. 1997. Reproductive management of lactating dairy cows using synchronization of ovulation. J Dairy Sci, 80(2): 301-306.

Sartori, R., Haughian, J. M., Shaver, R. D., Rosa, G. J., & Wiltbank, M. C. 2004. Comparison of ovarian function and circulating steroids in estrous cycles of Holstein heifers and lactating cows. J Dairy Sci, 87(4): 905-920.

Silva, T. V., Lima, F. S., Thatcher, W. W., & Santos, J. E. P. 2015. Synchronized ovulation for first insemination improves reproductive performance and reduces cost per pregnancy in dairy heifers. J Dairy Sci, 98(11): 7810-7822.

TMR AUDITS FOR IMPROVED FEEDING MANAGEMENT AND PROFITS

Thomas J. Oelberg, Dairy Field Technical Specialist, Diamond V

SUMMARY

The goals of a heifer-feeding program are to raise healthy heifers to calve at 22 to 24 months of age and to have the heifers consistent in body weight and size. One of the keys to raising consistent heifers is to have the nutrition to be the same for every bite, every heifer and every day. Total mixed rations (TMR) are formulated to contain a combination of feedstuffs that provide the right balance of nutrients in every bite taken by an heifer. Poorly mixed TMRs negatively impact animal performance and health. A system has been developed to monitor how well the feedstuffs are blended and delivered to the feed bunk. This system is called the TMR Audit(1). There are eleven factors in the TMR mixing process that each can create variation in the TMR before it is delivered to the feed bunk. Time-lapsed game cameras are utilized to evaluate animal access to the TMR and feed push up routines.

TMR AUDIT

The TMR Audit(1) was first introduced in 2008 and has been a very effective tool in reducing variation in TMRs, reducing fuel, labor and feed loss due to shrink. Most recently the audit has used time-lapsed game cameras to help evaluate feed bunk management. This manuscript will focus on the ten mixing factors that cause variation in TMR particle size and on key learnings from time-lapsed video of feed bunks.

THE ELEVEN FACTORS DURING TMR LOADING AND MIXING THAT CAUSE VARIATION

There are ten factors in the TMR loading and mixing process that can contribute to TMR variation individually or in combination. Each of these will be discussed in detail. They are:

1. Worn mixer augers, kicker plates and knives
2. Auger timing in mixers
3. Un-level mixers
4. Mix time after the last added ingredient
5. Loading position on the mixer box
6. Load size
7. Hay quality and processing
8. Loading sequence
9. Liquid distribution
10. Vertical mixer auger speed
11. Forage restrictor settings on vertical mixers

MIXER WEAR AND TIMING OF AUGERS

TMR particle size consistency as well as moisture and nutrient consistency along the feed bunk (TMR mix quality) can decrease significantly with worn blades, kicker plates and augers (1). The easiest way to evaluate wear on augers is to look for feed under horizontal augers or reels and to look for the feed ring inside vertical mixers. The mixing efficiency on vertical auger mixers depends on the condition of the edge on the auger flighting and on the condition of the kicker plate, shoe or deflector. The edge of the flighting should not have rounded corners. The degree and speed of wear on the augers, kicker plates and knives depends on the size of the feedlot and the amounts of hay, baleage or straw fed. Routine replacement of blades, kicker plates and augers are required to keep TMRs consistent.

AUGER TIMING

Make sure both horizontal and vertical augers are properly timed according to manufacturer's handbook. The easiest way to check for proper timing on vertical mixers is to watch and make sure the kicker plates do not meet in the same location at the same time in twin- or triple-auger pull-type mixers. However, this does not apply for truck-mount twin-auger mixers as most are hydraulic driven. Pull-type vertical mixers with automatic transmissions will also have timed augers. Horizontal mixer augers have timing marks that need to be set properly before the drive chain is attached to all augers.

UN-LEVEL MIXERS

Un-level mixers cause migration of the heaviest and most dense materials in the TMR to the lowest section of the mixer wagon. Figure 1 shows a shaker box analysis of ten samples taken from a triple–auger vertical that was parked in a ramp that was too short causing the grain-concentrate portion of the TMR to migrate to the back of the mixer box. Notice how the levels in the bottom screen increase from sample 1(front) to sample 10(back) and the opposite trend can be observed for the middle screen which would have less dense feedstuffs such as haylage, corn silage and small particles of hay. This is a very typical pattern in the Penn State particle separator analysis for both un-level mixer boxes and for improper loading position on vertical wagons.

LOADING POSITION ON THE MIXER BOX

Loading position on the mixer box refers to the location on the mixer box where the feeder is dumping ingredients in. Improper loading position on the mixer box will create a poorly mixed TMR(1). Figure 2 shows the influence of loading a liquid protein supplement in the back of a dual-auger vertical wagon on moisture and protein levels in the TMR. Both moisture and protein increase linearly as you move from front to back of the wagon. This resulted in a very inconsistent TMR along the feed bunk. Because cows are quite territorial within the pen, not all cows will get the same nutrition nor will they get the same effective particle size. This leads to differences in rumen health and digestion, rumination patterns and manure consistency among cows within the pen fed this ration. Most dual-auger and triple auger vertical wagons move feed back and forth in the wagon, but it takes time. These results show that feed dumped in either end of these wagons does not get completely mixed during routine mixing. If mixing time is increased so that the TMR is completely mixed then there is increased risk of decreasing effective particle size in the TMR. The increased mixing time would also increase fuel and labor cost. It best to load the mixers at the proper position.

MIX TIME AFTER THE LAST ADDED INGREDIENT

One of the most common mistakes in TMR mixing is lack of mix time after the last added ingredient (usually corn silage or liquid supplement)(1). Often times the corn silage at the top of the load does not get mixed and is delivered towards the end of the load as pure corn silage. This is even more prevalent as mixer boxes are over-filled. Suggested mix times after the last ingredient with tractors/trucks at nearly full power (1700 to 2000 rpm engine speed) are 2 to 5 minutes. Inadequate mix times resulted in an inconsistent TMR (Table 1) comparing 3.5 versus 5 minutes of mix time in a 4-auger horizontal mixer on coefficients of variation for the average levels observed in the shaker box screens.

LOAD SIZE

Over-filling

Over-filling the load capacity can occur on all types of mixer wagons resulting in poor mix quality of the TMR(1). It is a very common mistake in TMR mixing on many dairies and feedlots. Overfilling occurs for several reasons:

- Under sizing the mixer box for the dairy
- In-accurate pen counts
- Changes in forage moisture levels, i.e. drier silages take up more space
- Too large of an increase in bunk calls where the mixer box is already at full capacity

Reducing the load size in a 4-auger mixer by 5000 pounds decreased the coefficient of variation (table 2) of the average levels of TMR in all three trays of the Penn State Particle Separator and improved TMR mix quality.

Under filling vertical mixers

Under filling of vertical mixers occurs when the TMR does not reach the top of the augers so that all of the ingredients are pushed off the augers and mixed. This happens often on many dairies that are mixing for small pens such as close-up dry and fresh pens(1).

HAY QUALITY AND PROCESSING

Poor hay quality and inadequate processing make TMRs very inconsistent and can affect both variation and level of milk components in a herd. Clumps of hay and straw in TMR indicates poor processing and mixing of the forage which leads to poor rumen health and growth performance of heifers. Most feedlots and dairies pre-process the hay before mixing into a TMR. This drastically reduces TMR mixing

time, improves loading accuracy of the hay and improves consistency TMR. Hay particle length should be the width of a heifer's mouth and straw should be processed to 1.5 to 2 inches to prevent sorting.

LOADING SEQUENCE

Generally, lower density and large particle feeds are loaded first, followed by dry more dense feeds followed by wet feeds and last with liquid. One exception to loading liquids last is liquid molasses. Of the dry more dense feeds, the lower-inclusion level feeds are added first so that they can be blended properly(2). Use the ratio of 50:1 to blend lower inclusion dry feeds such as rumen by-pass fats and vitamin/mineral premixes(2). Example, if 50 lb. of rumen by-pass fat is being added, then the load size should be no more than 2500 lb. The mixer should be running to allow the lower inclusion feed to mix.

TMR mix quality was improved dramatically by increasing mix time after the last added ingredient from 2 to 4 minutes and then changing mix order to further improve the mix quality.(Figure 3).

LIQUID DISTRIBUTION

Liquids such as water, whey and cane molasses are routinely added to TMR to add moisture, sugar or are used as a carrier for micro ingredients. Another important reason liquids are added to the TMR is to help reduce sorting by cattle. The liquids, especially cane molasses and liquid whey are sticky and they help bind the smaller particles to the larger forage particles. As a result, the levels of on the bottom pan of the Penn State shaker box will shift to the middle and top screens by as much 5 to 7 percentage units depending on type and level of liquid added directly to the TMR.

Except for liquid molasses, it is best to add water and liquid whey last to the TMR to prevent any balling or clumping of the drier ingredients (2). The best method of adding liquid molasses to a TMR is adding it first to an on-farm premix and then add the premix to the TMR. If loading liquid molasses directly to a TMR, add it to the dry ingredients In the beginning of the loading process and be sure to have augers turning at high rotational speed. The goal is to avoid feed balls with the molasses and avoid dumping the molasses directly on the metal mixer parts. There are two challenges of adding liquid directly to the TMR, time and distribution. Depending on the amount of liquid added to the TMR and the sizes of the pumps and pipes to load the liquid, the amount of time it takes to add liquid can range from 2 to 10 minutes per load and sometimes even longer. This can create a bottleneck in getting cattle fed on time for larger operations. Many dairy operations are adding the liquid to the on-farm commodity blend(1). Improper distribution of the liquid can make the TMR very inconsistent along the feed bunk(1).

VERTICAL MIXER AUGER SPEED

The influence vertical auger speed on TMR mix quality and apparent improvement in dairy cattle performance has been documented in a case study (1). Improved milk and energy-corrected milk (Figure 4) were associated with improved TMR mix quality after vertical auger speed was increased with proper engine speed and mixer gear box setting. Vertical auger speeds are based on tractor pto standard speed of 1000 rpm. A list of various brands of TMR mixers with suggested augers speeds are shown in table 4. When in doubt on correct auger speed, use the TMR Audit sampling and Penn State Particle Separator procedures to determine if TMR mix quality standards have been met with a given auger speed.

FORAGE RESTRICTOR SETTINGS

Most brands of vertical mixer have forage restrictors mounted on the side of the mixer box. The forage restrictors, when properly set, improve hay processing without impeding TMR mix quality. If the forage restrictors are moved too far into the mixer box, mixing can be impeded resulting in a poorly mixed TMR (table 3).

MONITORING FEED BUNKS WITH TIME-LAPSE CAMERAS

Time-lapse game cameras set to record photos of feed bunks of lactating and dry cows every 5 seconds for several consecutive days have shown the following:

- There are cows at the feed bunk at all hours of the day
- Cows are often out of feed for 4 to 7 hours mostly during the time from 10 pm to 4 am
- Uneven TMR delivery along the bunk often

results in partially empty bunks

- There is no efficient way to re-distribute feed along the feed bunk even in J-bunks that run partially empty during the early morning hours
- Level of feed push out is a poor indicator of feed access
- More frequent push up of feed has improved performance on many dairies where cattle had limited access to feed
- Robots are an effective tool to push up feed on a routine basis
- Shifting feed deliveries to later in the day allows more feed in bunks during the early morning hours when there is less labor to watch the bunks and to push up feed

CONCLUSIONS

An on-farm system to test TMR consistency along the feed bunk and to evaluate mixer performance has been developed. Implementation of this system has improved TMR consistency on many dairies across the U.S. The standard for TMR particle size consistency determined on 10 samples is 2.5% or less coefficient of variation for the average levels on middle and bottom screens of the Penn State Particle Separator. Frequent feed push is a critical part of a good feeding management program.

REFERENCES

1. Oelberg, TJ and Stone, WC. 2014. Monitoring Total Mixed Rations and Feed Delivery Systems. Vet. Cin Food Animal 30:721-744.
2. Oelberg, T.J. 2015. Effective Outcomes of TMR Audits. Tri-state Nutrition Conference. Pgs: 121-132.

TABLES

2. Influence of load size in a 4-auger horizontal mixer on TMR mix quality (percent coefficient of variation).

	Penn State Shaker Box Results					
	Over-filled			Normal Filled		
Bunk Sample #	Top	Middle	Bottom	Top	Middle	Bottom
1 Front	4.9	45.9	49.2	5.6	44.8	49.6
2	2.9	46.3	50.7	6.0	46.0	48.0
3	2.3	44.2	53.5	4.7	46.2	49.1
4	3.8	44.0	52.2	7.4	45.9	46.7
5	4.8	43.8	51.4	5.5	44.5	50.0
6	3.4	47.7	48.9	8.8	42.8	48.5
7	4.3	44.6	51.1	7.0	46.5	46.5
8	3.8	44.2	51.9	8.1	44.1	47.8
9	7.0	37.3	55.7	7.2	43.9	48.9
10 Back	3.6	38.8	57.6	5.9	44.1	50.0
Average, %	4.1	43.7	52.2	6.6	44.9	48.5
CV, %	31.58	7.39	5.22	19.35	2.72	2.58

2. Influence of load size in a 4-auger horizontal mixer on TMR mix quality (percent coefficient of variation).

	Penn State Shaker Box Results					
	Over-filled			Normal Filled		
Bunk Sample #	Top	Middle	Bottom	Top	Middle	Bottom
1 Front	4.9	45.9	49.2	5.6	44.8	49.6
2	2.9	46.3	50.7	6.0	46.0	48.0
3	2.3	44.2	53.5	4.7	46.2	49.1
4	3.8	44.0	52.2	7.4	45.9	46.7
5	4.8	43.8	51.4	5.5	44.5	50.0
6	3.4	47.7	48.9	8.8	42.8	48.5
7	4.3	44.6	51.1	7.0	46.5	46.5
8	3.8	44.2	51.9	8.1	44.1	47.8
9	7.0	37.3	55.7	7.2	43.9	48.9
10 Back	3.6	38.8	57.6	5.9	44.1	50.0
Average, %	4.1	43.7	52.2	6.6	44.9	48.5
CV, %	31.58	7.39	5.22	19.35	2.72	2.58

3. Influence of forage restrictor setting on TMR mix quality(%CV).

Sample Position	Forage restrictors set all the way in			Forage restrictors set half way in		
	Top	Middle	Bottom	Top	Middle	Bottom
1 Front	4.6	45.4	50.0	6.2	41.6	52.2
2	3.9	45.2	51.0	5.3	41.3	53.4
3	6.0	43.5	50.5	5.4	40.3	54.3
4	4.2	44.2	51.6	6.2	40.5	53.3
5	3.5	46.1	50.3	4.8	41.8	53.4
6	4.8	42.0	53.2	5.1	39.8	55.2
7	2.9	40.0	57.1	5.4	40.1	54.5
8	3.8	41.7	54.5	5.2	41.6	53.2
9	3.8	38.3	57.9	5.1	40.2	54.8
10 Back	1.8	38.3	59.9	5.0	40.4	54.6
Average	3.9	42.5	53.6	5.4	40.8	53.9
% CV	28.12	6.78	6.66	8.86	1.82	1.72

4. Vertical mixer manufacturers recommendations for rotational speed on augers.

Brand	Auger Rotational Speed, rpm	
Jaylor	38-41	
Kuhn	20-22	
Laird	20-22	
Lowen	34-36	
Lucknow	38-40	
NDE	25-28	
Patz	38-41	
Peecon	38-21	12-15 on some models
Precon triple auger	16-20	
Penta	28-30	
Roto-Mix	26-50	
Supreme older models	36-38	
Supreme new models	30-32	
Triolet	28-30	

FIGURES

Figure 1. Influence of un-level mixer box on TMR particle size distribution on the Penn State Shaker box screens.

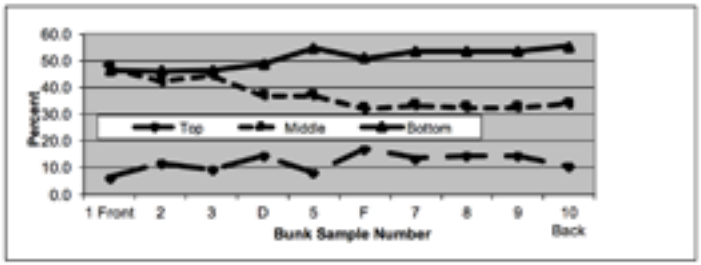


Figure 2. The influence of loading a liquid protein supplement in the back of a dual-auger wagon on moisture and crude protein levels in the TMR

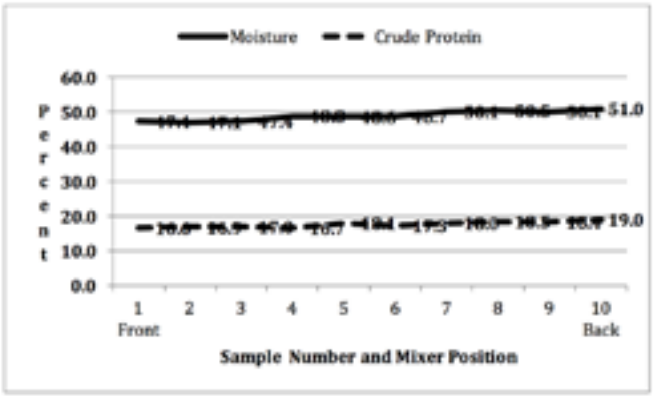
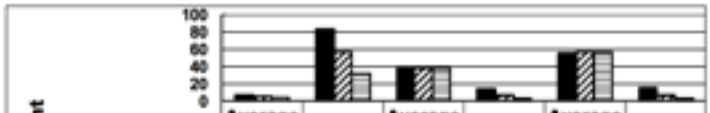
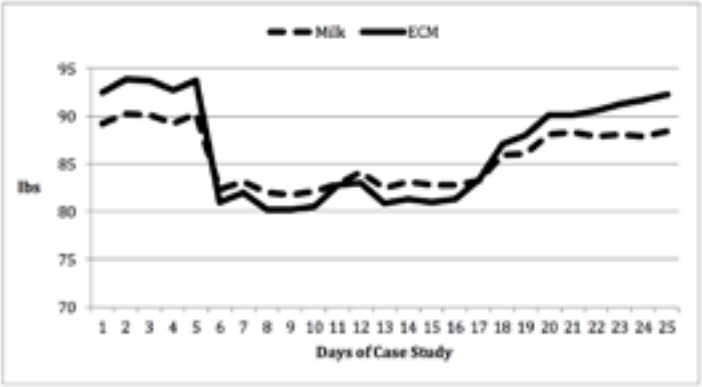


Figure 3. Influencing of mixing time after the last added ingredient and loading sequence on TMR variation



	Top		Middle		Bottom	
	Average, %	CV,%	Average, %	CV,%	Average, %	CV,%
Mixing Time	6.7	82.8	37.9	14.2	55.4	15.7
Loading Sequence	4.7	57.4	38.0	6.2	57.3	7.0
Normal	4.4	32.2	38.4	3.1	57.1	3.0

Figure 4. Influence of vertical mixer auger speed on TMR mix quality and milk production.



ANIMAL WELFARE: WADING THROUGH THE CONTROVERSY

Sandra Stokes Goff, Stagecoach Consulting Services

Take home message: Good animal welfare programs facilitate better environments for cows, as well as better work environments for the employees. Comfortable, well-cared for animals allow employees to get their jobs done as expected. Third-party verification of these animal welfare programs can increase consumer confidence in agriculture.

Consumer's attitudes are framed, in part, by news programs that show animals being abused, neglected, or handled poorly. Documentaries such as "Death on a Factory Farm" create negative images of livestock farmers. When abuse videos are noted on social media, flurries of negative discussion ensue. While some of these abuse videos have proven to be misrepresentations, some of them have been proven to be true.

Fifty years ago, the average consumer still had a direct connection to agriculture. That is not the case today. According to 2010 Census Bureau, approximately seventy-five percent of the United States is urban, twenty-five percent live in 50 largest cities, and ten percent live in 10 largest cities. As the consumer's connection to agriculture diminishes, farms get larger and the perception that 'factory farms' do not care for the animals is grown. In 1950, the American farmer fed 27 people; in 2015, the American farmer feeds about 155 people worldwide (American Farm Bureau Federation).

Based on these public concerns, the agribusiness industry has become involved in defining how animals are treated on farms where meat, eggs, and milk are producer for their suppliers. United Egg Producers (UEP) increased the cage space for laying hens. In 2010, California banned tail docking on dairy cows by a sixty-three percent majority vote. Several states, including Main, Ohio, and New Jersey, have since followed suit. In 2011, the state of Ohio established a livestock regulatory board to establish care standards for livestock. In 2014, the American Veterinary Medical Association (AVMA) opposed the routine tail docking of cattle.

Animal welfare is both a scientific and a social issue. Scientifically, the evaluation of welfare involves both individual and groups of animals by measuring their behavior (natural versus abnormal), changes in physiology (hormonal responses to stress), health parameters (disease, injury, pain), and productivity (milk production, growth rates, reproductive rates). Independently, these parameters have limited or may have a biased representation of the issue. The AVMA defines animal welfare as how an animal is coping with the conditions in which it lives. It further states that protecting an animal's welfare means providing for its physical and mental needs, by providing diseases prevention, veterinary treatment, shelter, management, nutrition and humane handling/slaughter.

Discussing animal welfare can lead to an antagonistic debate between people with various perceptions of animal use. It is important to understand the difference between animal welfare and animal rights. Proponents of animal welfare are those who seek to improve treatment and well-being of animals. This segment believe that humans can interact with animals in entertainment, industry, sport, recreation, but that interaction should also include providing responsible care. This group is more prone to utilize scientific evidence to base animal care and handling guidelines. Whereas animal rights advocates have the philosophical view that animals have rights similar to or the same as humans. This group believes that humans do not have the right to use animals at all and wish to ban all use of animals by humans. People with this mind-set do not want scientific justification for how animals are raised or used.

Ultimately, no one wants to see animals abused or hurt. Welfare proponents have provided some good guidelines to defend basic animal care. Some of these defend our production practices (dehorning), and some of these make us question our production practices (tail docking). Many interactions between people and animals occur in dairy production. Aversive handling at young age can create problems for that heifer throughout its life cycle on a dairy. Negative experiences with human caretakers can establish fear in animals, making them more difficult to handle. This will be intensified as the heifer grows to the age of calving and lactation,

where she will be expected to go through a parlor at least twice each day. Increasing the gentle handling of younger animals has been shown to decrease their fear of humans. Dr. Temple Grandin has long advocated that one of the primary factors in determining how animals are treated is the attitude of the caretaker. Caretaker training can improve the skills, as well as the attitudes, of animal handlers and thus reduce the reactionary fear in animals they are handling.

Food companies are being challenged to address consumer concern of how animals are treated on-farm. This issue is being pushed back up the food chain to the supplier and, ultimately, to the producer. Many farms looking to their future are developing animal care programs to socially defend their production practices to their neighbors, their community, and their consumers. They are very concerned about being the next social video. While some of the activist videos may misrepresent production practices, some of these have exposed major problems. The majority of problems seen have been around animal handling (use of prods, tail twisting), untreated lameness, calf processing procedures (handling, dehorning, castration), and non-ambulatory care and handling. From all of these videos, there appears to be a serious disconnect between management intentions (Standard Operating Procedures) and daily employee actions. Root cause analyses from many of these videos traces back to the training program of caretakers. Often times, there simply isn't one. Caretaker training programs need to convey (1) the protocol details (tasks), (2) the risks of not using the protocol, and (3) management's commitment to animal welfare. Animal welfare is truly dependent on the owner's values and attitudes; it is not related to size of facility, as social media tends to portray. The main goal of any on-farm animal welfare program should be to create team behavior, so working together to resolve problem situations (non-ambulatory animals, etc.) is the norm. This goes far toward reducing the potential for animal abuse. Welfare is a truly a combination of facilities and people. There are many areas around a dairy that should challenge us to review how animals naturally behave. Great strides have been made in our knowledge of cow comfort in dairy housing: whether it is our understanding the cows' need for adequate space (to allow natural behavior in resting and rising) or her desire to lie on well-bedded surfaces and stand on soft floors. Best management practices have also supported her desire to drink after being milked, and thus the provision of water troughs at the parlor exit were recommended.

Like any management strategy, creating an animal welfare program is not going to be a one-time effort and writing the final draft. This is an on-going process that involves refining daily tasks toward best animal care. There is usually a better way of doing things, so continual review and improvement should be the driving energy behind all programs. The primary resource needed to implement an animal welfare program is management commitment - not any different than any other successful business endeavor.

Science alone will not prevail. Food companies and farms are feeling more and more pressure to provide proof they are actually doing what they say they are doing. On-farm audits can provide third-party verification of production practices for consumers. Additionally, regular audits can provide feedback to management that what they WANT done is actually BEING done. This can give a manager an evaluation of procedural drift that may be occurring and allow them to alter their training to address the drift. A common misconception is that welfare audits dictate the management of the farm; this is not true. However, they do set acceptable outcomes of farm management, such as the percentage of acceptable lameness, thin cows, dirty cows, etc. Animal welfare audits should verify that animals are cared for properly, to contemporary standards, but allow management will meet each standard in its own way.

All animal welfare programs should be based on continual improvement, not on punishment, to encourage producer advancement in animal care. But to truly engage the industry, there needs to be an incentive for the producer to improve. For many producers in the industry, the incentive may be pride in their operation and their reputation. For other, the incentive may be their market has put a condition on their selling their product.

Differentiating between evaluations and audits involves the verification process and the subsequent follow-up action. The value of third-party audits is that they provide more credence to the farm program in that the auditor is not financially vested in the farm and whether it passes or not. Additionally, there are is a follow-up process for non-conformances to ensure continual improvement. An audit involves verification of parameters to the extent the auditor is comfortable that what is said is actually happening. For example: The herd health plan states that all animals are observed once daily and any animal suspicious of health complications is pulled for further evaluation. Verification for this could include: (1) viewing the Standard Operating Procedure, (2) asking employees about the protocol, (3) observing throughout the herd if there are any animals that need attention, (4)

looking at animals in the hospital for the severity of their illness, or (5) reviewing hospital records for length of stay. An auditor should use several types of verification to support their conclusion. Just one of the above observations may not give an accurate representation of how the process works on a regular basis. The intent behind the original question is whether animals are looked at on a daily basis for abnormalities AND that abnormalities are given review and treatment on a timely basis.

Whether an evaluation or an audit, any and all aspects of the farm where livestock pass through are to be viewed. This encompasses the calf barn, the milking parlor, the hospital, loading areas, and all housing types.

COMPONENTS OF ANIMAL WELFARE PROGRAMS/AUDITS

Standard Operating Procedures. Basic SOPs should be developed for all major stations across the dairy: maternity, calf care, milking, herd health, hospital/non-ambulatory, foot health program, and euthanasia. Additional SOPs that traverse the dairy may include employee training, facility maintenance, animal handling and transportation, and records. This is not an exhaustive list, but hopefully gives thought to areas for consideration. Initially, many audits accepted non-written protocols or herd health plans IF more than one person could corroborate the same information when questioned independently. However, this issue has evolved to where protocols are required to be written down (herd health plans, milking protocols, calf care protocols, etc.). It is in the best interest for producers to have this information written down in the event of an emergency where an "extra" has to fill in for a caretaker. Having the SOP written down helps ensure the animals are taken care of in a consistent manner. These protocols do not have to be fancy or exhaustive, but do need to reflect the basic care expected to be given. Additionally, caretakers need to be trained on them and they need to be available for review to the caretakers that might need to use them.

Caretaker Training. As mentioned above, caretakers need to be trained on the expected protocols for their area. Additionally, training must include managements' expectations of animal care. A no-tolerance of abuse policy should be included and each caretaker should have a signed care statement on file. All training should be reviewed at least annually, with a protocol for oversight or re-training sooner, if needed. While this may sound awkward, it will go far in supporting management if an event occurs. This is even encouraged in family operations. Furthermore, outside contractors (foot trimmers, haulers, breeders, etc.) must be made aware of the animal care policy and have signed statements on file with the facility as well.

Animal Observations. A primary barometer for evaluating animal care is letting the animals tell as much of the story as they can. The audits I am familiar with have similar observations, including:

- *Body condition:* evaluates the nutrition programs' ability to meet the production status of the animal
- *Locomotion:* verifies the foot care program, as well as parts of the herd health plans intent to observe all animals daily and catch abnormalities quickly
- *Hygiene:* assesses the routine efforts of facility cleanliness
- *Hock and knee lesions:* gages cow comfort in their housing type

COMMERCIAL ANIMAL WELFARE AUDIT PROGRAMS

There are several commercial programs available to the dairy industry. They vary in how they are implemented on-site or how the program is managed, but they all contain the core parameters listed above. There are evaluation programs, such as National Milk Producers Federation FARM Program (Farmers Assuring Responsible Management). This program does not contain a pass/fail option, but is developing an action plan protocol to improve conditions that don't meet their criteria. Other programs are true audit programs and do contain pass/fail options. These programs, such as Validus' Animal Welfare Review – Dairy and American Humane Certified, have been available for several years. Other programs may include various state, association, and/or cooperative programs more specific to associations or niche markets.

CONCLUSIONS

Good animal welfare programs facilitate better environments for cows, as well as better work environments for the employees. Comfortable, well-cared animals are easier to work with and may be more productive. Implementing a third-party audit of your program can identify problem areas and improve the welfare of your animals. These programs can provide valuable feedback and help manage procedural drift in daily tasks.

USING KNOWLEDGE OF CALF BEHAVIOR TO IMPROVE GROWTH, HEALTH, AND WELFARE

Emily K. Miller-Cushon, Department of Animal Sciences, University of Florida
Trevor J. DeVries, Department of Animal Biosciences, University of Guelph

INTRODUCTION

Despite many advances in our knowledge of calf management and nutrition, the dairy industry continues to be challenged with finding ways to raise calves in such a manner that not only optimizes health, growth, and efficiency, but also is best for their welfare. This paper will identify some of those welfare challenges and how we can use knowledge of calf behavior to identify housing and feeding programs that optimize growth, health, and welfare. A primary focus will be on identifying those factors, including the level of milk feeding, timing and method of weaning, impact of solid feed type, and housing, that contribute to a smooth transition from milk to solid feed at the time of weaning.

MILK FEEDING LEVELS

There are a range of viewpoints on how best to feed and manage dairy calves early in life. Traditional approaches to rearing dairy calves have focused on stimulating early solid feed intake through restricting intake of milk or milk replacer. A conventional milk feeding rate is approximately 10% of a calf's birth weight, an amount that translates to between 4 and 5 L/day, supporting under 0.5 kg/d of weight gain (Appleby, 2001; Jasper and Weary, 2002). This conventional approach to feeding calves facilitates early weaning and has been viewed as economically appealing due to reduced feed costs. However, there is increasing on-farm adoption of alternative feeding programs which provide a higher plane of nutrition. Feeding programs which provide greater milk allowances support greater growth relative to outcomes of conventional restricted feeding, and thus are typically referred to as "intensified feeding," or "feeding for accelerated growth" or "feeding for biologically normal growth". These feeding programs provide quantities of milk that more closely resemble intake levels of a suckling calf, and allow "biologically appropriate" growth rates (Drackley, 2008), which fall between 0.75 and 1 kg/d (Appleby, 2001; Tedeschi and Fox, 2009). In supporting increased intake, intensified feeding programs provide a number of immediate benefits, including greater growth prior to weaning, performance of natural feeding patterns, and improved welfare. Further, recent interest has turned to longer-term impacts of greater rates of weight gain early in life, such as improved performance in lactation.

In contrast to the restricted amounts of milk provided in conventional feeding programs (10% of BW, or 4 to 5 L/d), calves provided more milk are able to double their nutrient intake (Khan et al., 2011a), consuming between 8 and 16 L/d when milk is provided ad libitum (Appleby, 2001; Jasper and Weary, 2002; Miller-Cushon et al., 2013a). In terms of milk replacer, conventional feeding programs typically provide 1 to 1.5% of BW on a dry matter (DM) basis whereas intensified programs provide milk at 2 to 3% of BW on a DM basis. Some intensified feeding programs also alter the DM content of the milk replacer in addition to the feeding amounts; for example, providing milk replacer prepared with 18% compared to 12% DM (Terré et al., 2009).

Improved growth in intensified feeding programs can be accomplished by providing higher amounts of milk replacer (Diaz et al., 2001; Brown et al., 2005) as well as whole milk (Jasper and Weary, 2002). However, a calf's protein requirement increases with rate of body weight gain; thus, feeding a conventional milk replacer (containing 20 to 22% CP and 20 to 21% fat) at a greater rate will not supply sufficient protein for lean tissue growth and surplus energy will be converted to fat (Drackley, 2008; Brown et al., 2005). When energy is not limiting, calves have increased lean tissue growth when milk replacer contains 26 to 28% CP, and 15 to 20% fat (Diaz et al., 2001). In comparison, whole milk contains approximately 27%

protein and 26 to 28% fat (Appleby, 2001; Shamay et al., 2005).

Intensified feeding programs have marked impacts on performance of the calf early in life, including improved rate of weight gain, structural growth, and efficiency of feed conversion (Diaz et al., 2001; Khan et al., 2007). Whereas conventional feeding programs typically support 0.3 to 0.6 kg/d in growth, intensified feeding programs allow weight gain ranging from 0.6 to over 1 kg/d. For calves provided milk ad libitum, average daily weight gain is typically between 0.8 and 1.2 kg/d (Appleby, 2001; Miller-Cushon et al., 2013a; Jasper and Weary, 2002). Advantages in structural growth (girth and height) in calves managed in an intensified feeding program have been noted both preweaning and postweaning (Khan et al., 2007).

In addition to impacting growth, the milk feeding program greatly influences feeding behavior patterns of the calf. Intensified feeding systems, especially those that provide ad libitum access to milk or milk replacer, allow calves to exhibit a diurnal pattern of milk intake (Miller-Cushon et al., 2013a). Calves provided milk ad libitum have peaks of feeding activity at sunrise and sunset, and consume milk in 8 to 10 meals/day (Appleby, 2001; Miller-Cushon et al., 2013a). This pattern of milk intake and resembles the natural behavior of a calf nursing the dam (Lidfors et al., 1994; de Passillé, 2001). In contrast, calves fed according to conventional practice typically receive their milk allotment in two feedings per day, such that total time spent feeding during the day is greatly reduced. For example, calves provided milk at a rate of 5L/d spent about 10 min/d feeding, whereas calves provided milk ad libitum spent 45-60 min feeding (Appleby et al., 2001; Miller-Cushon et al., 2013a).

Calves fed restricted quantities of milk have frequent unrewarded visits to the feeder (De Paula Vieira et al., 2008; Borderas et al., 2009), suggesting that they are hungry (De Paula Vieira et al., 2008). Further, calves are highly motivated to suck and will spend considerable amounts of time engaged in non-nutritive sucking when provided restricted amounts of milk (Miller-Cushon et al., 2013a). In addition to differences in feeding behavior, calves provided restricted amounts of milk spent less time lying (Borderas et al., 2009; De Paula Vieira et al., 2008), vocalized more frequently (Thomas et al., 2001), and performed less play behavior (Krachun et al., 2010). Thus, intensified feeding systems have clear welfare implications for the calf, allowing performance of natural feeding behavior patterns and reducing hunger.

From an economic perspective, motivation for feeding greater amounts of milk to calves depends in part on the potential long-term impacts of this feeding practice on performance of the calf. In controlled studies, early plane of nutrition has been found to have a number of impacts on longer-term production potential. In comparison to providing calves with restricted access to a low-energy milk replacer (23% crude protein, 15% fat), provision of whole milk to calves in ad libitum amounts was reported to have a range of long-term positive effects across different studies, including reduced age at conception and calving (Bar-Peled et al., 1997), increased BW at calving (Bar-Peled et al., 1997; Moallem et al., 2010), and improved milk production (Bar-Peled et al., 1997) or milk fat yield (Shamay et al., 2005; Moallem et al., 2010).

Similarly, results of studies comparing different amounts and qualities of milk replacer suggest that an intensified milk replacer feeding program reduces age at first calving (Raeth-Knight et al., 2009; Davis Rincker et al., 2011). Regression analysis of several published data sets suggests a positive impact of preweaning growth on later milk production, with an improvement in milk production of 225 kg for an increase in pre-weaning ADG of 100 g/d (Bach, 2011). Soberon et al. (2012) also reported a positive correlation between preweaning ADG with first lactation milk yield, suggesting an improvement in milk yield of 850 to 1,113 kg for every 1 kg of preweaning ADG. Davis Rincker et al. (2011) reported an economic analysis suggesting that, although cost of intensified feeding was greater than conventional, total costs by time of first lactation were not different.

Despite significant effects of intensified feeding programs on feeding behavior of the calf prior to weaning, there is little evidence to suggest that preweaning milk feeding level has a persistent effect on feeding patterns (Miller-Cushon, 2013a). However, Miller-Cushon (2013a) reported that, in the week after weaning, calves previously provided restricted amounts of milk consumed their solid feed more quickly and had larger meals, compared to calves provided milk ad libitum. Although differences in meal characteristics did not persist, differences in rates of intake after weaning suggest that previous experience with a restricted feeding scenario may have some impact on feeding motivation.

WEANING STRATEGIES

Although intensified feeding programs hold much potential to improve short and long-term performance and welfare of dairy calves, there remain challenges with their implementation. The

long-standing popularity of conventional restricted milk feeding programs was based on encouraging solid feed intake early in life and facilitating a smooth transition at weaning. Solid feed intake early in life is critical for rumen development, and consistent weight gain through weaning requires that the calf be consuming sufficient amounts of solid feed prior to removal of milk (Khan et al., 2011a). When provided greater quantities of milk, calves have less frequent and smaller meals of concentrate (Miller-Cushon et al., 2013a). Consequently, rumen development is delayed, such that post-weaning nutrient digestibility is lower in calves provided more milk (Terré et al., 2007; Hill et al., 2010). Thus, a challenge with an intensified feeding program is to support consistent growth through weaning.

Although greater weaning weights as a result of increased pre-weaning nutrition can be maintained into the post-weaning period (e.g. 8 kg weight advantage at 20 d post-weaning (Jasper and Weary, 2002) and 20 kg weight advantage at 56 d post-weaning; Miller-Cushon et al., 2013a), these results are not consistent. A number of studies indicate that weight gain of calves provided great quantities of milk may suffer at time of weaning if solid feed intake prior to weaning was low. For example, weight gain of calves provided milk replacer ad libitum may plateau during weaning whereas restricted-fed calves maintain consistent growth (ADG of -0.03 vs 0.6 kg/d; Miller-Cushon et al., 2013a). In some cases, differences in weight gain through weaning negated any body weight advantage arising from the pre-weaning feeding program (Borderas et al., 2009; DePassillé et al., 2011). This suggests that maintenance of greater body weights is extremely sensitive to weaning method.

The most important aspect of a weaning program is encouraging sufficient intake of solid feed intake prior to removal of milk. A gradual weaning process that encourages greater solid feed intake appears to maintain weight advantages for calves managed in intensified feeding systems. Khan et al. (2007) employed a step-down weaning method, reducing milk quantity 20 d prior to weaning at 7 weeks, and found that calves previously fed milk ad libitum maintained a weight advantage 40 d post-weaning. In a study by Sweeney et al. (2010), calves were fed up to 12 kg of milk/d by automated feeders, and weaned at 41 d abruptly or over 3 gradual weaning periods (4, 10, or 22 d). Those researchers found that during the 9 d following weaning, the calves weaned over 22 and 10 d ate more starter and had better weight gains than abruptly weaned calves and those weaned over 4 d. Further, they found that abruptly weaned calves lost weight during that period. These studies suggest that a gradual weaning program is necessary, particularly when feeding higher levels of milk.

Another important factor influencing the success of weaning, as well as post-weaning performance, is the age at which weaning occurs. de Passillé et al. (2011) reported that calves provided greater quantities of milk had no weight advantage over conventionally-fed calves after abrupt weaning at 7 weeks, but when weaned later (at 13 weeks), calves had begun consuming more solid feed and maintained a weight advantage over calves provided less milk. In a more recent study, Eckert et al. (2015) compared weaning calves at 6 vs 8 weeks of age; in that study calves were fed 8 L/d of milk, which was stepped down to 4 L/d for one week prior to weaning. The results of that study demonstrated that the later weaned calves (at 8 weeks) had more nutrient intake, higher growth rates post-weaning, more gastrointestinal development at weaning, and fewer behavioral signs of weaning distress compared with those weaned at 6 weeks of age.

SOLID FEED INTAKE AND SELECTION

In addition to the milk feeding program, solid feed provision is an important component of early management. When managed in conventional feeding systems, calves are typically provided ad libitum access to a high-energy grain concentrate alongside restricted quantities of milk. Early intake of concentrate is critical for rumen development, as rumen papillae development occurs in response to butyrate produced through fermentation of carbohydrates (Warner et al., 1956; Sander et al., 1959). Provision of forage has long been discouraged, out of concern that it will displace concentrate intake and, consequently, impair rumen development (Hill et al. 2008; Kertz et al. 1979). However, there is evidence to suggest that forage provision does not need to reduce concentrate intake (Khan et al. 2011b; Castells et al. 2012) and, further, may positively impact ruminal environment, reducing acidity of ruminal fluid (Suárez et al. 2007; Khan et al. 2011b) and improving feed efficiency (Coverdale et al. 2004). Provision of chopped forage has also been noted to reduce non-nutritive oral behavior of the calf (Castells et al., 2013; Montoro et al., 2013) suggesting that it may satisfy a motivation to perform oral foraging-type behavior.

Results of feeding hay seem to depend on the form and type of hay. The positive effects of hay intake on nutrient digestibility are reduced when hay is finely ground, suggesting that benefits of hay are, in

part, due to its physical effectiveness (Montoro et al., 2013). It has also been shown that providing alfalfa hay may reduce concentrate intake, as calves consumed larger amounts of alfalfa hay compared to other types of hay, such as ryegrass (Castells et al., 2012).

It is interesting to note that when offered a choice of hay and concentrate, calves selected a proportion of hay ranging between 5 and 30% of total DM intake (Castells et al., 2012; Miller-Cushon et al., 2013b; Khan et al., 2011b), depending on the type of hay provided and, potentially, other nutritional factors such as milk intake. Selection in favor of hay has been found to decrease after weaning, suggesting that calves may alter dietary selection patterns in response to energy requirements (Miller-Cushon et al., 2013b).

In all, these research results indicate that, in addition to provision of a high-quality starter concentrate, offering limited amounts of a physically effective fiber from forage (limited to 5 to 10% of total DMI) may also be ideal for calf growth and development.

SOCIAL HOUSING AND FEEDING MANAGEMENT

Implementation of intensified feeding programs can also impact feeding management on a larger scale. Whereas conventionally-raised calves are typically housed individually, intensified feeding systems are often being adopted hand-in-hand with group-housing systems. Group housing of calves allows for the social facilitation of feeding behavior, resulting in calves beginning to consume solid feed earlier in life and consuming more solid feed prior to, and at, weaning (Hepola et al. 2006; De Paula Vieira et al. 2010; Miller-Cushon and DeVries, 2016). Group-housed calves also vocalized less during weaning (De Paula Vieira et al., 2010), suggesting that social contact is beneficial during this stressful transition. Calves housed with social contact gain weight more consistently through weaning (Chua et al., 2002; Miller-Cushon and DeVries, 2016), likely due in part to both greater intakes of solid feed prior to removal of milk and reduced stress. Thus, social contact may contribute to a successful weaning transition of calves managed in an intensified feeding program. Further, results from Miller-Cushon and DeVries (2016) suggested that providing a social environment for calves early in life may have positive impacts meal patterning, which persist post-weaning, and that early social contact may increase the longer-term preference for social feeding.

A major factor helping the implementation of intensified feeding programs is the growing adoption of computerized calf-feeding systems. These systems reduce the manual labor associated with increasing milk allotments, facilitate group-housing for calves while allowing for monitoring of individual intake, and provide control over feeding patterns and weaning programs. Calves fed by a computerized feeder are typically managed in larger groups, with 10 to 15 calves per feeder (Weber and Wechsler, 2001; Jensen and Holm, 2003).

One of the perceived challenges associated with group-feeding of calves has been cross-sucking. Dairy calves are highly motivated to suck when they taste milk (De Passillé, 2001). If calves do not have the opportunity to express this behavior while eating (i.e. when consuming milk from a bucket), they start "sucking" objects (non-nutritive sucking) or other calves (non-nutritive cross-sucking) after drinking, trying to cope with the lack of a teat and fulfill the desire to suck (De Passillé, 2001). Researchers have demonstrated than calves are provided more milk, particularly through some type of teat-based system (automated feeder or otherwise), calves will have longer feeding periods, which is positively associated with feeling satiation and reduced non-nutritive sucking (De Passillé, 2001; Veissier et al., 2002). For calves fed by automated feeders, De Passillé et al (2004) concluded that cross-sucking is controlled if sufficient time to suck is allowed.

Controlling competition is, thus, also key factor in group-housing situation. Competition could be reduced when milk allowance and number of meals are increased (Jensen and Holm, 2003; De Paula Vieira et al., 2008; Herskin et al., 2010), and when calf age and size range in the pen is minimized (Færevik et al., 2010). The number of available feeding places (for milk and/or solid feed) plays a role in competition as well. Even minimal competition for access to artificial teats (1:2 ratio of teat to calf) has been shown to reduce milk intake in the early weeks of life for calves fed ad libitum (Miller-Cushon et al., 2014). Further, calves chose to stand and feed at the same time, even when provided a single feeding space (Miller-Cushon et al., 2014), suggesting that calves may be motivated to feed in synchrony rather than adopting different feeding schedules.

Exposure to a competitive feeding environment also has potential to have longer-term impacts on feeding and social behavior. Compared to calves reared in a non-competitive feeding environment, calves reared with restricted teat access were found to persistently displace each other more frequently and consume their feed more quickly after weaning, despite having unrestricted access to feed buckets during the post-weaning stage (Miller-Cushon et al., 2014). Persistent competitive behavior has potential to pose problems later in life, as

competition for access to feed in adult cattle encourages large and infrequent meals (Hosseinkhani et al., 2008; DeVries and von Keyserlingk, 2009), which can negatively affect ruminal pH (Krause and Oetzel, 2006). Thus, as intensified feeding systems are increasingly adopted, further work is encouraged to assess longer-term effects of different management strategies on both performance and behavioral development of dairy calves.

CONCLUSIONS

In summary, varied approaches to calf management and nutrition have both immediate and longer-term implications for calf performance, behavior and welfare. When managed in intensified feeding systems, calves will consume at least twice the amount of nutrients typically supplied according to conventional feeding strategies, supporting greater rates of growth and reducing hunger. Feeding behavior is greatly influenced by feeding program, with access to greater quantities of milk allowing the expression of more natural feeding behavior patterns, such as those exhibited by a calf suckling the dam, and reducing behavioral indicators of hunger. Further, greater rates of gain prior to weaning are associated with earlier calving ages and improved milk production, suggesting that there may be a longer-term economic advantage to providing calves with more milk.

Successful weaning of calves, especially those provided greater quantities of milk, requires a gradual process of reducing milk intake to encourage sufficient solid feed intake prior to removal of milk. There is also growing evidence that provision of hay may be beneficial in encouraging greater total intake prior to weaning. Group-housing is becoming more prevalent and social housing for calves holds a number of benefits including encouraginggreater solid feed intake and reduces stress through weaning. However, competition in group-housed calves may reduce milk intake when access to teats is restricted. Further research in this area is needed to refine approaches for housing calves in large social groups, and to identify the longer-term behavioral and performance implications of early life factors.

ACKNOWLEDGEMENTS

This paper is an updated version of a proceedings paper written for, and presented at, the 2015 Florida Ruminant Nutrition Symposium held in Gainesville, FL in February 2015. Much of the research presented in this manuscript was funded by the Natural Sciences and Engineering Research Council of Canada, the Ontario Ministry of Agriculture, Food, and Rural Affairs, the University of Guelph, Nutreco Canada, the Canadian Foundation for Innovation and the Ontario Research Fund.

REFERENCES

Appleby, M. 2001. Performance and feeding behaviour of calves on ad libitum milk from artificial teats. Appl. Anim. Behav. Sci. 74:191–201.

Bach, A. 2011. Optimizing production of the offspring: Nourishing and managing the dam and the calf early in life. J. Anim. Sci.

Bar-Peled, U., B. Robinzon, E. Maltz, H. Tagari, Y. Folman, I. Bruckental, H. Voet, H. Gacitua, and A.R. Lehrer. 1997. Increased weight gain and effects on production parameters of Holstein heifer calves that were allowed to suckle from birth to six weeks of age. J. Dairy Sci. 80:2523–2528.

Borderas, T. F., A. M. de Passillé, and J. Rushen. 2009. Feeding behavior of calves fed small or large amounts of milk. J. Dairy Sci. 92:2843–2852.

Brown, E. G., M. J. Vandehaar, K. M. Daniels, J. S. Liesman, L. T. Chapin, D. H. Keisler, and M. S. W. Nielsen. 2005. Effect of increasing energy and protein intake on body growth and carcass composition of heifer calves. J. Dairy Sci. 88:585–94.

Castells, L., A. Bach, G. Araujo, C. Montoro, and M. Terré. 2012. Effect of different forage sources on performance and feeding behavior of Holstein calves. J. Dairy Sci. 95:286–293.

Chua, B., E. Coenen, J. van Delen, and D. M. Weary. 2002. Effects of pair versus individual housing on the behavior and performance of dairy calves. J. Dairy Sci. 85:360–364.

Coverdale, J. A., H. D. Tyler, J. D. Quigley, and J. A. Brumm. 2004. Effect of various levels of forage and form of diet on rumen development and growth in calves. J. Dairy Sci. 87:2554–2562.

Davis Rincker, L. E., M. J. VandeHaar, C. A. Wolf, J. S. Liesman, L. T. Chapin, and M. S. Weber Nielsen. 2011. Effect of intensified feeding of heifer calves on growth, pubertal age, calving age, milk yield, and economics. J. Dairy Sci. 94:3554–3567.

DePassillé, A. M., T. F. Borderas, and J. Rushen. 2011. Weaning age of calves fed a high milk allowance by automated feeders: effects on feed, water, and energy intake, behavioral signs of hunger, and weight gains. J. Dairy Sci. 94:1401–1408.

De Passillé, A. M. 2001. Sucking motivation and related problems in calves. Appl. Anim. Behav. Sci. 72:175–187.

De Passillé, A. M., J. Rushen, and D. Weary. 2004. Designing good environments and management for calves. Adv. Dairy Technol. 16:75-89.

De Paula Vieira, A., V. Guesdon, A. M. de Passillé, M. Vonkeyserlingk, and D. Weary. 2008. Behavioural indicators of hunger in dairy calves. Appl. Anim. Behav. Sci. 109:180–189.

De Paula Vieira, A., M. A. G. von Keyserlingk, and D. M. Weary. 2010. Effects of pair versus single housing on performance and behavior of dairy calves before and after weaning from milk. J. Dairy Sci. 93:3079–3085.

Diaz, M. C., M. E. Van Amburgh, J. M. Smith, J. M. Kelsey, and E. L. Hutten. 2001. Composition of growth of Holstein calves fed milk replacer from birth to 105-kilogram body weight. J. Dairy Sci. 84:830–42.

Drackley, J. K. 2008. Calf nutrition from birth to breeding. Vet. Cinics North Am. Food Anim. Pract. 24:55–86.

Eckert, E. C., H. E. Brown, K. E. Leslie, T. J. DeVries, and M. A. Steele. 2015. Weaning age impacts growth, feed intake, gastrointestinal development and behavior of Holstein calves fed an elevated plane of nutrition during the pre-weaning stage. J. Dairy Sci. 98: 6315-6326.

Færevik, G., M. B. Jensen, and K. E. Bøe. 2010. The effect of group composition and age on social behavior and competition in groups of weaned dairy calves. J. Dairy Sci. 93:4274-4279.
Hepola, H., L. Hanninen, P. Pursiainen, V.-M. Tuure, L. Syrjala-Qvist, M. Pyykkonen, and H. Saloniemi. 2006. Feed intake and oral behaviour of dairy calves housed individually or in groups in warm or cold buildings. Livest. Sci. 105:94–104.

Hill, T. M., H. G. Bateman, J. M. Aldrich, and R. L. Schlotterbeck. 2008. Effects of the amount of chopped hay or cottonseed hulls in a textured calf starter on young calf performance. J. Dairy Sci. 91:2684–2693.

Hill, T. M., H. G. Bateman, J. M. Aldrich, and R. L. Schlotterbeck. 2010. Effect of milk replacer program on digestion of nutrients in dairy calves. J. Dairy Sci. 93:1105–1115.

Hosseinkhani, A., T. J. Devries, K. L. Proudfoot, R. Valizadeh, D. M. Veira, and M. A. G. von Keyserlingk. 2008. The effects of feed bunk competition on the feed sorting behavior of close-up dry cows. J. Dairy Sci. 91:1115–1121.

Jasper, J., and D. M. Weary. 2002. Effects of ad libitum milk intake on dairy calves. J. Dairy Sci. 85:3054–3058.

Jensen, M. B., and L. Holm. 2003. The effect of milk flow rate and milk allowance on feeding related behaviour in dairy calves fed by computer controlled milk feeders. Appl. Anim. Behav. Sci. 82:87–100.

Herskin, M. S., F. Skjøth, and M.B. Jensen. 2010. Effects of hunger level and tube diameter on the feeding behavior of teat-fed dairy calves. J. Dairy Sci. 93:2053-2059.

Kertz, A. F., L. R. Prewitt, and J. P. Everett. 1979. An early weaning calf program: Summarization and review. J. Dairy Sci. 62:1835–1843.

Khan, M. A., H. J. Lee, W. S. Lee, H. S. Kim, S. B. Kim, K. S. Ki, J. K. Ha, H. G. Lee, and Y. J. Choi. 2007. Pre- and postweaning performance of holstein female calves fed milk through step-down and conventional methods. J. Dairy Sci. 90:876–885.

Khan, M. A., D. M. Weary, and M. A. G. von Keyserlingk. 2011a. Invited review: effects of milk ration on solid feed intake, weaning, and performance in dairy heifers. J. Dairy Sci. 94:1071–1081.

Khan, M. A., D. M. Weary, and M. A. G. von Keyserlingk. 2011b. Hay intake improves performance and rumen development of calves fed higher quantities of milk. J. Dairy Sci. 94:3547–3553.

Krachun, C., J. Rushen, and A. M. de Passillé. 2010. Play behaviour in dairy calves is reduced by weaning and by a low energy intake. Appl. Anim. Behav. Sci. 122:71–76.

Krause, K., and G. Oetzel. 2006. Understanding and preventing subacute ruminal acidosis in dairy herds: A review. Anim. Feed Sci. Technol. 126:215–236.

Lidfors, L., P. Jensen, and B. Algers. 1994. Suckling in free-ranging beef cattle – Temporal patterning of suckling bouts and effects of age and sex. Ethology. 98:321-332.

Miller-Cushon, E. K., R. Bergeron, K. E. Leslie, and T. J. Devries. 2013a. Effect of milk feeding level on development of feeding behavior in dairy calves. J. Dairy Sci. 96:551–564.

Miller-Cushon, E. K., R. Bergeron, K. E. Leslie, G. J. Mason, and T. J. Devries. 2013b. Effect of early exposure to different feed presentations on feed sorting of dairy calves. J. Dairy Sci. 96:4624–4633.

Miller-Cushon, E. K., R. Bergeron, K. E. Leslie, G. J. Mason, and T. J. DeVries. 2014. Competition during the milk-feeding stage influences the development of feeding behavior of pair-housed dairy calves. J. Dairy Sci. 97:6450–6462.

Miller-Cushon, E. K., and T. J. DeVries. 2016. Effect of social housing on the development of feeding behavior and social feeding preferences of dairy calves. J. Dairy Sci. 99:1406-1417.

Montoro, C., E. K. Miller-Cushon, T. J. DeVries, and A. Bach. 2013. Effect of physical form of forage on performance, feeding behavior, and digestibility of Holstein calves. J. Dairy Sci. 96:1117-1124.

Moallem, U., D. Werner, H. Lehrer, M. Zachut, L. Livshitz, S. Yakoby, and A. Shamay. 2010. Long-term effects of ad libitum whole milk prior to weaning and prepubertal protein supplementation on skeletal growth rate and first-lactation milk production. J. Dairy Sci. 93:2639–2650.

Raeth-Knight, M., H. Chester-Jones, S. Hayes, J. Linn, R. Larson, D. Ziegler, and B. Ziegler. 2009. Impact of conventional or intensive milk replacer programs on Holstein heifer performance through six months of age and during first lactation. J. Dairy Sci. 92:799–809.

Sander, E. G., R. G. Warner, H. N. Harrison, and J. K. Loosli. 1959. The stimulatory effect of sodium butyrate and sodium propionate on the development of rumen mucosa in the young calf. J. Dairy Sci. 42:1600–1605.

Shamay, A., D. Werner, U. Moallem, H. Barash, and I. Bruckental. 2005. Effect of nursing management and skeletal size at weaning on puberty, skeletal growth rate, and milk production during first lactation of dairy heifers. J. Dairy Sci. 88:1460–1469.

Soberon, F., E. Raffrenato, R. W. Everett, and M. E. Van Amburgh. 2012. Preweaning milk replacer intake and effects on long-term productivity of dairy calves. J. Dairy Sci. 95:783-793.

Suárez, B. J., C. G. Van Reenen, N. Stockhofe, J. Dijkstra, and W. J. J. Gerrits. 2007. Effect of roughage source and roughage to concentrate ratio on animal performance and rumen development in veal calves. J. Dairy Sci. 90:2390–403.

Sweeney, B. C., J. Rushen, D. M. Weary and A. M. de Passillé. 2010. Duration of weaning, starter intake and weight gain of dairy calves fed large amounts of milk. J. Dairy Sci. 93: 148-152.

Tedeschi, L. O., and D. G. Fox. 2009. Predicting milk and forage intake of nursing calves. J. Anim. Sci. 87:3380–3391.

Terré, M., M. Devant, and A. Bach. 2007. Effect of level of milk replacer fed to Holstein calves on performance during the preweaning period and starter digestibility at weaning. Livest. Sci. 110:82–88.

Terré, M., C. Tejero, and A. Bach. 2009. Long-term effects on heifer performance of an enhanced-growth feeding programme applied during the preweaning period. J. Dairy Res. 76:331–9.

Thomas, T. J., D. M. Weary, and M. C. Appleby. 2001. Newborn and 5-week-old calves vocalize in response to milk deprivation. Appl. Anim. Behav. Sci. 74:165–173.

Veissier, I., A. M. de Passillé, G. Després, J. Rushen, I. Charpentier, A. R. Ramirez de la Fe, and P. Pradel. 2002. Does nutritive and non-nutritive sucking reduce other oral behaviors and stimulate rest in calves? J. Anim. Sci. 80:2574-2587.

Warner, R. G., W. P. Flatt, and J. K. Loosli. 1956. Dietary factors influencing the development of the ruminant stomach. J. Agric. Food Chem. 4:788–792.

Weber, R., and B. Wechsler. 2001. Reduction in cross-sucking in calves by the use of a modified automatic teat feeder. 72:215–223.

NOTES