MANAGING THE WEANING TRANSITION FOR SUCCESSFUL CALF PROGRAMS

T. S. Dennis, F. X. Suarez-Mena, T. M. Hill, J. D. Quigley, and W. Hu
Nurture Research Center, Provimi North America, Cargill Animal Nutrition, Brookville, OH 45309

INTRODUCTION

With increased emphasis on early life feeding programs for calves, more information regarding successful weaning management is needed. Dairy farmers and calf raisers are feeding double, and sometimes nearly triple the liquid feeding rates that had been recommended for decades prior. While growth rates are often excellent when high milk feeding rates are used pre-weaning, much of the growth advantage gained is lost due to poor growth rates in the weeks following weaning. Several recently published studies have aimed to elucidate causes for reduced growth rates after weaning, or the “weaning slump”, and some have shown poor starter digestibility as a result of less accumulated starter intake before weaning is a major driver. However, poor weaning management in general can result in reduced growth rates post-weaning, as more studies have shown that length of weaning, milk-reduction procedures, starter composition and physical form, forage provision, and a myriad of other factors contribute to how well calves adjust before, during, and immediately after weaning.

MILK FEEDING RATE AND DIET DIGESTIBILITY AROUND WEANING

Much of the push for feeding high amounts of milk or milk replacer (MR) has been spurred by several recent studies suggesting greater pre-weaning average daily gain increases first lactation milk yields. The simplest way to increase weight gain is to increase energy and protein intakes by feeding more milk or milk replacer. However, recent studies from Penn State (Gelsinger et al., 2016) and the University of Minnesota (Chester-Jones et al., 2017) have shown that starter intake is equally important to pre-weaning average daily gain and the subsequent effects on milk production in the first lactation. One benefit of obtaining growth from starter versus the liquid diet is dry feeds positively impact digestive system development by providing substrate to the developing rumen microbiota (Baldwin et al., 2004) and substrate to the small intestine to jump-start digestive enzyme secretion (Swanson and Harmon, 2002). Additionally, one Cornell study (Soberon et al., 2012) linking pre-weaning weight gain to milk production in heifers also reported that pre-pubertal average daily gain had a greater impact on first lactation milk production than pre-weaning average daily gain alone. This suggests that a more balanced diet between liquid and solid feed that optimizes growth before and after weaning is needed for successful feeding programs.

The liquid feeding program can have a profound impact on solid feed intake and rumen development in pre-weaned calves. Kristensen et al. (2007) reported reticulorumen wet weights of 5 wk-old calves declined with increasing milk allowance, despite similar rumen epithelial morphology between calves fed 0.4, 0.6, 0.8, and 1.0 kg MR DM per d. These results corresponded to reductions in starter intake with increasing MR allowance, which may indicate physical rather than chemical rumen development is affected by MR feeding rate. Kosiorowska et al. (2011) observed similar responses to Kristensen et al. (2007) in rumen weights with increasing whole milk allowance. However, Khan et al. (2008) observed increased starter intake, reticulorumen weights, papillae length, and papillae density when calves were gradually weaned from whole milk fed at 20% of BW compared to a conventional milk feeding program (10% of BW until 49 d of age). Inconsistency in the data available may be partially explained by age at weaning, weaning protocols, differences in protein and energy intake, proportion of protein to energy in the liquid diet, and starter nutrient composition and physical form.

To help identify programs that support early starter intake but also take advantage of growth from greater MR feeding rates, Hill et al. (2010) fed calves one of four MR programs: 1) 0.4 kg of DM of a 21% crude protein (CP), 21% fat MR powder fed daily for 42 d; 2) 0.7 kg of DM of a 27% CP, 17% fat MR powder fed daily for 42 d; 3) 0.7 kg of DM of a 27% CP, 17% fat MR powder daily fed for 28 d; or 4) up to 1.1 kg of DM of a 29% CP, 21% fat MR daily fed for 49 d. Digestibility estimates were made at 8 wk of age. While calves fed up to 1.1 kg/d of MR DM had the greatest growth rates to 8 wk, weight gain and feed efficiency were poorer for those calves previously fed the highest MR rate. Much of this reduction may be explained by the depression in apparent organic matter (OM) digestibility in the immediate wk after weaning. Subsequent research trials have also illustrated MR feeding rates greater than 0.7 kg/d of DM depress apparent OM, NDF, CP, and fat digestibility immediately after (Chapman et al., 2016) and up to 4 wk post-weaning (Hill et al., 2016a; Dennis et al., 2018). These studies suggest calves fed large amounts of MR pre-weaning may have difficulty digesting nutrients from solid feed during the weaning transition.

There are several implications to these findings to consider. For example, starters containing greater amounts of fibrous by-products may be difficult to digest if calves are fed large amounts of liquid pre-weaning. Also, it may be necessary to use complex MR reduction strategies to ensure starter intake and diet digestibility is adequate prior to weaning. Because fiber digestion is primarily influenced by cellulolytic fermentation in the rumen, the low digestibility of NDF observed in these studies may indicate the rumen is less prepared for solid feed digestion in calves fed greater amounts of MR (Chapman et al., 2016). To better understand the changes in diet digestibility with age, Hill et al. (2016b) fed calves a moderate (0.7 kg/d of MR DM) or high (up to 1.3 kg/d of MR DM) milk replacer feeding program and monitored changes in nutrient digestion at three time points pre- and post-weaning. Calves fed more MR exhibited lesser apparent NDF digestion at 3, 6, and 8 wk of age. In contrast, calves fed the moderate MR program consumed more starter throughout the trial, which likely hastened rumen development as NDF digestion increased from approximately 15% at 3 wk of age to approximately 35% by 8 wk of age. Digestion of NDF in calves fed the higher level of MR did not change markedly through the 8 wk study and there were few differences with advancing age. Together, these trials identify one of likely many factors contributing to reduced growth rates around the weaning transition due to high MR feeding rates.

WEANING PROTOCOLS

A possible remedy to slowed growth post-weaning when feeding high amounts of MR may be gradually reducing MR allowance over several days to stimulate starter intake before weaning.

Several researchers have tested gradual weaning protocols in calves fed large amounts of MR (Sweeney et al. 2010; Hill et al., 2012; Dennis et al., 2018) and reported some degree of success when weaning occurred over at least a 10 d period. Additionally, Hill et al. (2016a) reported increased post-weaning digestion and growth after gradually weaning high MR-fed calves over a 3 wk period compared to a 1 wk period (stepped-down from 1.1 kg/d of MR). Later weaning ages when feeding a high rate of MR have been suggested to assist with the success of feeding programs when measuring BW gain up to 13 wk of age (Eckert et al., 2015; Meale et al., 2015). Eckert et al. (2015) reported 9 kg heavier calves at 10 wk of age with 8 vs. 6 wk weaning ages and Meale et al. (2015) reported 5 kg heavier calves at 13 wk of age with 12 vs. 8 wk weaning ages. Steele et al. (2017) reported gradually weaning calves over 12 d when fed up to 1.4 kg/d of MR DM resulted in lighter weaning weights, but similar BW at 8 wk of age to calves abruptly weaned at 7 wk of age. However, all three of these studies did not report structural growth measurements and post-weaning measurements were assessed over a short period of time. More recently, Dennis et al. (2018) reported gradual weaning over 2 wk when calves were fed up to 1.1 kg/d of MR DM did not improve growth rates to 16 wk of age to any large degree compared to calves fed 0.7 kg/d or calves fed up to 1.1 kg/d and weaned abruptly at 6 or 8 wk of age, but did improve diet digestibility post-weaning compared to calves weaned abruptly and earlier than 8 wk of age. While gradual weaning over at least 10 d appears to be the best course of action when feeding higher rates of MR, there does not appear to be an advantage in growth rate or diet utilization up to 8 wk post-weaning compared to feeding less MR pre-weaning.

IMPACT OF CALF STARTER COMPOSITION

Calf starter is an important piece of the pre-weaning feeding program and is typically offered within the first few days of life in order to encourage intake and rumen fermentation early in the pre-weaning period. Composition and physical form can vary widely depending on regional feedstuffs, processing, and other factors, but most formulations include starches, sugars, and protein from cereal grains, oilseeds, and by-product feeds. Fermentable starches and fiber are utilized by newly established populations of microbiota to produce VFA, of which propionate and butyrate are stimulatory for chemical development of the rumen epithelium (Baldwin et al., 2004). Khan et al. (2008) reported corn- and wheat-based calf starters increased rumen papillae length, density, and rumen wall thickness compared to oat- and barley-based calf starters, illustrating that starch source can affect rumen development. Castells et al. (2013) observed increased rumen weight as a percent of the total gastrointestinal tract and increased papillae length for calves fed a pelleted starter without forage provision (alfalfa or oat hay). However, when feeding calf starter diets varying in starch concentration (35 vs. 11% of DM), Kosiorowska et al. (2011) did not detect differences in rumen papillae morphology or rumen weight. The effects of starch and fiber in calf diets on rumen development has not been clearly defined by the current literature, however growth responses to starch have been recently reviewed.

Hu et al. (2018) performed a meta-regression using several published trials on the effects of starch level in starter feeds for calves up to 16 wk of age. In calves under 8 wk of age, weight gain and frame growth increased with increasing starch content. However, feed efficiency (BW gain/DM intake) was not improved in calves less than 8 wk of age in response to starch. In contrast, feed efficiency in addition to weight gain and frame growth increased with increasing starch in calf starter in calves between 8 and 16 wk of age. These results were unsurprising as metabolizable energy (ME) estimates in starters increased with increasing starch concentration. However, what is important to note is calves often have difficulty consuming enough ME through weaning to support growth rates similar to those achieved with the milk feeding program (Steele et al., 2017). Therefore, providing dry feeds with greater ME content and digestibility will help support growth rates when milk is removed from the diet.

FORAGE PROVISION BEFORE WEANING

There has been discussion in the last few years regarding offering forage or roughage to pre-weaned calves to improve growth rates and reduce rumen acidosis. Khan et al. (2016) suggested forage is necessary for better rumen health in calves transitioning to solid feed, however the literature only supports forage inclusion when calf starter particle size is small. Specifically, when pelleted feeds with moderate to high concentrations of starch (30 to 40% of dry matter) are fed to pre-ruminating calves, one can presume that starch fermentation is rapid due to both smaller particle size and heat-treatment of starch that occurs during the pelleting process. Unfortunately, data is limited investigating the effects of starch processing on rumen fermentation in pre-weaning calves. Lesmeister and Heinrichs (2004) reported feeding texturized calf starters with 30% starch, steam-flaked corn inclusion reduced starter intake compared to whole or dry-rolled corn. The authors did not measure diurnal variations in rumen pH, but given that rumen VFA concentrations were greater and rumen pH was lower for calves fed steam-flaked corn up to weaning, accumulation of fermentation acids may have resulted in reduced starter intakes and calves experiencing acidosis. However, it is important to stress that starch content was equal among formulas used by Lesmeister and Heinrichs (2004) as ingredients only differed in corn processing.

Terré et al. (2015) reported when calves were fed a pelleted starter with straw or texturized starter without straw, rumen pH was similar despite increased total dry feed intake for calves fed pelleted starter with straw. When pelleted feed was offered without straw, both rumen pH and starter intakes were lesser compared to calves fed pelleted starter with straw (Terré et al., 2015). Starter starch content was not reported, but given the inclusion of corn, wheat, barley, and oats was over 70% of the formula for both starters, starch levels would likely have been in excess of 40% on a DM basis. Greenwood et al. (1997) fed diets that were identical in ingredient and nutrient composition and only differed in processing and particle size. Bromegrass hay was included in all diets at a rate of 15% on an as-fed basis and hay was either finely ground or coarsely chopped (average particle length was not reported). Starch content was not reported by Greenwood et al. (1997), but given the inclusion of corn (41%) and oats (15%) in the starter, starch content would likely be greater than 35% of the diet on a DM basis. Small particle size coupled with high starch concentrations likely contributed to reduced pH and parakeratosis observed in calves fed a finely ground compared to a coarse diet where abrasiveness differed. Similar abrasiveness values could be achieved with coarse grain inclusion as particle size would require reduction in order to pass from the rumen to the lower gut. Prior to Greenwood et al.

(1997), Warner et al. (1973) reported starter particle size, and not fiber content, increased solid feed intake, the age at which calves began ruminating, and time spent ruminating when fed a mash compared to a pelleted starter with no forage provision or bedding. Rumination is an important behavior for reducing particle size and buffering the rumen, therefore earlier exhibition of this behavior would be considered positive for rumen development and health in calves. Unfortunately, there is limited peer-reviewed data illustrating the effects of starter physical form on rumination behavior in calves before weaning. Responses reported by Greenwood et al. (1997) and Terré et al. (2015) could support forage feeding as a way to buffer the rumen when highly processed starches are fed to calves before weaning, but forage provision should be evaluated relative to other factors in the diet, including starter particle size, starch source, and starch processing. This topic is reviewed in greater detail in Suarez-Mena et al. (2016).

POST-WEANING PERFORMANCE UP TO 4 MONTHS OF AGE

Reduced digestibility coefficients for calves with reduced starter intakes, as was evident in work from Hill et al. (2009), potentially reflects a reduction in rumen development, which would have significant effects on post-weaning performance. However, information is limited for rumen development post-weaning, despite an acknowledged difference in rumen volume from weaning to maturity. The reticulorumen increases in volume from 30% to nearly 70% of the total foregut volume from birth to weaning (Warner et al., 1956), yet weaned calves typically experience reduced growth rates and intake when fed forages and high-fiber feed sources (Jahn et al., 1970, Hill et al., 2008) generally utilized in mature ruminant diets. It also stands to reason that following weaning, there is some capacity for continued rumen development in response to increased energy intake from highly digestible carbohydrates.

Diet form and carbohydrate inclusion could also affect rumen development as energy availability may be altered by particle size and would differ between starch and forage fiber sources. Davidson et al. (2012a) evaluated physical form of grower diets for 13 to 24 wk old Holstein steers and reported similar growth and physical rumen development; however, there was a tendency to reduce rumen papillae length in cranial ventral tissue samples for calves fed texturized compared to pelleted diets. Davidson et al. (2012b) also tested different hay types fed to 13 to 22 wk old Holstein steers and observed steers fed higher CP, lower NDF alfalfa hay exhibited greater papillae surface area in ventral tissue samples compared to steers fed lower CP, higher NDF grass hay. However, baseline slaughter data were not reported and rumen development may have been affected by previous plane of nutrition. From both of these trials, it appears that diet digestibility post-weaning and forage quality may play a role in morphological development of rumen tissue.

Research from our group supports feeding diets with limited amounts of fiber and forage in order to increase ME intake from highly digestible carbohydrates (Hu et al., 2018). This is particularly important when considering the pre-weaning feeding program. Dennis et al. (2017) showed when comparing calf starter to MR feeding rate on overall growth to 16 wk of age, BW gain improved 17% (13 kg) when feeding a high starch calf starter for 16 wk whereas a high MR feeding rate (up to 1.1 kg/d of DM) only improved BW gain 9% (7 kg). Much of this discrepancy is likely explained by previously discussed reductions in diet digestibility up to 4 wk post-weaning when calves are fed more MR. However, performance through the weaning transition is also linked to many other nutrition- and management-related factors.

SUMMARY

While growth in body weight and frame to weaning can be indicative of a successful pre-weaning feeding program, factoring performance during the weaning transition and growth from birth to at least 16 wk of age may give a better indication of the overall success of a calf program. Nutrition, including liquid feeding rates and starter composition and quality, as well as weaning protocols have a high impact on the success of the weaning transition due to the effects on rumen development and diet digestibility.

REFERENCES

Baldwin, R., K. McLeod, J. Klotz, and R. Heitmann. 2004. Rumen development, intestinal growth and hepatic metabolism in the pre-and postweaning ruminant. J. Dairy Sci. 87:E55-E65.

Castells, L., A. Bach, A. Aris, and M. Terre. 2013. Effects of forage provision to young calves on rumen fermentation and development of the gastrointestinal tract. J. Dairy Sci. 96(8):5226-5236.

Chapman, C. E., P. S. Erickson, J. D. Quigley, T. M. Hill, H. G. Bateman Ii, F. X. Suarez-Mena, and R. L. Schlotterbeck. 2016. Effect of milk replacer program on calf performance and digestion of nutrients with age of the dairy calf. J. Dairy Sci. 99(4):2740-2747.

Chester-Jones, H., B. J. Heins, D. Ziegler, D. Schimek, S. Schuling, B. Ziegler, M. B. de Ondarza, C. J. Sniffen, and N. Broadwater. 2017. Relationships between early-life growth, intake, and birth season with first-lactation performance of Holstein dairy cows. J. Dairy Sci 100:3697-3704.

Davidson, J. A., T. E. Johnson, B. L. Miller, K. B. Cunningham, H. C. Puch, K. M. O'Diam, and K. M. Daniels. 2012a. Comparison of feed form (pelleted vs. textured) on growing performance and rumen papillae development of dairy steers. J. Dairy Sci. 95(Suppl 2):543.

Davidson, J. A., T. E. Johnson, H. C. Puch, and B. L. Miller. 2012b. Influence of hay type on ruminal papillae surface area of growing sairy steers from 13 to 22 wk of age. J. Dairy Sci. 95(Suppl 2):545.

Dennis, T. S., F. X. Suarez-Mena, T. M. Hill, J. D. Quigley, and R. L. Schlotterbeck. 2017. Effects of egg yolk inclusion, milk replacer feeding rate, and low-starch (pelleted) or high-starch (texturized) starter on Holstein calf performance through 4 months of age. J. Dairy Sci 100:8995-9006.

Dennis, T. S., F. X. Suarez-Mena, T. M. Hill, J. D. Quigley, R. L. Schlotterbeck, and L. Hulbert. 2018. Effect of milk replacer feeding rate, age at weaning, and method of reducing milk replacer to weaning on digestion, performance, rumination, and activity in dairy calves to 4 months of age. J. Dairy Sci 101:268-278.

Eckert, E., H. E. Brown, K. E. Leslie, T. J. DeVries, and M. A. Steele. 2015. Weaning age affects growth, feed intake, gastrointestinal development, and behavior in Holstein calves fed an elevated plane of nutrition during the preweaning stage. J. Dairy Sci. 98(9):6315-6326.

Gelsinger, S. L., A. J. Heinrichs, and C. M. Jones. 2016. A meta-analysis of the effects of preweaned calf nutrition and growth on first-lactation performance. J. Dairy Sci. 99(8):6206-6214.

Hill, T. M., H. G. Bateman, J. M. Aldrich, and R. L. Schlotterbeck. 2008. Effects of feeding different carbohydrate sources and amounts to young calves. J. Dairy Sci. 91(8):3128-3137.

Hill, T. M., H. G. Bateman, J. M. Aldrich, and R. L. Schlotterbeck. 2009. Effects of fat concentration of a high-protein milk replacer on calf performance. J. Dairy Sci. 92(10):5147-5153.

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(3):1105-1115.

Hill, T. M., H. G. Bateman, J. M. Aldrich, and R. L. Schlotterbeck. 2012. Methods of reducing milk replacer to prepare dairy calves for weaning when large amounts of milk replacer have been fed. Prof. Anim. Sci. 28(3):332-337.

Hill, T. M., J. D. Quigley, H. G. Bateman II, F. X. Suarez-Mena, T. S. Dennis, and R. L. Schlotterbeck. 2016a. Effect of milk replacer program on calf performance and digestion of nutrients in dairy calves to 4 months of age. J. Dairy Sci. 99:8103-8110.

Hill, T. M., J. D. Quigley, F. X. Suarez-Mena, H. G. Bateman II, and R. L. Schlotterbeck. 2016b. Effect of milk replacer feeding rate and functional fatty acids on dairy calf performance and digestion of nutrients. J. Dairy Sci. 99(8):6352-6361.

Hu, W., T. M. Hill, T. S. Dennis, F. X. Suarez-Mena, J. D. Quigley, J. R. Knapp, and R. L. Schlotterbeck. 2018. Relationships between starch concentration of dry feed, diet digestibility, and growth of dairy calves up to 16 weeks of age. J. Dairy Sci 101:7073-7081.

Jahn, E., P. Chandler, and C. Polan. 1970. Effects of fiber and ratio of starch to sugar on performance of ruminating calves. J. Dairy Sci. 53(4):466-474.

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

Khan, M. A., H. J. Lee, W. S. Lee, H. S. Kim, S. B. Kim, S. B. Park, K. S. Baek, J. K. Ha, and Y. J. Choi. 2008. Starch source evaluation in calf starter: II. Ruminal parameters, rumen development, nutrient digestibilities, and nitrogen utilization in Holstein calves. J. Dairy Sci. 91(3):1140-1149.

Kosiorowska, A., L. Puggaard, M. S. Hedemann, J. Sehested, S. K. Jensen, N. B. Kristensen, P. Marycz, and M. Vestergaard. 2011. Gastrointestinal development of dairy calves fed low- or high-starch concentrate at two milk allowances. Animal. 5(2):211-219.

Kristensen, N. B., J. Sehested, S. K. Jensen, and M. Vestergaard. 2007. Effect of milk allowance on concentrate intake, ruminal environment, and ruminal development in milk-fed Holstein calves. J. Dairy Sci. 90(9):4346-4355.

Lesmeister, K. E. and A. J. Heinrichs. 2004. Effects of corn processing on growth characteristics, rumen development, and rumen parameters in neonatal dairy calves. J. Dairy Sci. 87(10):3439-3450.

Meale, S. J., L. N. Leal, J. Martín-Tereso, and M. A. Steele. 2015. Delayed weaning of Holstein bull calves fed an elevated plane of nutrition impacts feed intake, growth and potential markers of gastrointestinal development. Anim. Feed Sci. Technol. 209:268-273.

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(2):783-793.

Steele, M. A., J. H. Doelman, L. N. Leal, F. Soberon, M. Carson, and J. A. Metcalf. 2017. Abrupt weaning reduces postweaning growth and is associated with alterations in gastrointestinal markers of development in dairy calves fed an elevated plane of nutrition during the preweaning period. J. Dairy Sci 100:5390-5399.

Suarez-Mena, F. X., T. M. Hill, C. M. Jones, and A. J. Heinrichs. 2016. Review: forage provision on feed intake in dairy calves. Prof. Anim. Sci. 32:383-388.

Sweeney, B. C., J. Rushen, D. M. Weary, and A. M. de Passille. 2010. Duration of weaning, starter intake, and weight gain of dairy calves fed large amounts of milk. J. Dairy Sci. 93(1):148-152.

Terré, M., L. l. Castells, M. A. Khan, and A. Bach. 2015. Interaction between the physical form of the starter feed and straw provision on growth performance of Holstein calves. J. 98(2):1101-1109.

Warner, R., J. Porter, and S. Slack. 1973. Calf starter formulation for neonatal calves fed no hay. Pages 116-122 in Proc. Cornell Nutr. Conf. Cornell University, Ithaca, NY.

Warner, R. G., W. P. Flatt, and J. K. Loosli. 1956. Ruminant nutrition, dietary factors influencing development of ruminant stomach. J. Agric. Food Chem. 4(9):788-792.