# If Calves Could Talk, What Would They Say About Their Feeding Program?

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## Take Home Message

- Early weaning programs emphasized limited milk replacer (MR) feeding in order to limit feed costs, to increase calf starter (CS) intake, and to stimulate rumen development. When accelerated MR feeding programs were initiated, they emphasized feeding more MR and with a higher CP level to increase ADG more nearly to a calf's ability to grow without excessive fattening. The optimal MR fat level was 15%.
- Feeding texturized calf starters with minimal fines contributes to more functional rumen development, more intake and daily gain, and greater digestibilities vs all pelleted starters.
- Feeding clean water, and warmer in colder temperatures, facilitates dry matter intake (DMI) at a ratio of 4:1.
- Benefit from accelerated MR feeding programs was postulated to decrease age at first calving by one or more months. But most recent data indicate the primary benefit appears to be additional milk yield in first and subsequent lactations related to ADG before weaning. When an additional kg ADG prior to weaning results in 850 kg more milk in the first lactation, this benefit would have the greatest economic return. And is much greater value than the yearly rate of genetic progress at about 100 kg.
- An additional 235 kg more milk was produced in the first lactation and 903 kg over 3 lactations for every Mcal ME intake above maintenance during the pre-weaning period. Calves born during winter months (0.2° C) consumed an average of 1.43 Mcal/d less energy above maintenance than calves born during warmer months (19.2° C).
- If calves could talk, they would say feed me more of a higher protein milk replacer before weaning, and have me at least double my birth weight by 2 months of age.

## Introduction

"Milk replacers" probably began when whole milk (WM) on the farm was often skimmed off with the fat used to make butter. The skim milk was then a byproduct and often fed to calves or pigs as a MR. This is most likely why earlier fabricated MR from dried ingredients had what is now considered lower fat content. Warner (1960) conducted a trial with 120 Holstein heifer calves purchased at 3 d of age. They were fed 81.7 kg WM, 11.35 kg of 2% fat MR, 11.35 kg of 25% coconut fat MR, and 11.35 kg of 25% lard oil MR. The amount of WM fed was based on having the same digestible energy as the latter two higher fat MR when reconstituted at 0.227 kg per 4.09 kg water and fed twice daily for 22 d. Average daily gain (ADG) was about 0.454 kg, which was acknowledged as satisfactory gain for herd replacements at that time (Table 1). Warner noted that calves on the 2%

fat MR also ate more ($P < 0.05$) CS and achieved the same ADG as did the other higher fat MR or WM.

**Table 1. Daily gain and calf starter intake for calves fed several milk diets up to 7 weeks of age (Warner, 1960).**

| Diet | No. calves | ADG, kg | Starter intake, kg/d |
|---|---|---|---|
| Whole milk | 30 | 0.49 | 35.4[a] |
| 2% fat replacer | 30 | 0.48 | 39.7[b] |
| 25% coconut fat replacer | 30 | 0.47 | 35.7[a] |
| 25% lard oil replacer | 30 | 0.43 | 34.2[a] |

[ab] $P < 0.05$ Means in columns differ if superscripts differ among means.

## Early Weaning Programs

The 1950s, 1960s, and into the 1970s were a golden age of studies on rumen development in dairy calves (Warner, 1991). Program approach then was to minimize cost and amount of MR fed, and to wean early by encouraging CS intake. An example of this program (Porter et al. 2007, trial was conducted in 1972-1973) is where calves were fed a total of 9.72 kg MR reconstituted with water, were abruptly weaned when they consumed an average of 0.68 kg/d CS for 4 to 5 days, and averaged 28 days on trial when fully weaned. Several MR were used and ranged from 22 to 24% CP with 8 to 20% fat (J.C. Porter personal correspondence, June 2009). The ADG before weaning was only 0.16 kg with 0.34 kg daily CS intake, but the study was also done to highlight effects of four CS studied. For 4 weeks following weaning, ADG was 0.57 kg with daily CS intake averaging 1.6 kg. Feeding identical formulas as texturized vs pelleted CS resulted in earlier and more extensive rumination, more rumen papillae length, and an average of 5 percentage units greater digestibilities.

A review of 22 published studies from 1967 to 1977 (Kertz et al., 1979) found an average weaning age of 32 d (range of 19 to 52), average daily dry milk/MR fed of 0.39 kg (range of 0.25 to 0.74), average daily CS intake of 0.30 kg (range of 0.12 to 0.59), only 5 studies fed forage and daily intake averaged 0.09 kg, and ADG averaged 0.30 kg (range of 0.09 to 0.50). This was compared to 5 studies with 18 treatments summarized over a 3-yr period at the authors' commercial calf research facility. All calves were weaned at an average age of 31d comprising a 28-d MR feeding period after 3 d of colostrum and transition milk feeding. All calves were fed 0.227 kg dry reconstituted into 1.89 l water and fed twice daily for 3 wk followed by only one feeding during the 4$^{th}$ wk before full weaning. Average daily CS intake was 0.46 kg (range of 0.31 to 0.66) while ADG averaged 0.32 kg (range of 0.21 to 0.46). All MR fed contained 22% CP on an air-dry powder basis while fat content averaged 9.8% air-dry powder basis with a range of 8 to 15%. The major variable in all of these studies was protein sources in MR. Soy flours, some soy protein concentrates, and some fish protein sources resulted in poorest ADG with accompanying lower CS intake when these protein sources provided one-half of total MR CP. Lower CS intake was similar to impact of poorer quality protein sources seen in monogastrics where lower intake and ADG often resulted. Calf trial treatments which resulted in ADG of less than 0.32 kg (average of 0.26), 0.32 to 0.36 kg (average of 0.33), and greater than 0.36 kg (average of 0.33) were associated with average daily CS intakes of 0.40, 0.48, and 0.58 kg. Consequently, CS intake representing 65% of the variation in ADG. Calf starter intake represented an increasing proportion of the calf's total daily nutrition averaging 11, 28, 46, and 76% during wk 1, 2, 3, and 4.

## Fat and Protein Levels in Milk Replacers

After the 1970s, MR protein levels migrated down from 22 to 20%, and fat levels migrated up from ~10 or 12 % to 20%. This was related more to marketing and controlling feeding costs with the nutritional benefit being higher fat levels increased energy intake of calves from MR. As fat levels increased, that also increased costs, so protein level was decreased to help off-set much of that increased cost. Thus the "industry standard" 20/20 MR evolved. One study (Kuehn et al. 1994) illustrated that an unintended consequence resulted when fat content was increased in MR. A trial was conducted from March through October with 120 calves at three MN locations (two used outdoor hutches). Calves were started on trial at 14 d of age following colostrum for the first 4 d, and then followed by feeding a 21.4% CP and 21.6% fat DM basis MR until d 14. No CS was fed during this period. Then calves were fed 20% CP MR on a DM basis with either 15.6 or 21.6% fat, and texturized CS with either 3.7 or 7.3% total fat with the difference in fat coming from inclusion of ground roasted soybeans. Starter and water were available free choice from d 14 to 56 with no forage fed. Before weaning, calves consumed more CS ($P < 0.01$) and gained more body weight (BW, $P = 0.04$) than when fed the lower 15.6% fat MR. There was some carryover effect postweaning as CS intake continued at greater level ($P = 0.04$) for the 15.6% fat MR although ADG difference decreased and no longer was significantly different. The reason for this difference in ADG before weaning was evident when metabolizable energy (ME) intakes (Table 2) were calculated. Greater CS intake on the 15.6% fat MR treatment more than compensated for the lower ME MR intake on this treatment. Overall effect was 7 % more ME intake on the low fat MR treatment. This similar level (7%) of higher ME intake continued from CS alone even after calves had been weaned for 14 d. Thus, the higher energy intake from the 21.6% fat MR was more than compensated with lower CS ME intake resulting in less total energy intake compared to a low fat MR treatment. This effect is virtually ignored when high fat MR are recommended. Granted, this study did not cover the coldest weather month in MN of November, December, and January. Also, not generally acknowledged, is added value of heat of rumen fermentation from CS in meeting energy requirements during cold weather.

**Table 2. Calculated total Mcal metabolizable energy (ME) intakes and daily gains from treatments differing in milk replacer fat level (Kuehn et al., 1994).**

| Mcal | ME intake | ME intake |
|---|---|---|
| % fat in milk replacer | **15.6** | **21.6** |
| d 14-42 | | |
| Milk replacer | 43.7 | 48.0 |
| Starter | 52.2 | 41.9 |
| Total | 95.9 | 89.9 |
| Daily gain, kg | 0.50$^{a}$ | 0.43$^{b}$ |
| d 42 -56 | | |
| Starter | 73.7 | 69.2 |
| Daily gain, kg | 0.95 | 0.93 |

$^{ab}P < 0.05$ Means with different superscripts within rows differ.

During cold weather there are several options to increase energy intake from MR (Kertz, 2008). More MR can be fed, a higher fat level can be used, or a fat supplement can be added to the liquid feeding program. Simply feeding more MR may seem like the best approach, but that means that protein will be overfed since colder weather has little impact on increasing protein requirement (NRC

2001). A higher fat level MR could be used, but that means carrying another product to feed and maybe overfeeding energy, dependent on the weather, age, and CS intake of the calves. The last option of using a fat supplement may provide the greatest flexibility, but still requires some management decisions and practices to implement.

If calves are fed MR longer, more, and with a greater fat content there is a substitution effect with the greater these factors are, the more negatively they will impact CS intake. Greater fat level in the MR reduced CS intake as just noted in the study by Kuehn et al. (1994). When MR contained 12% fat, and calves were weaned at either 4 or 6 wk (Kertz, 1987), for each lb more MR consumed from 4 to 6 wk weaning age, CS consumed was 0.9 kg less. But when WM (~28% fat on DM basis) was fed and calves weaned at either 4 or 8 wk (Quigley et al., 1985), amount of CS consumed was 1.6 kg less. Thus, there is a considerable range in amount of energy from milk/MR fed and its impact on CS intake.

A confounding factor in consumption of CS is the availability of clean water. Calves consume four times more water than DMI from CS (Kertz et al., 1984). This ratio before weaning is lower at 2 to 1 when also considering water mixed with MR, but then this ratio quickly elevates to 4 to 1 after weaning (Quigley et al., 2006). This ratio of 4 to 1 water/DMI continues after the calf period as recent studies showed a similar relationship in growing heifers (Lascano and Heinrichs, 2011) and lactating dairy cows (Kramer et al., 2009).

## Milk Replacer Feeding Scenarios

There are a variety of liquid feeding programs used by dairies in the U.S. (NAHMS, 2007). Larger herds use more nonmedicated MR, more pasteurized waste milk, and less unpasteurized saleable milk than smaller herds (Table 3). But it also is evident that many dairies use a combination of liquid feeds for their calves as the last column sums to 136%. How can such programs be evaluated? It depends on how complete and accurate input information is.

**Table 3. Liquid feeding programs as a percentage of all operations by herd size (NAHMS, 2007).**

| Dairy size, cows | Small <100 | Medium 100-499 | Large 500 or > | All |
|---|---|---|---|---|
| Nonmedicated milk replacer | 11.4 | 14.2 | 26.4 | 12.7 |
| Medicated milk replacer | 55.2 | 68.2 | 43.6 | 57.5 |
| Unpasteurized waste milk | 32.2 | 25.7 | 27.6 | 30.6 |
| Pasteurized waste milk | 1.0 | 3.0 | 28.7 | 2.8 |
| Unpasteurized saleable milk | 32.2 | 17.4 | 12.1 | 28.0 |
| Pasteurized saleable milk | 1.3 | 1.6 | 2.0 | 1.4 |
| Other | 2.6 | 3.5 | 4.9 | 2.9 |

The 2001 National Research Council (NRC) Nutrient Requirements for Dairy Cattle Young Calf Model was utilized to illustrate how MR feeding programs would provide for energy allowable daily gain (EDG) and protein allowable daily gain (PDG). A zone of thermal neutrality temperature of 20°C was used, and both EDG and PDG plotted for respective BW shown. Intervals of 3.94 kg BW were used to illustrate typical BW that would be experienced by Holstein calves in their first several mo of life.

Using a 20/20 MR fed at 0.227 kg mixed into 1.89 L water and fed twice daily (Figure 1), there is only enough CP and energy for just over 0.227 kg ADG when a calf weighed 43.1 kg. As a calf increased in BW, and maintenance energy requirements increased, EDG rapidly decreased while PDG decreased much less rapidly. Thus, more MR is needed for an increased ADG with increasing BW. If the 20/20 MR were fed at 0.68 kg divided into twice daily feedings, amount of water/MR fed as a liquid must be increased to 2.84 L twice daily in order to maintain the same ~12.5% solids. If not done, osmolality would be unduly increased which could lead to some degree of digestive upset, and possibly predispose to a clostridia problem. Currently, many have increased the typical 0.227 kg feeding rate to 0.454 kg MR in 3.78 L divided into twice daily feedings. That provides approximately 15% solids, the practical upper limit MR feeding level recommended.

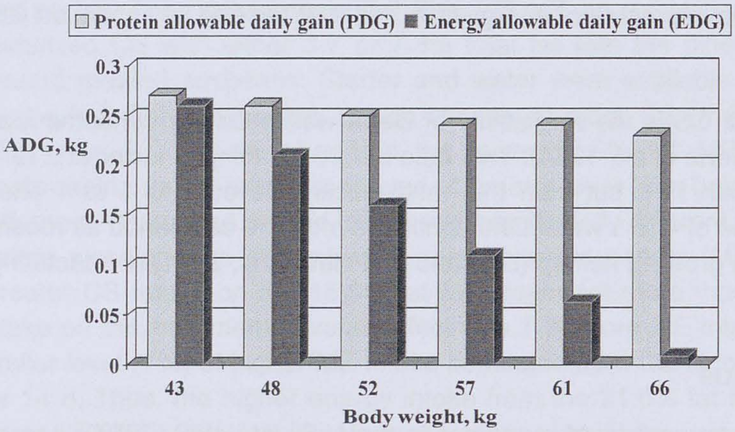


**Figure 1. Predicted PDG and EDG using the NRC 2001 Young Calf Model and a milk replacer (MR) feeding program of 0.227 kg 20% CP and 20% fat MR mixed into 1.89 L water and fed twice daily at 20° C ambient temperature.**

Increased MR feeding rate to 0.68 kg/d vs 0.454 kg/d resulted (Figure 2) in doubling ADG to greater than 0.454 kg initially, EDG being greater than PDG initially, and then much less of a decrease of EDG which is now more closely matched to PDG. But this also required 2.83 L per MR feeding in order not to exceed the 15% solids mixing rate.

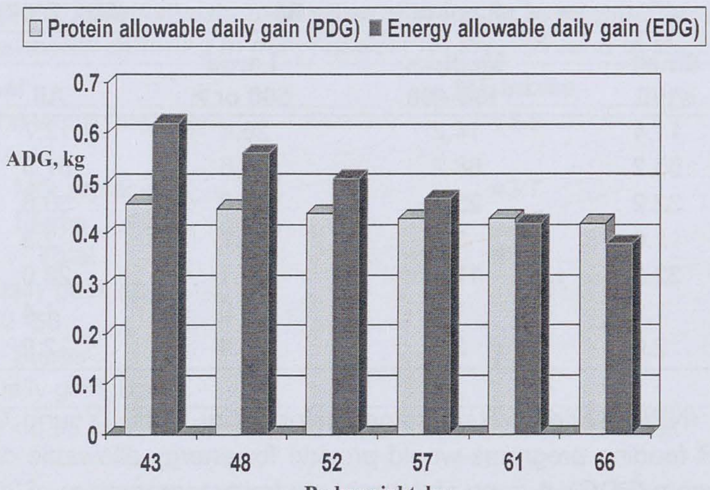


**Figure 2. Predicted PDG and EDG using the NRC 2001 Young Calf Model and a milk replacer (MR) feeding program of 0.34 kg 20% CP and 20% fat MR mixed into 2.84 L water and fed twice daily at 20° C ambient temperature.**

Figures 1 and 2 only considered effect of MR feeding, not effect of CS. Starter intake is influenced by a number of factors: nature and quality of the starter, level of MR feeding, fat level of MR (Kuehn et al., 1994), water cleanliness and availability, and combinations of these factors. Using assumed

CS intakes which would approximately double each week (Kertz et al., 1979; Stamey et al., 2011a), intakes used were 57 g/d during wk 3, 114 g/d during wk 4, 227 g/d during wk 5, 454 g/d during wk 6, 908 g/d during wk 7 when one feeding of MR was eliminated, and 1.82 kg/d during wk 8 after calves were fully weaned. This assumed pattern is likely high for MR feeding levels above 0.454 g/d. Adding these assumed CS intakes to Figure 2 resulted in Figure 3. Daily gain due to the additive effect of MR and CS would have been above 0.454 kg/d starting at 57 kg BW; and during wk of 66 kg BW, would have been nearly 0.68 kg. During once daily MR feeding wk, ADG would have decreased to about 0.454 kg/d until the following wk of 75 kg BW when CS intake would have doubled to 1.8 kg/d. This increased ADG, to the target range of 0.8 to 0.9 kg/d, is the goal for the entire post-weaning period for heifers up until first-calving.

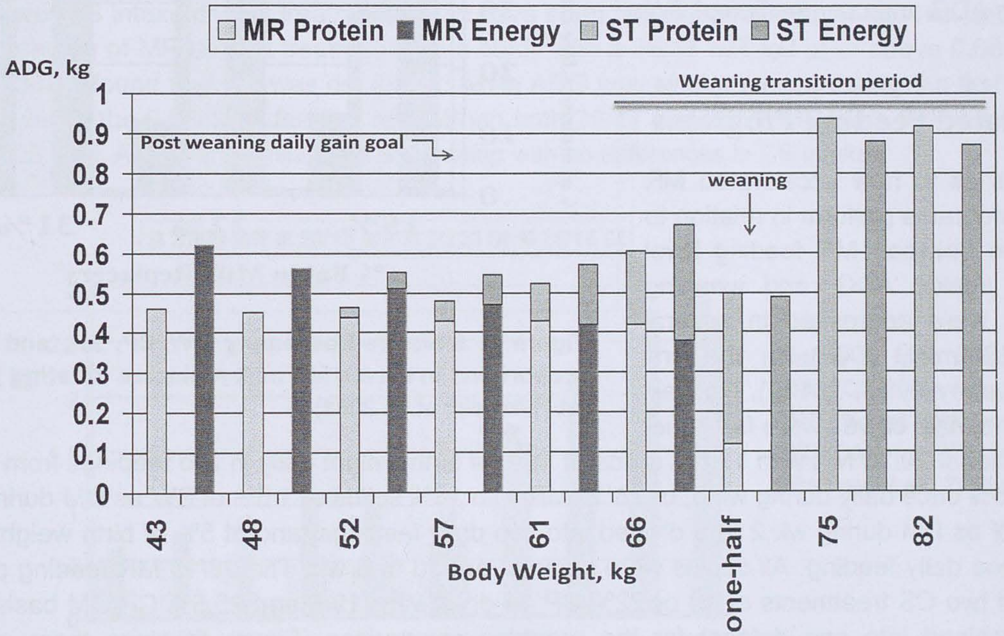


**Figure 3. Predicted ADG from milk replacer (MR) protein and energy provided and from starter (ST) protein and energy provided for a 20% protein and 20% fat MR fed at 0.32 kg in 2.84 L water twice daily until only one-half of that was fed for a wk followed by full weaning. The weaning transition period is the two wk before and two wk after weaning. The post weaning ADG goal is 0.8 to 0.9 kg.**

## Advent of Accelerated Milk Replacer Feeding and Related Research Trials

In 2001, Tikofsky et al. published a study in which Holstein bull calves were fed a constant energy and protein level from MR which differed in having either 15, 21, or 32% fat. Intakes were adjusted weekly resulting in a similar daily empty BW gain of 0.62 kg. No CS was fed. Final target BW of 85 kg was selected because this is an upper limit at which most commercial dairies feed MR before weaning. Body composition data are plotted on a moisture-free basis (Figure 4) because there is an inverse relationship between body fat and water (Reid et al., 1955). Fat content of empty BW was greater ($P < 0.006$) for 32% vs 21% fat, and for 21 vs 15% fat. Fat content of empty BW, without correction for moisture content, was 8.5% for 15% MR, 9.9% for 21% fat MR, and 11.5% for 32% fat MR. Since ADG were the same across treatments, Figure 4 shows that % body fat progressively increased with % fat in MR, while both % CP and ash in empty BW proportionately decreased. Thus 15% fat became the optimum level in accelerated MR programs.

Subsequent studies (Diaz et al. 2001; Blome et al. 2003; Brown et al. 2005; Bartlett et al. 2006, and Davis-Rincker et al., 2011) indicated that accelerated (also termed biologically normal, enhanced, or intensive, i.e. greater than typical traditional MR feeding programs) programs had beneficial results on ADG and composition of BW gain.

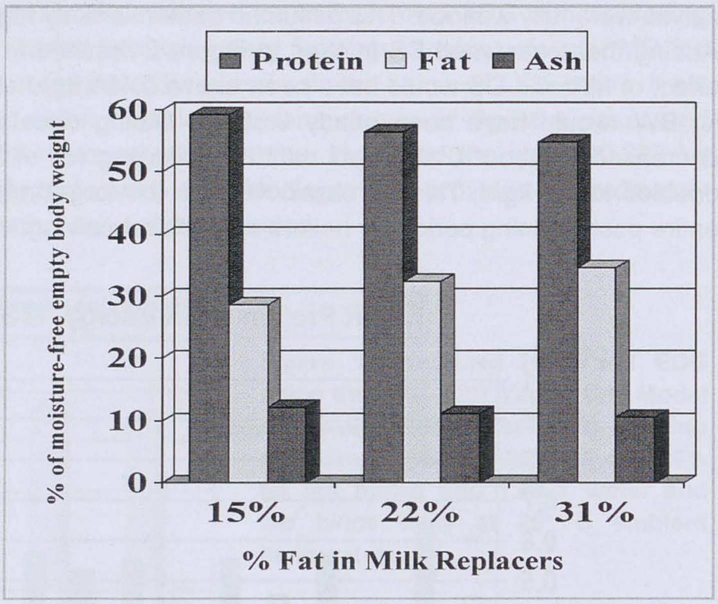


**Figure 4. Moisture-free empty BW CP, fat, and ash proportions in calves fed milk replacers differing in % fat (Tikofsky et al. 2001).**

## Accelerated Feeding Programs

Questions as to how accelerated MR feeding programs perform in relation to interaction between MR feeding level and CS intake, ADG, and weaning transition were addressed in several studies (Stamey, 2008). In the first study (Stamey et al., 2011a), Holstein female and male calves were fed either a conventional 20/20 MR with 12.5% solids at 10% of birth weight daily in two feedings from wk 1 to 5 and at 5% once daily during wk 6; or 28/15 MR with 15% solids at 1.5% of BW as DM during wk 1, 2% of BW as DM during wk 2 to 5 divided into two daily feedings, and at 5% of birth weight during wk 6 in one daily feeding. All calves were weaned at end of 6 wk. The 28/15 MR feeding program contained two CS treatments of 18 or 22% CP air-dry DM or 19.6 and 25.5% CP DM basis; which were combined into one dataset for the graphing comparison (Figure 5) since there were no significant differences between the two starter treatments (a corollary study was done with bull calves which also found no difference between the same 18 and 22% CP starters—Stamey et al., 2011a). Lower 20/20 MR feeding ($P < 0.01$) resulted in greater CS intake ($P < 0.02$) but less ADG and height increase ($P < 0.02$) than 28/15 treatments during preweaning. Total MR intakes were 19.3 for 20/20 and 34.7 kg for 28/15 with CS DMI before weaning were 14.0 and 7.3 kg, respectively, with another 25.4 kg DMI during the two wk after weaning. With greater DMI from MR, lower CS DMI resulted on 28/15 MR. But total nutrient intake was greater on 28/15 resulting in greater (Figure 6) ADG except for wk 7 which was just after full weaning. Figure 5 shows that loss in 28/15 MR DMI with full weaning was not equalized by CS DMI vs 20/20 MR treatment during wk 7, but it was during wk 8-10 when ADG was similar between MR treatments.

The second study (Stamey et al., 2011b) compared a 20/20 MR feeding program (conventional--CON) with an 18% CP CS to a 26/18 higher level MR feeding program (moderate--MOD) with a 20% CP CS, and to a 28/20 highest level MR feeding program (aggressive--AGR) with a 22% CP CS. Each MR was fed at different levels, but all calves were weaned at the end of 6 wk of age, and kept in individual hutches until the end of 9 wk of age. After that they were group-fed in super hutches until 12 wk of age. As MR feeding level increased from 15.8 to 31.4, and 38.2 kg for treatments, respectively, CS intake preweaning decreased inversely to MR intake at 42.2, 20.0, and 11.4 kg (Figure 7). This CS intake pattern continued to a lesser extent postweaning during wk 7-9. Preweaning ADG followed pattern of daily MR intake at 0.43, 0.55, and 0.64 kg, respectively. Postweaning ADG was 1.0, 1.1, and 0.82 kg, respectively, with AGR 28/20 MR treatment being lower than the MOD 26/18 MR treatment. The MOD 26/18 MR treatment carried over its intermediate ADG preweaning into intermediate CS intake, but with highest ADG of 1.09 kg postweaning. This reflects that the AGR 28/20 MR treatment calves gained more preweaning due to greatest MR consumed, but the lowest CS intake preweaning carried over into the lowest CS intake postweaning for this treatment. The MOD 26/18 MR treatment had the best overall scenario among these treatments. In particular, Figure 8 shows that while AGR 28/20 MR had the best ADG for the first 4 wk, ADG decreased the most during wk 6 of one-half MR feeding, and did not catch up until wk 9. Lower CS intake on this treatment would have been related to higher MR fat level and greatest level of feeding of MR among treatments. In a study with a 26/17 MR fed at or above 0.68 kg/d, Hill et al., (2007a) found that CS was decreased while ADG was similar except during the first wk when it was lower at the 0.68l kg/d feeding rate. When both 26/17 and 28/20 MR were fed at a high daily rate of 0.98 kg/d, ADG were similar prior to weaning with no differences in CS intake.

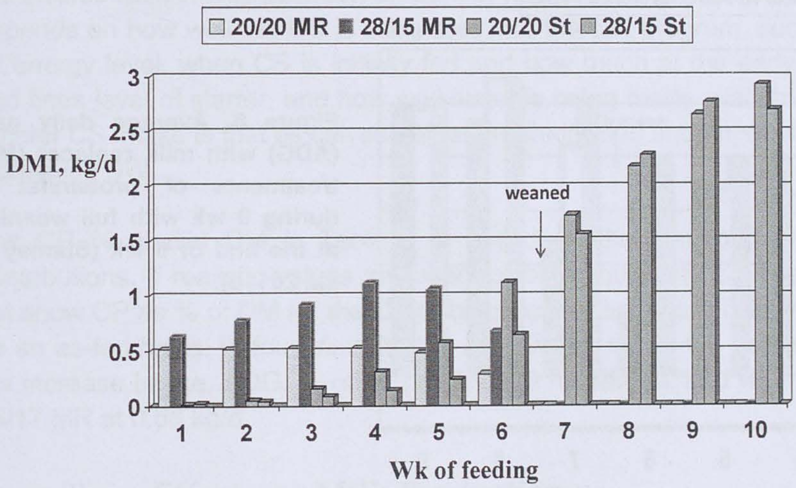


**Figure 5. Milk replacer (MR) 20% CP/20% fat and 28% CP/15% fat DMI and starter (ST) DMI for MR treatments (Stamey et al., 2011a).**

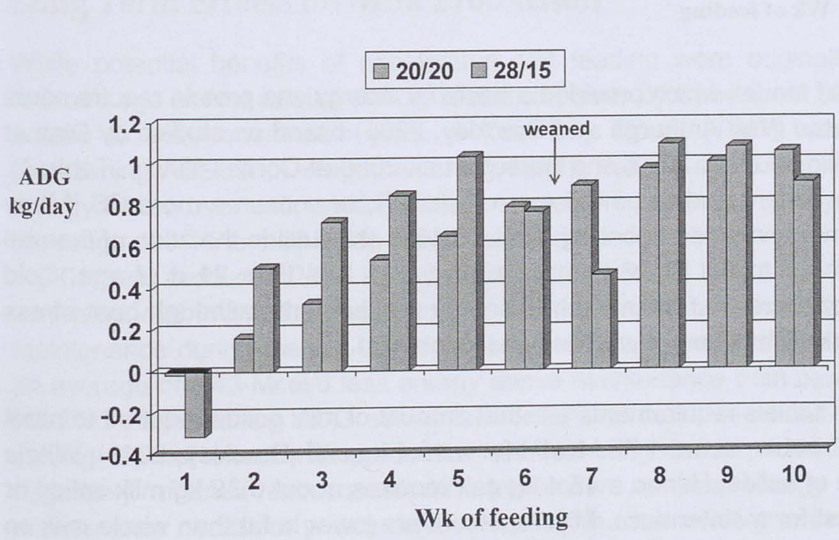


**Figure 6. Average daily gain (ADG) weekly for 20% CP/20% and 28% CP/15% fat milk replacers (MR) over pre- and post-weaning periods (Stamey et al., 2011b).**

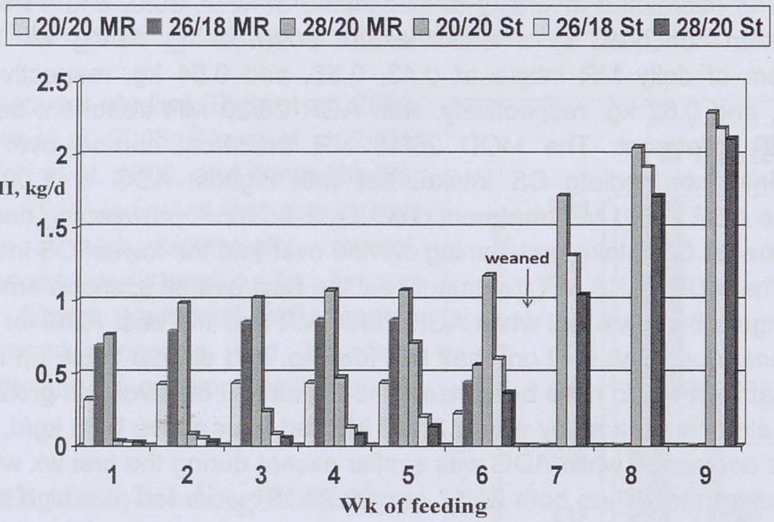


**Figure 7. Dry matter intakes (DMI) of protein/fat % milk replacer (MR) treatments and of accompanying starter (ST) treatments (Stamey et al., 2011b).**

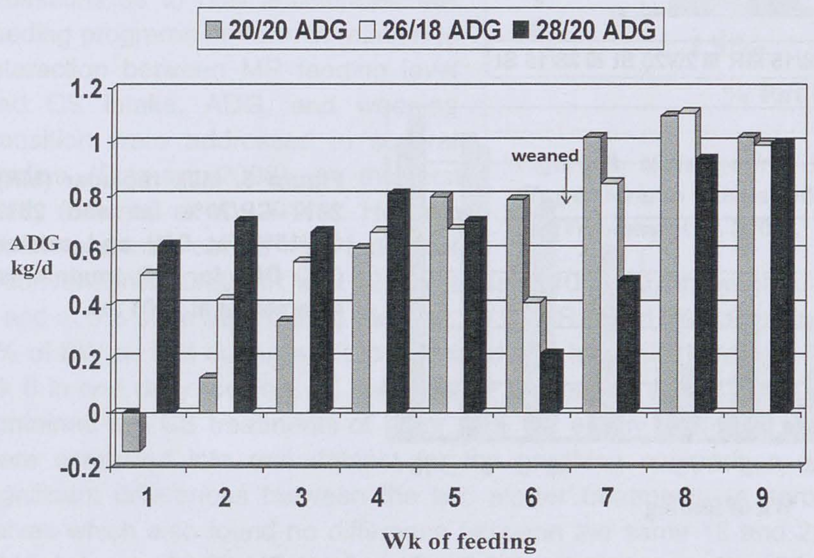


**Figure 8. Average daily gain (ADG) with milk replacer (MR) treatments of protein/fat % during 9 wk with full weaning at the end of 6 wk (Stamey et al., 2011b).**

The 2001 Dairy NRC Young Calf Model, which provided a basis for energy and protein requirements of calves, has since been updated (Van Amburgh and Drackley, 2005) based on studies by Diaz et al. 2001, Tikofsky et al. 2001, Blome et al. 2003, and Bartlett et al. 2006 at Cornell-Illinois, Table 4). For calves to grow faster, they either need to be fed more milk, MR, or consume more CS if they were older calves; and requirements needed to be adjusted if calves are outside the zone of thermal neutrality. The 2001 NRC uses 15 to 25 °C for this zone for calves less than 21 d of age. Cold weather has the most impact on increased maintenance energy requirements although heat stress can also increase requirements which have not yet been well quantified.

Some key comments about this table's requirements are that amount of milk solids required to meet maintenance requirements is sizeable, about 1.75 Mcal/d for a 45.4 kg calf (Drackley, 2010). Whole milk has about 5.28 ME ME/kg of solids. Hence a 45.4 kg calf requires about 0.32 kg milk solids or 2.5 kg of whole milk (~2.2 L) just for maintenance. Milk replacers are lower in fat than whole milk so

0.38 kg of MR (4.6 Mcal/kg) would be required for the 45.4 kg calf to meet its maintenance requirements. Considering WM to MR depends on what objectives are with a liquid feeding program, and preferences.

**Table 4. Nutrient requirements and estimated gain:feed for a 110 lb calf under thermal neutral conditions, using the Cornell-Illinois modification of NRC (2001) equations (Van Amburgh and Drackley, 2005).**

| ADG kg/d | DMI % of BW | ME Mcal/d | CP g/d | CP % of diet DM | Estimated gain:feed |
|---|---|---|---|---|---|
| 0.20 | 1.05 | 2.34 | 94 | 18.0 | 0.38 |
| 0.40 | 1.30 | 2.89 | 150 | 22.4 | 0.63 |
| 0.60 | 1.57 | 3.49 | 207 | 26.6 | 0.77 |
| 0.80 | 1.84 | 4.40 | 253 | 27.4 | 0.86 |
| 1.00 | 2.30 | 4.80 | 318 | 28.6 | 0.87 |

For calves to grow faster, they need to be fed more milk or MR. As calves get bigger and older they can and should be eating more CS; but the substitution factor will be somewhat limiting because of the inverse relationship between amount of milk/MR fed/consumed and resultant CS intake. But that depends on how well the CS is integrated into the calf program, such as amount of milk/MR fed, its fat/energy level, when CS is initially fed and how much at the early stages of intake, physical form and fines level of starter, and how well water is being made available. An offsetting factor leading to greater CS intake is that as calves get larger, their need and impetus to eat more also increases with increasing BW.

The CP % of diet DM in Table 4 is based on the sum of both milk/MR and calf starter CP contributions. If realistic values are used for both liquid and CS intakes, the Young Calf Model will not show CP as % of DM for the CS to be greater than 18 to 20%, which is 16 to 18% CP for the CS on an as-fed basis. In four trials (Hill et al., 2007b), CP in CS greater than 18% as-is DM basis did not increase intake, ADG, or other parameters measured, and when fed 20/20 MR at 0.454 kg/d or 26/17 MR at 0.68 kg/d.

## Long Term Effects on Milk Production

While potential benefits of accelerated MR feeding were originally postulated as being due to reduced age at first calving (AFC), recent analyses by Soberon et al. (2011) indicated benefits may accrue to subsequent milk yield. A Test Day Model (TDM) was developed utilizing inputs of preweaning ADG, birth weight, weaning weight, calving age, birth year, birth month, and calculated energy intake over estimated maintenance requirements. For every additional 1 kg of ADG (within the range of 0.10 to 1.58 kg/d), 1,244 heifers produced 850 kg more milk during their first lactation ($P < 0.01$) and produced 2280 kg more during their first 3 lactations. An additional 235 kg more milk was produced in the first lactation and 903 kg over 3 lactations for every Mcal ME intake above maintenance during the pre-weaning period. Calves born during winter months (0.2° C) consumed an average of 1.43 Mcal/d less energy above maintenance than calves born during warmer months (19.2° C). Preweaning ADG accounted for 22% of variation in first lactation milk yield. Age at first calving did not affect milk production within a range of 20 to 30 mo. Colder weather for calves negatively affected subsequent milk production as less energy was available over increased maintenance needs for young calves resulting in their lower growth rate. Probable mechanisms for this increased milk yield are not understood, but are speculated to be related to very early mammary gland development. Drackley (2010) found an additional 10 studies which measured subsequent first lactation milk production as related to pre-weaning performance. All but one of those studies had positive effects on subsequent milk production.

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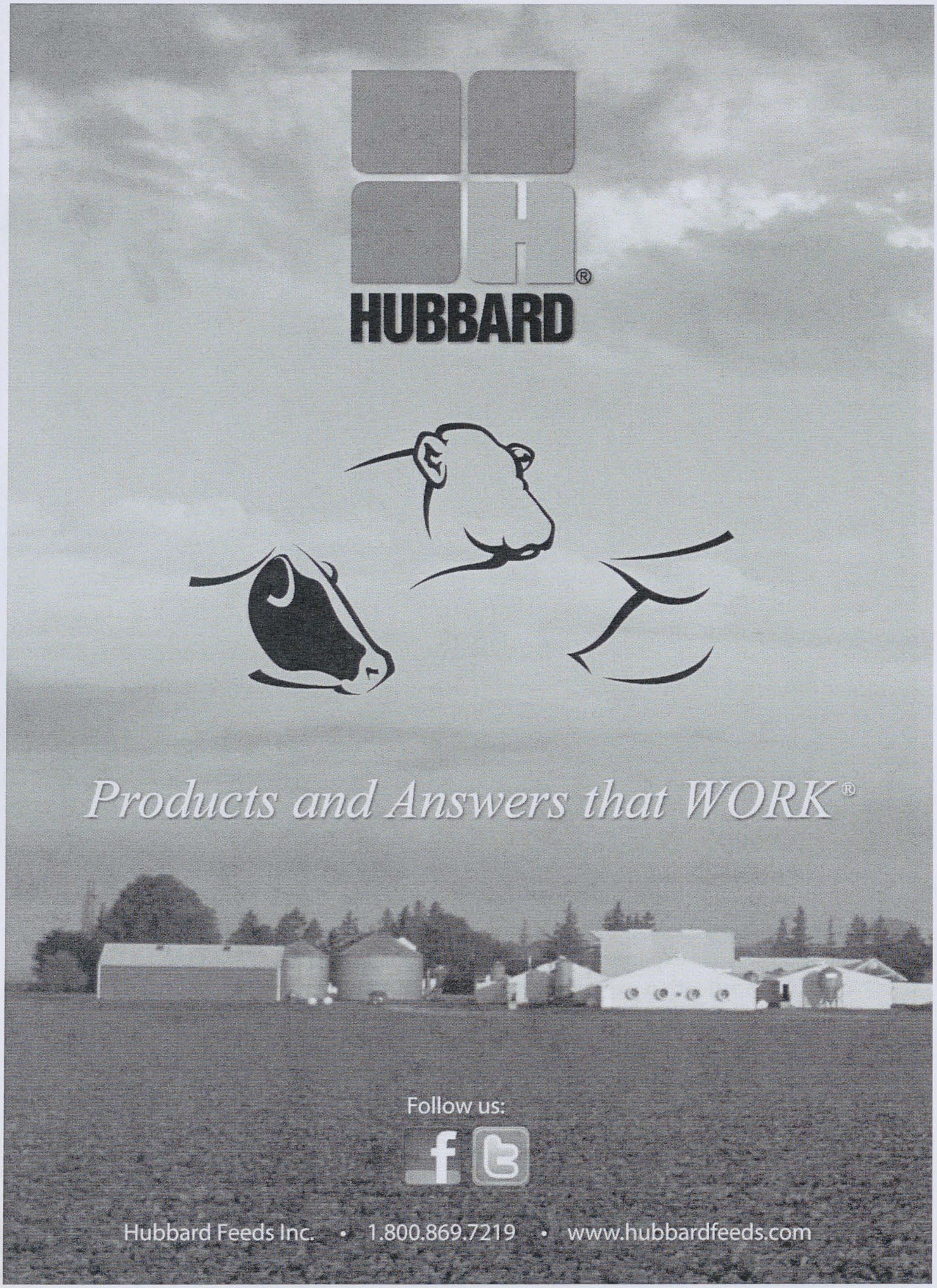
# Notes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