# Changes in Feeding Dairy Calves and Heifers During the Past 20 Years and Looking Ahead

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## Summary

Calves and heifers both have had a history around 40 years ago of being poorly fed and raised. This began to improve about 20 years ago due to research establishing that calves could be fed more of higher protein milk replacers to increase their growth closer to their biological possibility and with better quality forages grown for lactating cows also being fed to heifers. Fat level of milk replacers affects calf starter intake, with 15% fat having been shown in several trials to optimize metabolizable energy intake and body composition. Starter intake is limited by lack of clean water. But an undue focus on costs has led to a regression in calf starters, going from being texturized to all pelleted. This places calves in marginal acidosis and increases stress of calves moving from being individually fed before weaning to their first grouping postweaning. The Nutrient Requirements of Dairy Cattle Young Calf Model (NRC, 2001) has provided a very useful tool to evaluate young calf feeding programs and performance. The 2007 National Animal Health Monitoring System (NAHMS, 2007) survey included extensive calf and heifer questions and has provided new and useful information on practices in the U.S. Reducing variation in calf weight and intake at their first grouping has been shown to increase performance and reduce subsequent variation. These aspects of calf welfare and performance need more attention. There can be undue fattening with higher quality forages fed to heifers. Heifer dry matter **(DM)** intake has increased with increased genetics for cows, resulting in production of more milk. There are many other variables than nutrition that affect heifer performance. Limit feeding has been shown in research trials to be effective in growing heifers without negative effects. But on-farm application and management is daunting. Wisconsin field data showed increased daily feed costs as heifers get larger due to their increased maintenance needs. A model developed from a large Cornell University data base of calves through weaning has shown that preweaned daily gain differences related strongly to subsequent milk production. Looking ahead, we must remember always that a young calf is the most vulnerable animal on a dairy and also the most efficient at utilizing nutrients for growth. Feeding and management decisions must be made on these bases. Current calf death losses of 8 to 10% should become 3 to 5%, with stillbirths of about 5%. More attention needs to be paid to feeding more optimally the young calf before weaning. An undue focus on reducing feed cost for calves can have long term effects in not achieving a calf's truer genetic potential as a cow. We have tools, knowledge, and equipment to do a better job of raising calves and heifers.

## Introduction

An all-encompassing review of the past 20 years would be too extensive for the time and space available. Rather, this review will highlight key studies or results developed over that period of time

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for both calves and heifers. There will be some earlier history addressed in order to better understand where we have been and what the last 20 years have brought us. Two publications have been very beneficial to calf health, feeding, and management. The first is the Nutrient Requirements of Dairy Cattle (NRC, 2001), which not only contained an excellent and more comprehensive text than the previous 1989 edition, but also a software package termed the Young Calf Model. The latter has allowed evaluations of calf situations in which body weight **(BW)** and ambient temperature are inputted along with dietary nutrient sources, and then protein available daily gain **(PDG)** and energy available daily gain **(EDG)** are computed. This is a most useful tool to evaluate calf performance under various conditions. The second publication is from the National Animal Health Monitoring System (NAHMS, 2007). This survey was the first in the NAHMS series to extensively survey calf and heifer practices on U.S. dairy farms. As an example, liquid feeding practices were found to be quite variable and differed with size of herds (**Table 1**). Larger herds used more nonmedicated milk replacers **(MR)**, more pasteurized waste milk, and less unpasteurized saleable milk than smaller herds. But, it also is evident that many dairy farms use a combination of liquid feeds for their calves as the last column of all practices sums to 136%. Evaluation of any dairy's program depends on the completeness and accuracy of the input information.

## Colostrum

Newer evidence of the value of colostrum came from a study with a Brown Swiss herd in which calves at birth were force fed either 2 or 4 qt of colostrum at the first feeding (Faber et al., 2005). These 68 calves were then fed the same thereafter, beginning with colostrum and transition milk for the following 2 days. Those calves fed the 4 vs 2 qt colostrum at the first feeding had 60% less veterinary costs, 0.5 lb more daily gain at 14 months **(mo)** of age, 10% more 305-day mature equivalent milk during the 1st lactation (21,815 vs 19,712 lb), and 17% more 305-day mature equivalent milk during the 2nd lactation (24,869 vs 21,232 lb). This heartening new evidence about the value of colostrum was off-set by evidence of a previously unrecognized, but prevailing, issue—widespread bacterial contamination of colostrum (Godden, 2007). A field study of 12 MN farms revealed that when colostrum exceeded 100,000 cfu/ml of total plate counts **(TPC)** or 10,000 cfu/ml total coliform counts **(TCC)**, calves were 1.2 times more likely to get sick and 1.3 times more likely to die by 8 wk of age At the University of MN-Baldwin transition management facility, 36% of colostrum samples exceeded those counts. Most of this contamination was from milking equipment and buckets. Godden noted that of the three sources of bacterial contamination, contaminated equipment was a greater source of contamination than bacteria shed from the udder or from improper storage of colostrum. Recommendations included proper udder preparation; sanitized collection, storage and feeding equipment; not pooling (helps in prevention of *Johne's* disease spreading); and either refrigeration by 2 hours, use within 3 days, or freeze.

## Milk Replacers and Calf Starters

"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 days of age. Each calf was fed either 180 lb of WM, 25 lb of solids from 2% fat MR, 25 lb of 25% coconut fat MR, or 25 lb of 25% lard oil MR over 22 days. The amount of WM fed was based on having the same digestible energy as the latter 2 higher fat MR when reconstituted at 0.50 lb per 9 lb water and fed twice daily for 22 days. The average daily gain **(ADG)** was about 1.0 lb, which was acknowledged as satisfactory gain for herd replacements at that time (Table 2). Warner (1960) noted that calves on the 2% fat MR also ate more (P < 0.05) calf starter **(CS)** and achieved the same ADG as did the other higher fat MR or WM. 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. 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, allowing for 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.

A key study (Kuehn et al., 1994) illustrated that an unintended consequence resulted when fat content was increased in MR and CS. A trial was conducted from March through October with 120 calves at 3 MN locations (2 used outdoor hutches). Calves were started on trial at 14 days of age following colostrum for the first 4 days, and then followed by feeding a 21.4% CP and 21.6% fat MR until day 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 day 14 to 56 with no forage fed. Before weaning, calves consumed more CS (P < 0.01) and gained more BW (P = 0.04) when fed the lower 15.6% fat MR. There was some carryover effect postweaning as CS intake continued greater (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 3) were calculated. Greater CS intake on the 15.6% fat MR treatment more than compensated for the lower ME intake from MR on this treatment. The 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 days. Thus, the higher energy intake from the 21.6% fat MR was more than compensated with accompanying lower CS ME intake, resulting in less total energy intake compared to a lower fat MR treatment. This effect is virtually ignored when high fat MR are recommended. Granted, this study did not cover the coldest weather months 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.

In that same MN study (Kuehn et al. 1994) prior to weaning, there was no difference in MR or CS ME intake when comparing low vs high fat CS treatments (Table 4). After weaning, ME intake was less (P < 0.10) with the high fat CS due to lower (P < 0.05) starter DMI. Thus, the added fat from soybeans in the high fat CS reduced DMI and ME intake compared to the CS without added fat. This reduced intake could be due to ruminal and/or physiological feedback from the fat, or possibly some palatability effect although all components of the CS, except oats and rolled corn, were pelleted together. Other literature which I have reviewed show similar negative effects of increased fat in CS, resulting in reduced intake.

A confounding factor in consumption of CS is the availability of clean water. Calves consume 4 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 to DMI may well continue after the calf period, as a recent study showed a similar relationship in lactating dairy cows (Kramer et al., 2009).

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

Tikofsky et al. (2001) 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 1.36 lb. Body composition data are plotted on a moisture-free basis (Figure 1) because there is an inverse relationship between body fat and water (Reid et al., 1955). Fat content of empty BW was greater (P < 0.01) 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 1 shows that percentage of body fat progressively increased with percentage of fat in MR, while both percentage of 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; Davis-Rincker et al., 2006) 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. Bartlett et al. (2006) also noted that "These dietary effects on body composition and growth are not predicted by current (e. g. 2001) NRC standards." These differences were that the 2001 NRC does not account for the differences that dietary protein:energy have on body composition gain and that partial efficiency of conversion of ME to retained energy was lower and more variable than the constant of 65% used NRC (2001). The latter was attributed to older studies which fed heavier and fatter calves whole milk or skim milk-based MR more typical of veal production.

## 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 2 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 2 daily feedings, and at 5% of birth weight during wk 6 in one daily feeding. All calves were weaned at the end of 6 wk. The 28/15 MR feeding program contained 2 CS treatments of 18 or 22% CP as-is DM or 19.6 and 25.5% CP DM basis; which were combined into one dataset for the graphing comparison (Figure 2) since there were no significant differences between the 2 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 the 28/15 treatments during preweaning. Total MR intakes were 42.5 lb for 20/20 and 76.4 lb for 28/15, while CS DMI before weaning were 31 and 16 lb, respectively, with both treatments consuming another 56 lb DMI during 2 wk after weaning. With greater DMI from MR, lower CS DMI resulted on the 28/15 MR. But total nutrient intake was greater on 28/15, resulting in greater (Figure 3) ADG, except for wk 7 which was just after full weaning. Figure 3 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 in wk 8 to 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 to 34.8, 69.1, and 84.1 lb for treatments, respectively, CS intake preweaning decreased inversely to MR intake at 93, 44, and 25 lb (Figure 4). This CS intake pattern continued to a lesser extent postweaning during wk 7 to 9. Preweaning ADG followed the same pattern of daily MR intake at 0.95, 1.2, and 1.4 lb, respectively. Postweaning ADG were 2.2, 2.4, and 1.8 lb, respectively, with the 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, resulting in the highest ADG of 2.4 lb 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 5 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 the greatest level of feeding of MR among treatments. In a study with a 26/17 MR fed at or above 1.5 lb/day, Hill et al. (2007a) found that CS was decreased while ADG was similar, except during the first week when it was lower at the 1.5 lb/day feeding rate. When both 26/17 and 28/20 MR were fed at a high daily rate of 1.96 lb/day, ADG were similar by weaning with no differences in CS intake.

The Young Calf Model (NRC, 2001), which provided a basis for energy and protein requirements of calves, has since been revised (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 and Illinois (Table 5). For calves to grow faster, they either need to be fed more milk, MR, or consume more CS if they are older calves, and requirements needed to be adjusted if calves are outside the zone of thermal neutrality. The NRC (2001) uses 59 to 77°F for this zone for calves less than 21 days 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. 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 percentage of diet DM in Table 5 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 (NRC, 2001) will not show CP as a percentage 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, when fed a 20/20 MR at 1 lb/day or 26/17 MR at 1.5 lb/day.

## Calf Starter Particle Size

A key study (Porter et al., 2007) evaluated starters with 2 levels of fiber and in pelleted or mash (texturized) forms. Calves were in individual crates so there was no bedding consumption to confound the results. There were some benefits of the high fiber vs low fiber CS. That is to be expected with lower starch content when starters are formulated for higher fiber. There would be fewer tendencies for marginal ruminal acidosis with higher fiber content starters. But, the main advantages in this study were for the texturized starter vs pelleted starter (Table 6). The following differences ($P < 0.05$) resulted: increased daily gain post weaning (5 to 8 wk), and overall as well; increased starter intake after weaning, and overall as well; earlier ruminating; increased time ruminating; and increased digestibilities of DM, CP, ADF, and NDF. In addition, calves sacrificed on each treatment had numerically increased rumen pH, papillae length, and percentage muscle/mucosa - all indicating greater rumen function and development, consistent with the performance and digestibility parameters. Thus particle size in texturized CS likely is beneficial in creating more rumination, more salivation with more rumination, and more favorable rumen fermentation, minimizing marginal acidosis. Several studies recently have reported calf performance differences when calf starters differed in ingredients or physical forms, but these were confounded because hay (Khan et al., 2007; Kristensen et al., 2007) was also fed, or straw was used for bedding (Bach et al., 2007). The rejoinder usually is "but texturized starters cost more". This is most likely why there is a troubling pattern of decreased usage of texturized CS in the U.S. and in other countries as well.

## Calf Welfare, Feeding, and Management

Considerable attention is spent on cow comfort and welfare, and justifiably so. Over the last 10 years, a series of studies have been published by 2 groups in British Columbia, addressing issues really dealing with calf comfort and their performance. Interestingly, as if to highlight this work, one group published a key review (Khan et al., 2011), while the other group published a study on weaning age using automated feeders as related to intake, performance, and behavior (de Passille et al., 2011)—both in the March issue of the J. Dairy Sci. In *Feedstuffs* (www.andhil.com Online dairy columns*), I developed synopses of 4 different studies involving either of these two groups as follows. *Ad libitum* milk intake compared to conventional milk feeding (10% of BW) resulted in greater BW gains during the preweaning phase, and this resulted in greater BW at the end of the 63-day period. However, performance around weaning was affected in both treatments and more so with *ad libitum* milk feeding (Jasper and Weary, 2002). Gradual weaning over a 10-day period resulted in greater or more uniform BW gain before and after weaning than shorter or longer weaning periods when calves were weaned at 41 days of age and fed WM. While there was an inverse relationship between milk and starter intakes, the more gradual 10-day weaning period minimized the effect of calves' losing the greater energy density of milk and being replaced with starter intake (Sweeney et al., 2010). Sick calves are more likely to show differences in feeding behavior when fed milk at a high level than when limit fed milk. This can be an advantage to using automatic feeders if they are well maintained and managed and if feeding behavior data are closely scrutinized (Borderas et. al., 2009). A fairly quantitative advisory tool was developed to assist in the improvement of management practices that affect calf and heifer welfare on dairy farms. These practices would also help improve growth and development, just as cow comfort improves milk production (Vasseur et. al., 2010ab).

Many of the studies by these 2 groups involve the use of automatic milk/MR feeders. These originated in Europe and have greatly increased in Canada due primarily to labor savings. Their use in the U.S. has expanded, even into some very large operations. While labor can be reduced, it is critical that facilities and management practices are appropriate, and the level of labor must be elevated for best management.

## Heifers

Over the last 40 years, heifer-growing programs have undergone various phases. At one time, heifers were the forgotten animal on a dairy, often banished to the proverbial "back 40" acres. They had access to only poor pasture or poor quality forages. Then in the 1970s and 1980s, corn silage became popular for feeding to dairy cows and heifers. Too often, corn silage was available free choice to heifers, which resulted in their fattening, even if protein supplementation was adequate and grass or other hay also was available. In a classic study, Jahn and Chandler (1976) showed that with high fiber/low quality forage, there was a practical limit to how much protein could compensate for this low quality/high fiber forage. Stobo et al. (1966) found that with younger calves, increasing forage level had a double negative effect in that ADG was decreased as forage level increased from 4 to 61% while gut fill also increased, distorting true body growth. As increasing emphasis was placed on growing and harvesting higher quality forages for dairy cows, these forages were often fed to heifers too. At the same time, increasing emphasis was placed on higher genetic merit for cows. Consequently, intake of heifers increased with genetic merit too. And with higher quality forage, heifers could now get fat when fed virtually forage only diets. Some producers then began to seek and use some poorer quality roughage to reduce dietary energy concentration and to thereby limit energy intake when diets were fed free choice to heifers.

## Heifer Dry Matter Intake

Phenotypic variables in raising heifers are many as Hoffman (2004) listed 17 affecting performance *other than nutrition.* Nutrition itself is comprised of many variables, among which the largest is DMI. Dry matter intake prediction for heifers has been difficult. In the 1989 NRC, the prediction was based mainly on what the energy requirements were estimated to be, and then back calculating what the DMI would need to be to meet those requirements. This resulted in a similar curve to the 2001 NRC DMI prediction, except when heifers exceeded 990 lb of BW. This upswing segment of DMI in the 1989 DMI estimation was based on the assumption that lower quality/energy forages would be used for these larger heifers, which would then require this amount of DMI to meet these heifers' energy needs. In fact, lower quality forage would reduce DMI because of lower rate and extent of digestibility, which would also increase gut fill. In the 2001 NRC, actual dairy heifer DMI (Figure 6) were gathered (mainly from trials done over a 20 year period at the then Purina Mills Dairy Research Center) and plotted versus DMI prediction using the Beef NRC (1996) equation for beef heifers. The observed DMI (data points) were initially lower than predicted DMI (line), but then shifted higher and above the line when DMI was 5 kg/day (11 lb/day) and greater. This inflection corresponds to heifers over 6 mo of age. Greater DMI for dairy heifers versus beef heifers above this point may simply reflect the greater size (especially height) of dairy heifers, along with their genetic predisposition. Another key point to note is that the spread (variation) of actual DMI progressively increased as heifers ate more. In fact, this DMI variation in heifers is likely greater than in lactating cows. This may be due to greater genetic diversity in heifers, but it is more likely due to greater differences in the nature of feeding programs for heifers, along with their environmentally different situations.

## Grouping Issues

A Norwegian study (Færeverk et al., 2010) investigated how group composition affects behavior and weight gain of newly weaned dairy calves and how age within heterogeneous groups affects behavior and competition. In both groups of calves on the first day of grouping, calves spent more time exploring their new environment and less time eating and lying. In the social approach test, calves in homogeneous groups spent more time exploring than heterogeneous groups, possibly because they had less fear and were more exploratory in a novel social situation. As a newly weaned calf, young calves entering homogeneous groups gained more over the 14-day period than heterogeneous groups, possibly because the latter calves ate less (not measured) and had more fear than their older larger group mates. Within heterogeneous groups, older calves displaced more younger calves from the feed manger. In these heterogeneous groups, calves preferred a calf at the same age for a resting partner, with the average number of calves resting close together being 3.2 animals.

At the calf operation of a large dairy in ID, individual calf feed intakes were measured during the last 3 wk of 56 days in hutches in pre-weaned replacement Holstein calves and classified into highest quartile and lowest quartile (Matuk et al., 2010). Then 480 calves in groups of 20 were grouped into the following: 20 randomly chosen (Control), 20 with highest quartile (**HH**), 20 with lowest quartile (**LL**), 5 calves from lowest and 15 from highest quartiles (**LHH**), 15 calves from the lowest and 5 from highest quartiles (**LLH**), and 10 calves from each highest and lowest quartiles (**HL**). Calves were then fed a TMR of 95% starter with 5% alfalfa hay, and intake was measured for 4 wk in the pens. Average intakes and daily gain were greatest in descending order: HH, LHH, HL, Control, LLH, and then LL, with the exception of a switch between Control and LLH in daily gain vs intake. Similarly, variation in final BW was lowest for HH, and then increased in the following order: LL, Control, LLH, LHH, and HL. The first grouping of calves post-weaning is most critical. This study found that minimizing variation in that first grouping improved overall heifer performance and diminished variation. Thus, grouping according to intake/ performance may reduce variation in performance.

Bach et al. (2006) evaluated the impact of delaying heifers (n = 2,817 Holstein) from moving from one group to the next when they had not reached targeted BW for that group. This was done at a large calf/heifer ranch in Spain (disclosure, I have consulted for this operation) which raises for 140 other dairy farms, hence, there is a lot of potential genetic variation. Animals that were delayed, and then regrouped with a new set of younger incoming heifers, were weighed every 15 days until they reached the target BW and then they were moved up one group with their initial acquaintances. This resulted in improved daily gain of the older heifers. The overall increased daily gain observed for the first 18 days of regrouping disappeared 45 days later, as the daily gain of delayed animals was then similar to their non-delayed cohorts. Whether this was due just to social order differences, environmental differences, or differences in BW or age is not known.

**Limit Feeding, Feed Efficiencies, and Growth Efficiencies**

Extensive studies on limit feeding of heifers have been done at Penn State (Zanton and Heinrichs, 2009) and Wisconsin (Hoffman et al., 2007). Commercial application of limit-feeding appears limited by having suitable facilities, especially under-stocked bunk space, a higher level of management, adequate information for formulation of rations, and favorable feedstuff economics (Kertz, 2009). Feed efficiency data with growing dairy heifers are limited (Kertz, 2011). Because of so many variables affecting feed efficiency, it is difficult to compare feed efficiencies across studies or across operations. Thus, it is better to compare these values within a study or within an operation. Ultimately, economics of feed efficiency are what will determine any application as long as the desired growth is achieved without problems. There are definite differences in the efficiencies in which height and weight increases (Kertz et al., 1998). Generally, the younger a dairy calf/heifer, the more efficient she is in converting nutrients to growth. This is primarily a function of more BW having more maintenance needs (primarily energy), which must be first met before further growth can ensue. Height increase is particularly critical and age dependent in that of the 24 inch difference between birth and first-calving, 50% occurs in the first 6 mo of age, 25% in the following 6 mo, and only 25% in the last 12 mo. This is controlled biologically, primarily by growth hormone, and thus, cannot be compensated later in life like BW can undergo compensatory growth.

**Economics**

The last aspect to be briefly addressed is economics. This can vary considerably given differences in feedstuffs costs and in a multitude of other factors. A field data study was initially done (Hoard's Dairyman, 2000) with 62 herds in WI. This study was essentially repeated in 2007 using 49 dairy operations, with 4 being custom calf grower operations (Zwald et al., 2007). In both data sets, once calves went beyond the weaning phase, daily feed cost per heifer increased. This was because the feed sources progressively became more expensive but because maintenance costs progressively increase with more BW, resulting in less nutrients being available for growth until maintenance needs were met first. This principle is too often not recognized.

**Long Term Implications of Raising Heifers**

As noted in the study by Faber et al. (2005), feeding more colostrum after birth had a major influence on subsequent growth and milk production. While potential benefits of accelerated MR feeding were originally postulated as being due to reduced age at first calving, recent analyses by Soberon et al. (2011) indicate that benefits may accrue to subsequent milk yield. Greater than 90% of calves were fed a 28/15 MR at approximately 2% of BW (1.5 lb from day 2 to 7) and then 2.0 lb/day until weaned by at ~42 to 49 days of age (M. Van Amburgh, Cornell University, personal communication, 2010). Calf ADG varied from 0.29 to 2.71 lb/day in 792 heifer calves because of management, weather, genetics, and possibly other factors. Feeding treatments were not imposed to create different ADG. A Test Day Model 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 lb of ADG, heifers produced 1,067 lb more milk during their first lactation ($P < 0.01$) and continued to produce more during their second and third lactations. Preweaning ADG accounted for 25% of the variation in first lactation milk yield. Age at first calving within a range of 20 to 30 mo. did not affect milk production. 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 10 studies which measured subsequent first lactation milk production as related to pre-weaning performance. All but one of those studies (Morrison et al., 2010) had positive effects on subsequent milk production. The study by Raeth-Knight et al. (2009) was limited in finding statistically significant lactation differences because number of animals (18/ treatment) was too limited with the variability in lactation yield. Hence more studies, analysis of datasets, and number of animals are needed to more establish this apparent relationship.

## Other Studies and Sources of References

Many areas of calf welfare and behavior were not addressed in this review. Calf welfare and behavior do affect performance. More practical calf and heifer information can be sourced at the following websites:

1. www.andhil.com, **Online Dairy Columns*** for *Feedstuffs* and *Hoard's Dairyman* columns.
2. http://www.atticacows.com, Monthly *Calving Ease* newsletters.
3. http://www.calfnotes.com/, Monthly *Calf Notes*.
4. Davis, C.L., and J. K. Drackley. 1998. *The Development, Nutrition, and Management of the Young Calf*. Iowa State Univ Press, 338 pg (unfortunately this book is out of print).
5. http://spac.adsa.org/, Subscribable searchable database of this Conference proceedings, along with that of 37 other animal nutrition/production conferences.

## Looking Ahead

This listing is more about what should happen, not necessarily predictive of what will happen.

- We must always remember that a young calf is the most vulnerable animal on a dairy farm, and yet, also the most efficient at utilizing nutrients for growth. Feeding and management decisions should be made considering these facets.

- Current calf death losses of 8 to 10% should become 3 to 5%, with stillbirths of about another 5%.

- More attention needs to be paid to feeding more optimally the young calf before weaning, beginning with the first feeding of colostrum. Currently, cost is the driving factor because the industry does not recognize any long term negative impact from not doing a better job raising calves. For instance, the benefits of first feeding 4 qt of clean, high quality colostrum within 4 hours of birth, and then more optimal levels of MR to maximize true growth would likely cost about $25/calf. Add to that another $15/calf for a good quality texturized CS. Total increased calf costs are now $40. But, that is a minor cost ($\leq$ 3%) out of the $1,200 to 1,400 total costs to raise a heifer. Now, factor in if another 0.5 lb daily gain resulted by the end of 2 mo of life. This could translate into an additional 500 lb milk in the first lactation alone, and these calves are also likely to have less health problems, reducing medication and labor costs. Granted, these heifers may eat more feed, but their efficiency of utilizing that feed will be greater at a younger age and smaller BW. These benefits over costs should be worth at least a 2:1 return.

- We have tools, knowledge, and equipment to do a better job of raising calves and heifers. It is incumbent on all of us to help dairy producers and calf/heifer raisers better understand these factors and to better implement improved practices in raising calves and heifers.

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**Table 1.** 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 |
|---|---|---|---|---|
| Non-medicated 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 |

**Table 2**. Daily gain and calf starter intake for calves fed several milk diets up to 7 wk of age (Warner, 1960).

| Diet | No. calves | ADG, lb/day | Starter intake, lb/7 wk |
|---|---|---|---|
| Whole milk | 30 | 1.08 | 78.0[a] |
| 2% fat milk replacer (MR) | 30 | 1.06 | 87.4[b] |
| 25% coconut fat MR | 30 | 1.03 | 78.6[a] |
| 25% lard oil MR | 30 | 0.95 | 75.3[a] |

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

**Table 3.** Calculated total Mcal metabolizable energy (ME) intakes and daily gains from treatments differing in milk replacer fat level (Kuehn et al., 1994).

| ME Intake, Mcal | 15.6% fat | 21.6% fat |
|---|---|---|
| Days 14-42 | | |
| Milk replacer | 43.7 | 48.0 |
| Starter | 52.2 | 41.9 |
| Total | 95.9 | 89.9 |
| Daily gain, lb | 1.10[a] | 0.95[b] |
| Days 42 -56 | | |
| Starter | 73.7 | 69.2 |
| Daily gain, lb | 2.09 | 2.05 |

[ab] $P < 0.05$ Means with different superscripts within row differ.

**Table 4.** Calf starter (CS) dry matter intake (DMI) with or without inclusion of ground roasted soybeans resulting in differing fat content (Kuehn et al., 1994).

| | 3.7% fat | 7.3% fat |
|---|---|---|
| CS DMI, lb/day | | |
| Days 14 to 42 | 1.15 | 1.16 |
| Days 43 to 56 | 3.91[a] | 3.62[b] |
| Daily gain, lb | | |
| Days 14 to 42 | 1.03 | 1.00 |
| Days 43 to 56 | 2.18[a] | 1.97[b] |

[ab]$P < 0.05$ Means with different superscripts within row differ.

**Table 5.** Nutrient requirements and estimated gain:feed for a 110 lb calf under thermal neutral conditions, using the Cornell and Illinois modification of NRC (2001) equations (Van Amburgh and Drackley, 2005).

| ADG (lb/day) | DMI (% of BW) | ME (Mcal/day) | CP (g/day) | CP (% of diet DM) | Estimated gain:feed |
|---|---|---|---|---|---|
| 0.44 | 1.05 | 2.34 | 94 | 18.0 | 0.38 |
| 0.88 | 1.30 | 2.89 | 150 | 22.4 | 0.63 |
| 1.32 | 1.57 | 3.49 | 207 | 26.6 | 0.77 |
| 1.76 | 1.84 | 4.40 | 253 | 27.4 | 0.86 |
| 2.20 | 2.30 | 4.80 | 318 | 28.6 | 0.87 |

**Table 6.** Effects of physical form of calf starter on performance and digestibility (Porter et al., 2007).

| | Pelleted | Mash (texturized) |
|---|---|---|
| Daily gain, 5-8 wk, lb | 1.12[a] | 1.41[b] |
| Daily gain, 0-8 wk, lb | 0.70[a] | 0.90[b] |
| Starter intake, 5-8 wk, lb | 86[a] | 112[b] |
| Starter intake, 0-8 wk, lb | 105[a] | 134[b] |
| First week ruminating | 6.0[a] | 3.7[b] |
| % of time ruminating | 8.7[a] | 21.0[b] |
| Rumen pH | 5.0 | 5.4 |
| Papillae length, cm | 2.9 | 3.5 |
| Digestibility, % | | |
| Dry matter | 71.3[a] | 76.3[b] |
| Crude protein | 77.5 | 78.2 |
| ADF | 28.8[a] | 43.2[b] |
| NDF | 39.7[a] | 51.9[b] |

[ab]$P < 0.05$ Means with different superscripts within rows differ.

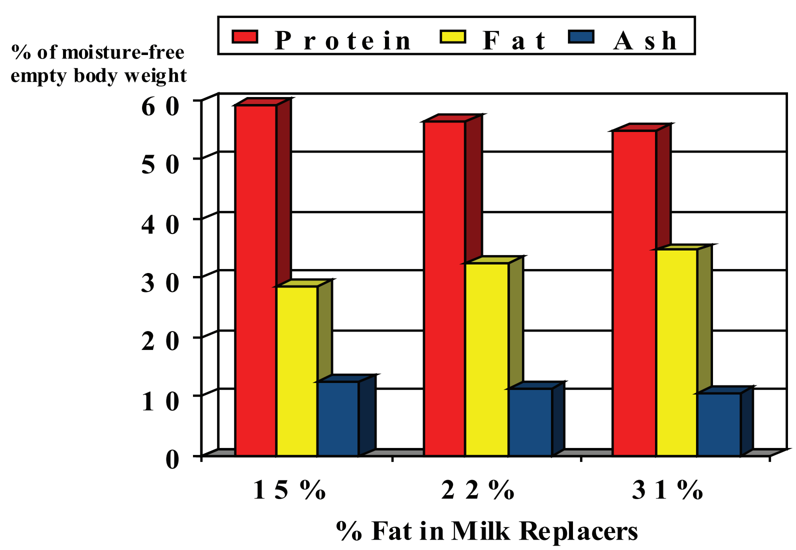


**Figure 1.** Moisture-free empty body weight crude protein, fat, and ash proportions in calves fed milk replacers differing in percentage of fat (Tikofsky et al., 2001).

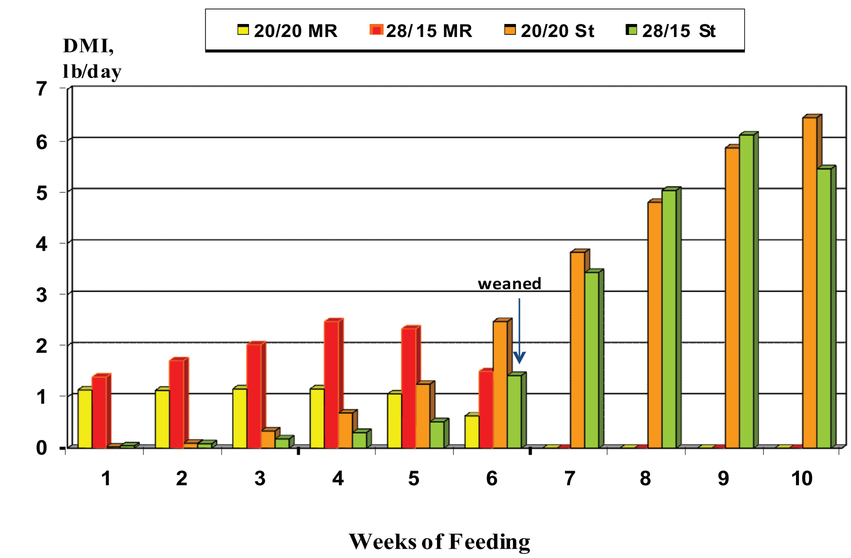


**Figure 2.** Effects of milk replacer (MR) with 20% CP/20% fat and 28% CP/15% fat dry matter intake (DMI) from MR and starter (St) for MR treatments (Stamey et al., 2011a). (Order of bars same as for treatment sequence).

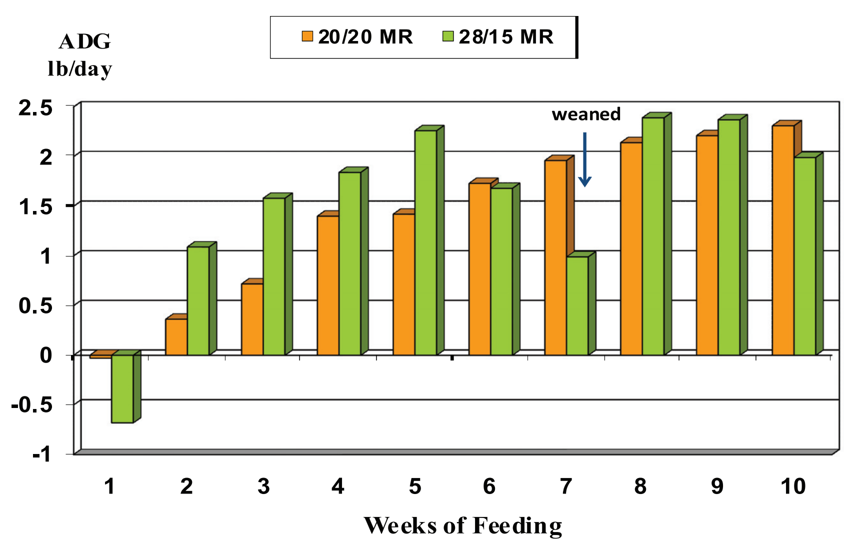


**Figure 3.** Average daily gain (ADG) weekly for 20% CP/20% and 28% CP/15% fat milk replacers (MR) over pre- and post-weaning periods (Stamey et al., 2011a). (Order of bars same as for treatment sequence).

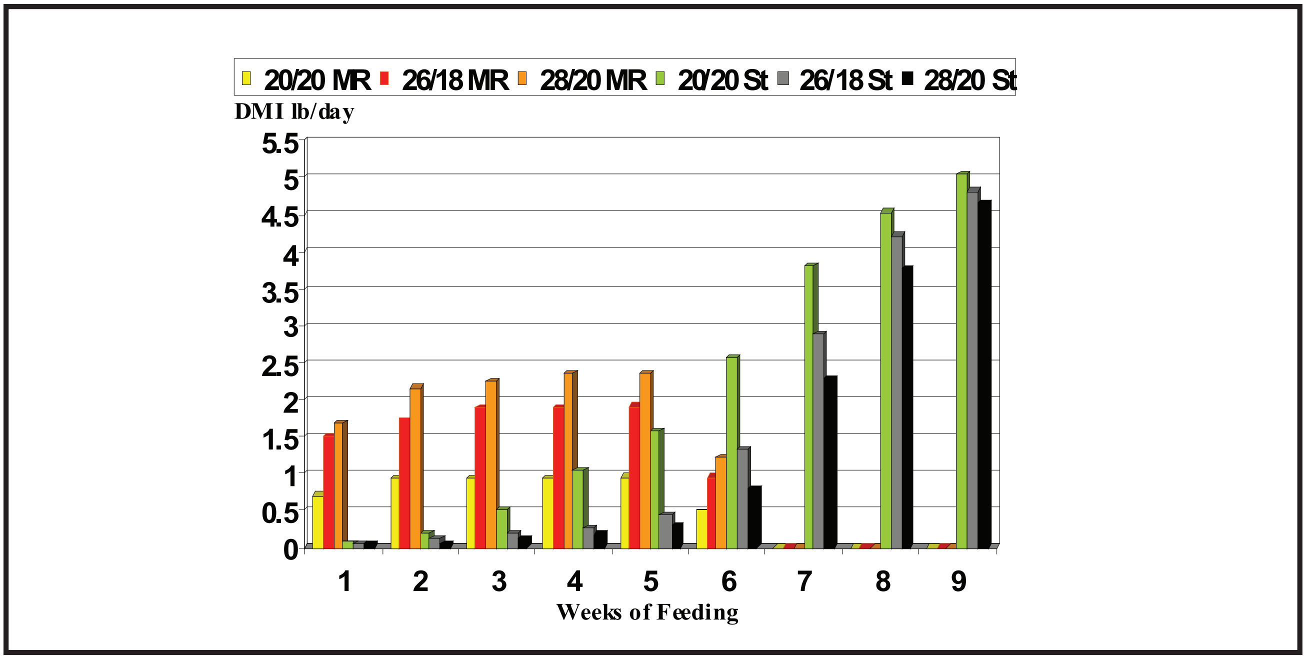


**Figure 4.** Dry matter intakes (DMI) of protein/fat percentages milk replacer (MR) treatments and of accompanying starter (St) treatments (Stamey et al., 2011b).

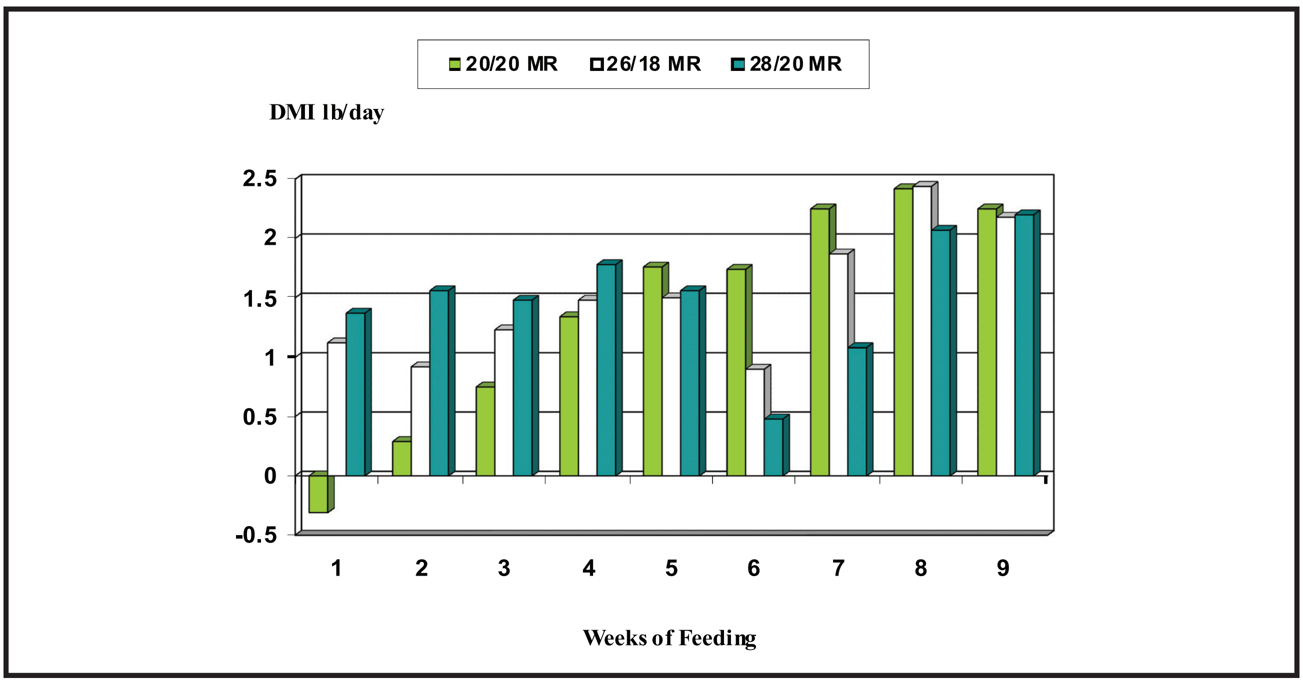


**Figure 5.** Average daily gain (ADG) with milk replacer (MR) treatments of protein/fat percentages during 9 wk, with full weaning at the end of 6 wk (Stamey et al., 2011b).

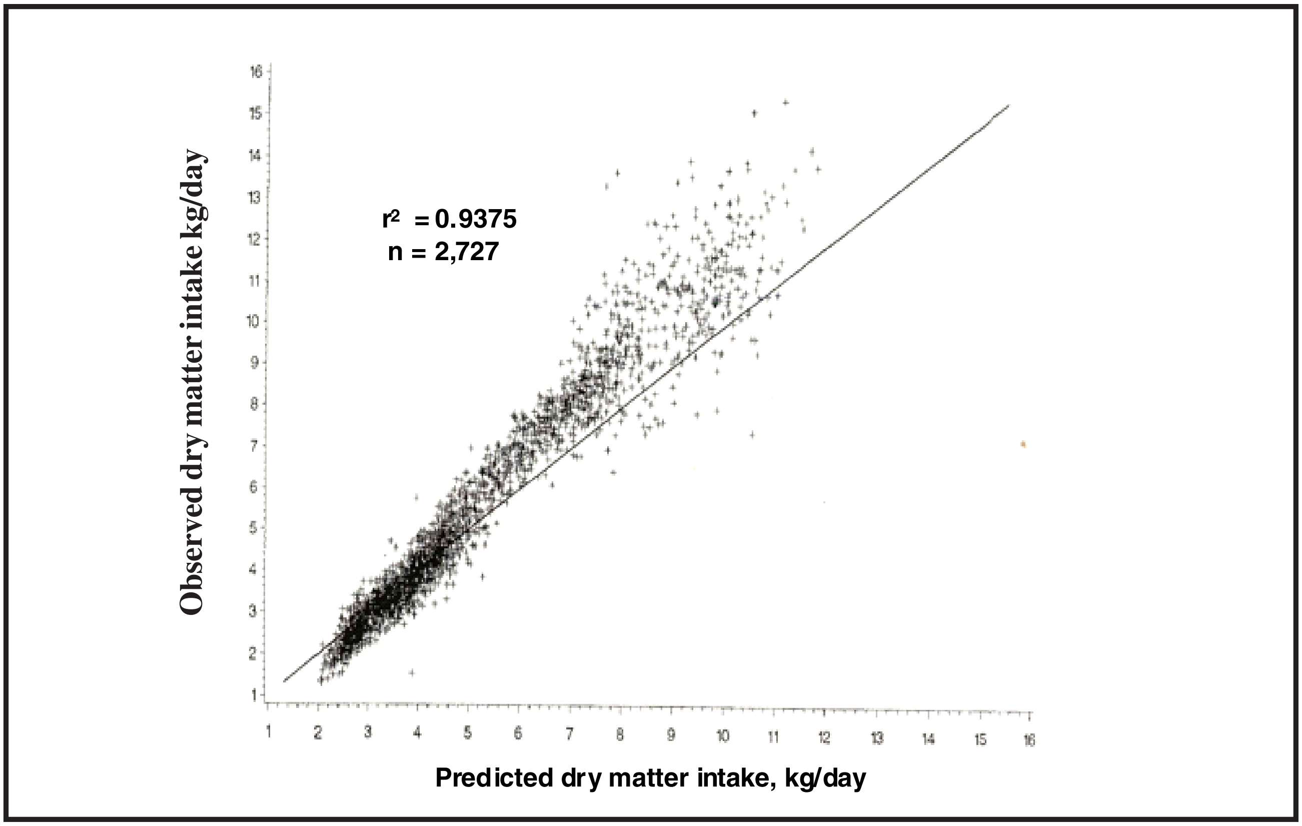


**Figure 6.** Dry matter intake (DMI) predicted from Beef NRC (1996) versus observed DMI from dairy heifers as used in the Dairy NRC (2001).