# Rates of growth for replacement heifers
# How a proper management program can save significant money

**James D. Quigley**
**Research & Technical Manager**
**Provimi North America**
**Brookville, OH USA**

## Introduction

Traditional recommendations for average daily gain (**ADG**) from weaning to breeding and breeding to calving are based on the assumption that the optimal age at first calving (**AFC**) is 22-24 mo of age. Calving heifers prior to 22 mo of age or later than 25 mo of age increase cost of production and may impair lifetime yield.

## Age at first calving – current status

The most recent NAHMS study (USDA, 2014) reported that the average AFC is 25.0 mo in the United States. However, there is considerable variation in operator reported AFC (Figure 1). Larger herds report younger AFC so that the mean age for all heifers is actually 25.0 mo. However, the greatest proportion of heifers calves at less than 24 months of age (Figure 2; USDA, 2014).

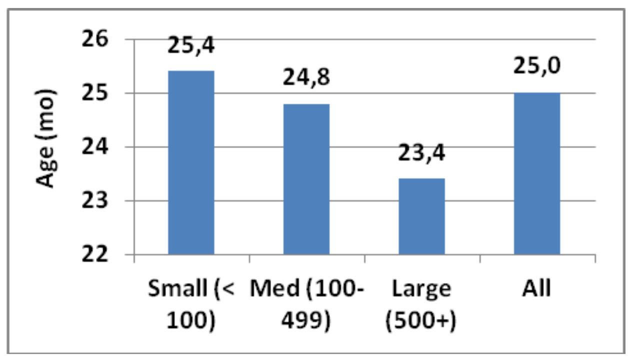


Figure 1. Owner reported average age at first calving in the U.S. from the 2014 NAHMS dairy survey (USDA, 2014).

It should be noted that owner reported survey data are subject to selective recall and response bias (the desire to provide the surveyor with the "correct" answer). Since most Extension specialists, veterinarians and dairy advisors recommend that heifers should calve at 22-24 mo of age, it is possible that at least some of the NAHMS data are affected by response bias.

Hare et al. (2006) used published DHIA records from 1979 to 2004 to estimate national AFC in the U.S. These researchers reported AFC to be 26.9 mo of age for Holsteins and 25.6 mo of age for Jerseys, using nearly 20 million DHIA records. The authors also reported that the mean AFC declined by approximately 3.4 d per year since 1980.

Figure 3 (from Hare et al., 2006) shows the change in AFC for dairy breeds in the U.S. Decline for Holstein cattle from 28 mo of age in 1980 to 25.3 mo in 2004 is indicative of the improvement by about 3 d/yr in AFC. The AFC for Jersey cattle declined from 26.5 mo of age in 1980 to 24 mo of age in 2004. Improvements in AFC for other dairy breeds are lower than for Jerseys or Holsteins; however, these breeds are also less important economically.

Assuming that AFC continued to decline by 3.4 d/yr since 2004, the average AFC in 2012 would be approximately 24.4 mo for Holsteins.

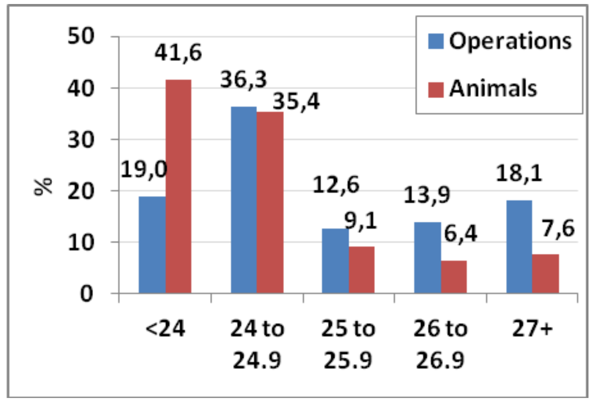


Figure 2. Percentage of operations (farms) and animals by age at first calving (months) in the U.S. from the 2014 NAHMS dairy survey (USDA, 2014).

**Heifers and efficiency**

The heifer enterprise represents a significant portion of the costs on a dairy farm. Depending on the source, the cost of rearing heifers is the second or third largest cost on the dairy farm (Heinrichs, 2014). Therefore, minimizing the cost while maximize economic return to the heifer enterprise is essential to profitability on the dairy farm.

We can consider the *efficiency* of the heifer enterprise and economic value of the product (milk production of heifers entering the milking string or for sale) divided by the input costs (feed, labor, capital). The consideration of efficiency of the entire enterprise necessarily alters our focus on the overall goal for the program. More specifically, our goal is to produce a heifer that is of sufficient size and strength to produce milk to her genetic potential. Further, she will have sufficient longevity to remain in the herd for several lactations.

An important limitation to calculation efficiency of the heifer enterprise is the lack of information available from which to make decisions. Although there is a wealth of information available on modern dairy farms to monitor and manage the milking cows, there is often a paucity of information available to manage heifers. We often lack information on growth (weight, height) and have little knowledge of the developmental progress of the animal through the essential stages of growth. An example of the limited nature of information available for heifers is shown in Figure 4.

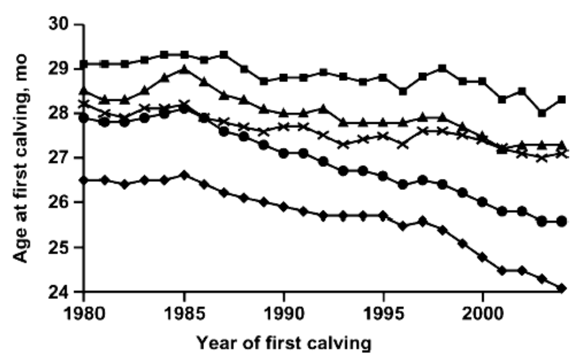


Figure 3. Change in age at first calving from 1980 to 2004 for Ayrshires (▪), Brown Swiss (Δ), Guersey (x), Holstein (●) and Jersey (◊) cows. From: Hare et al., 2006.

The lack of information profoundly limits our ability to modify the program. We are essentially managing "in the dark" and making decisions without the requisite information. This lack of information is a major contributor to the poor ages at first calving reported globally.

One method to determine the success of the heifer program is to monitor peak milk production of heifers compared to older animals. Extension publications in the United States suggest that heifers should produce at their peak milk production (approximately 100-110 days in lactation) approximately 75-85% of the peak milk produced by mature cows (typically, 50-60 days in lactation). This allows the producer to determine if heifers are raised sufficiently and have the requisite size and stature to compete for feed with the older animals and if they are sufficiently well developed to produce the milk of which they are genetically capable.


Figure 4. An example of the "technology" available with which farmers manage heifer breeding decisions.

**AFC – effects of nutrition**

A large body of research data documents the role of diet composition (particularly energy and protein) on body growth and mammary development. Studies from as early as the early 1900's documents the effect of too-rapid rates of BW gain in prepubertal heifers on milk production after calving, reproduction and, ultimately, longevity and profitability in the dairy herd. Post-pubertal growth rates appear to have less influence on mammary development (Sejrsen et al., 1982), and, as such, management programs for greater BW gain from breeding to calving may be warranted.

Feeding for rates of BW gain to achieve AFC younger than about 22-24 mo of age risk reduced milk production due to preferential deposition of lipid in the mammary parenchyma (Sejrsen and Purup, 1997) and increased risk of dystocia due to inadequate body size and excess body fat. Some researchers have suggested that performance of calves may be optimal at calving ages <22 mo of age (Mourits et al., 2000); however, most studies comparing AFC <22 mo have failed to be peer reviewed or were the result of computer simulations.

Requirements for maintenance and growth published by the NRC (2001) are based on estimating BW as a percentage of mature BW for the breed. An example of some requirements are in Table 1.

Early attempts to increase rate of BW gain prior to breeding utilized added energy, primarily by feeding additional corn silage or concentrate to young heifers (Swanson, 1960). These studies showed profound reduction in lactation after calving, primarily due to mammary fat deposition.

| BW, kg | NEg (Mcal/d) | MP (g/d) |
|---|---|---|
| **200** | 1.83 | 241 |
| **250** | 2.17 | 241 |
| **300** | 2.48 | 243 |
| **350** | 2.79 | 245 |
| **400** | 3.08 | 248 |

Table 1. Net energy for gain (NEg) and metabolizable protein (MP) requirements for a Holstein heifer (based on mature BW of 650 kg) gaining 800 g/d. From: NRC, 2001.

The role of protein in mammary development and fat deposition has also been evaluated. Diets fed for high rates of BW gain and containing greater amounts of CP and ME (i.e., 19.7% CP and 2.8 Mcal ME/kg DM) also resulted in lower milk production (Radcliff et al., 2000). Whitlock et al. (2002) also concluded that protein level or degradability had little effect on mammary development, provided that sufficient protein is available for normal body growth.

**AFC – previous data**

Numerous reviews of the literature related to nutritional effects on mammary development have been conducted.

In their 1997 review of the literature, Sejrsen and Purup (1997) concluded that "*Increasing feeding levels above moderate feeding results in reduced age at onset of puberty and may lead to reduced mammary growth and reduced milk yield potential of the heifers as cows. The effect seems to be present in all breeds, but the level of feeding that results in reduced milk yield potential varies between breeds. The effect of feeding level seems to be independent of diet composition, and the suggestion that the effect can be prevented by high level of protein is not substantiated by experimental data.*" The authors defined the critical ADG threshold as 600 to 700 g/d in large breed herds.

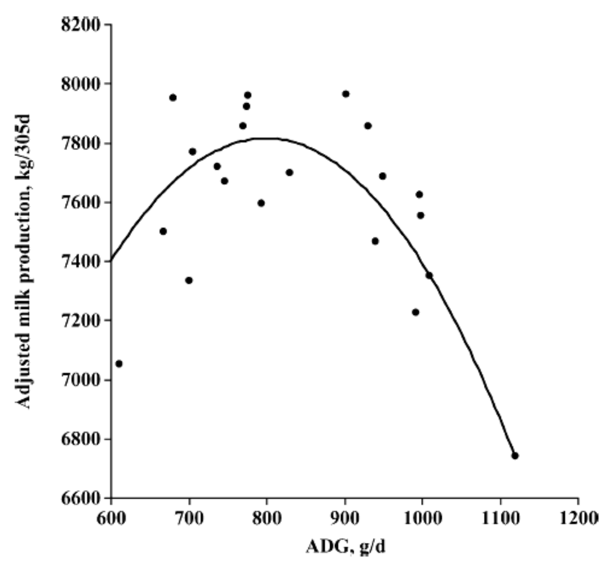


Figure 4. Meta-analysis of milk related to average daily BW gain from eight published research trials. From: Zanton and Heinrichs, 2005.

Zanton and Heinrichs (2005) summarized results of 15 published trials from 1990 to 2005. They conducted a meta-analysis of studies (n = 8 with a total of 472 animals) that met test criteria and evaluated the effect of prepubertal ADG and subsequent milk production.

Increasing prepubertal ADG resulted in a curvilinear effect on milk production and increased to maximal milk production (7,817 kg per 305-d lactation) at ADG of 799 g/d (Figure 4). Variation in ADG prior to puberty accounted for 62% of the variation in 305-d milk production and 53% of variation in 305-d fat corrected milk production.

The authors concluded: "*The results of this analysis indicate that, when raising dairy heifers for maximum first-lactation milk production, growth between approximately 150 to 320 kg of BW growth should be limited to around 800 g/d.*"

Other, more recent studies (e.g., Curran et al., 2013; Do et al., 2013) evaluated effects of age at first calving on lifetime production in heifers. Generally, most have concluded that AFC between 22-24 months of age maximized profitability. This is generally accomplished by reducing input costs of rearing with less effect on first lactation production.

Chester-Jones and Linn (2005) summarized results of six studies that compared AFC from 20.9 to 26.1 mo of age and concluded that, across all studies, heifers fed for faster growth rate and lower AFC (21.9 mo) calved 2.8 mo earlier and had 4.8% lower first lactation milk yields than those fed a more

| Ref[b] | AFC, mo[a] | | Prepubertal ADG, kg[c] | | BW post-calving, kg | | 1st lactation milk, kg | | |
|---|---|---|---|---|---|---|---|---|---|
| | Late AFC | Early AFC | Late AFC | Early AFC | Late AFC | Early AFC | Late AFC | Early AFC | % change |
| 1 | 26.1 | 22.9 | 0.74 | 0.74 | 502 | 452 | 4,444 | 4,168 | -6% |
| 2 | 23.0 | 21.9 | 0.68 | 0.83 | 506 | 543 | 9,152 | 9,604 | +5% |
| 3 | 24.5 | 21.3 | 0.68 | 0.94 | 549 | 505 | 9,852 | 9,367 | -5% |
| 4 | 23.6 | 20.7 | 0.77 | 1.12 | 538 | 514 | 8,601 | 7,487 | -13% |
| 5 | 25.4 | 22.4 | 0.77 | 1.13 | NR[d] | NR | 7,142 | 6,790 | -5% |
| 6 | 25.9 | 22.3 | 0.75 | 0.75 | 602 | 570 | 10,734 | 10,332 | -4% |

Table 2. Selected studies evaluating the effect of prepubertal growth and younger age at first calving (AFC) on milk yield. From: Chester-Jones and Linn, 2005.

[a]Adapted from Meyer et al. (2004).
[b]Research: 1 = Lin et al. (1986), 2 = Bar-Peled et al. (1997), 3 = Van Amburgh et al. (1998), 4 = Radcliff et al. (2000), 5 = Vicini et al. (2003a, 2003b), 6 = Ettema and Santos (2004).
[c]Prepubertal ADG rate calculated by Meyer et al. (2004) from research paper data.
[d]NR = not reported.

conventional program with calving at 24.7 mo (Table 2). Since reviews of Zanton and Heinrichs (2005) and Chester-Jones and Linn (2005), a few additional studies specifically with weaned calves have been reported.

A recent study by Morrison et al. (2012) concluded that increased milk allowance prior to weaning increased growth to 56 days, but all differences in animal size were unobservable by 12-18 mo of age. Further, there was no effect of additional milk allowance prior to weaning on subsequent milk production.

Davis-Rincker et al. (2011) fed pre-weaned calves milk replacer at conventional or intensified levels, then weaned calves at six weeks of age. From birth to six weeks of age, calves were offered starter containing 20% (conventional) or 24% (intensified) crude protein in addition to CMR at conventional or intensified rates. After weaning, calves were fed 2.7 kg/d of conventional calf starter and alfalfa hay for *ad libitum* consumption. Thereafter, calves were fed similar diets and transitioned to TMR diets until calving. Although calves fed the intensified diets were heavier and structurally larger at weaning, they reached puberty younger and lighter than conventionally-fed calves. There was no effect on post-calving milk production or reproductive efficiency.

Japanese researchers (Ishii et al., 2011) fed Holstein heifers diets containing 14% or 16% crude protein (supplemental protein provided by SBM) from 100 to 350 kg. Diets were also fed to achieve ADG of 0.75 or 1.0 kg. There were three diets fed MM (moderate growth = 0.75 kg ADG/d, moderate protein = 14% protein); HM (high growth = 1.0 kg/d, moderate protein), and HH (high growth, high protein = 16% protein). Actual growth rates were 0.97, 1.12, and 1.10 kg/d, respectively. Growth rate was increased by feeding for greater growth and calves fed HM and HH calved at 21 mo of age compared to 23 mo of age for calves fed MM. However, milk production in the first lactation was impaired. Calves fed for moderate growth and 14% CP produced 25% more milk than calves gaining >1.1 kg/day.

Bach et al. (2011) evaluated records from 7,768 Holstein heifers born from 2004 to 2006. Calves were raised on one contract heifer operation in Spain and then moved to their home farms prior to calving. Survival in the home farms was determined by Spanish national records and factors associated with calf rearing were associated with and the odds of the animal completing its first lactation.

Age at first calving as early as 662 d (21.8 mo) had no effect on survival of first-calf heifers to their second lactation. Heifers calving earlier (mean AFC = 23.8 mo) were more likely to survive to their second lactation compared to heifers calving later (mean AFP = 24.2 mo, $P < 0.05$). Also, as AFC increased, survival decreased. However, this regression analysis of AFC on survival did not account for milk production, calf survival, dystocia or other economic variables.

Heinrichs and Heinrichs (2011) monitored the effects of rearing management on growth of dairy heifers from birth to 4 mo of age with 795 Holstein heifers from 21 Pennsylvania farms. Subsequently, growth parameters including AFC, rates of disease, intake of starter and others were related production in the first lactation and lifetime production. The authors reported that, for each day increase in AFC, first-lactation milk 305-ME production declined by 2.37 kg ($P < 0.01$). Mean AFC in the dataset evaluated was 868.7 d (28.6 mo). The authors did not calculate economics of extended AFC or additional costs of rearing calves for extended period.

Ettema and Santos (2004) evaluated economic performance of Holstein heifers (n = 1,905) on three commercial dairies in California. Normal management on each farm was to raise heifers to gain 700-800 g/d from 4 mo to breeding and 800 to 900 g/d from breeding to approximately 8.5 mo of pregnancy (close up). Heifers were grouped retrospectively to Low (<700 g ADG/d), Medium (701-750 g ADG/d) or High (>750 g/d) growth groups and production parameters were compared.

The authors reported that AFC <700 d (<23.0 mo) was associated with reduced milk production. Heifers in the High age group produced more milk components (milk fat and protein) than heifers in the other two groups. Heifers in the Low and High groups had lower conception rates post-partum than heifers in the Medium group. Heifers that grew slowly (Low group) had more days open and required more inseminations than heifers in the High group. Economics favored heifers raised in the Medium group by \$138.33 compared to Low group heifers and \$98.81 compared to High group heifers. The authors concluded that maximal economic return occurred when heifers calved between 23.0 and 24.5 mo of age.

Pietersma et al. (2006) collected records from Holstein (n = 44,989) and Ayrshire (2,294) cattle from 1993 to 2003. Measurements regarding BW, height, condition and breedings were compared to lactation and other physical measures of animal size. Average age at first calving was 26.5 and 27.1 mo for Holsteins and Ayrshires, respectively. Correlation of AFC with first-lactation milk yield (corrected for year and herd effects) in Holsteins was 0.12 ($P < 0.0001$, n = 12,901) and 0.14 ($P < 0.005$, n = 508) in Ayrshires. These data suggested that as AFC increased first-lactation milk yield increased also.

**Management strategies**

The 2001 NRC utilizes growth as a percentage of mature BW (MBW) to determine degree of genetic maturity. A publication (2007) by the Bovine Alliance on Management and Nutrition (Industry working group cooperating with USDA to disseminate data from many NAHMS studies) published a report (BAMN, 2007) outlines a management strategy based on 2001 NRC growth targets (NRC, 2001). The methodology identifies key target BW for breeding (55%) and first calving (82%) as a percentage of mature breed weight. Thus, if mature breed weight for a Holstein cow is 680 kg, the target breeding BW would be 374 kg and post-calving BW is 558 kg. To achieve a target AFC of 24 mo, a heifer should be pregnant by 15 mo of age. Assuming two breedings per conception, breeding should commence at about 13.5 to 14 mo of age. Thus, a 42-kg Holstein calf at birth must gain 374-42 = 332 kg in 410 days, or a rate of ADG = 810 g/d.

Hoffman (2003) recommended BW for large breed (Holstein) heifers from birth (initial BW = 93 lbs) to 24 mo of age (pre-calving BW = 1,367 lbs). Regression of the growth targets produced a linear regression with $r^2$ of 0.999, suggesting a highly linear growth rate (Figure 5). Assuming 30.42 days per month, the target ADG is 53.475 / 30.42 = 799 g/d.

Moderate rates of BW gain prior to breeding (≤800 g/d) may be followed by more rapid rates of gain from conception to calving, as first lactation milk production is significantly affected by calving BW. The caveat is that heifers should not gain too much BW prior to calving to increase the risk of dystocia and periparturient metabolic disorders. Hoffman et al. (1996) concluded that calves fed for accelerated post-pubertal growth (933 g/d) and not bred for early calving grew too fat (condition score = 4.2 on a scale of 1 = thin to 5 = obese) and, thus, had a higher dystocia index than heifers fed for

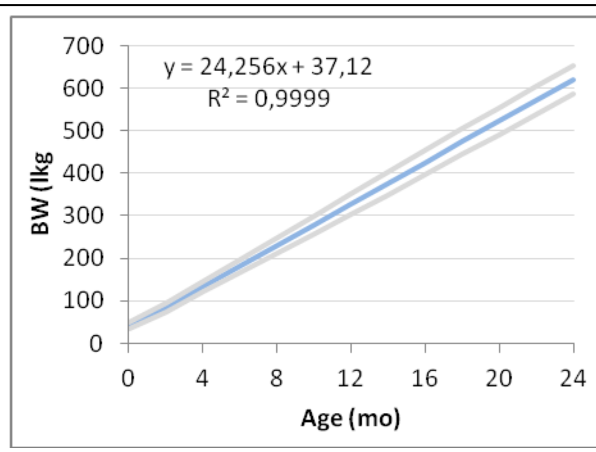


Figure 5. Target growth rates for Holstein heifers including high and low targets based on genetic variation. Adapted from Hoffman, 2003.

normal rates of gain. Waltner et al. (1993) reported that fat-corrected milk increased as body condition scores increased to 3.5 in first-lactation heifers; thereafter, milk production declined, but particularly at condition score = 4. Thus, these data collectively suggest that excessive fattening of heifers prior to parturition (condition ≥4) should be avoided.

There appear to be few economic scenarios to justify slower feeding of heifers for delayed calving (Pecsok et al., 1992), except, perhaps, low input pasture-based programs. Increasing growth by feeding additional forage and/or concentrate to reduce AFC to 22-24 mo of age is almost always more economical than delaying AFC by reducing nutrient density or availability.

**AFC – effects of reproduction**

Because gestation in cattle is fixed at approximately 280 days, reducing AFC is generally accomplished by reducing age at breeding and ensuring that heifers reach breeding at a level of reproductive maturity to ensure high conception rates.

Puberty in dairy heifers is related more to BW than age, *per se*, and is achieve at approximately 40-50% of mature BW. Under well managed conditions, puberty may occur between 9 and 12 mo of age, thereby allowing the heifer to cycle several times before breeding.

Conception rate in conventionally bred (not using sexed semen) in U.S. heifers averaged 56% between 2006 and 2008 (Norman et al., 2010); this is higher for heifers bred with sexed semen, which was reported to be 39% (Norman et al., 2010).

Kuhn et al. (2006) evaluated conception rate in U.S. Holstein heifers using DHIA data with 537,938 breedings of 362,512 heifers in 2,668 herds from 41 states between 2003 and 2005. They reported that optimal conception rate occurred when heifers were 15-16 mo of age (55.8%); heifers 13-14 mo of age had a slightly lower rate (55.7%). Ages below 13 mo or above 16 mo of age resulted in sharp declines in conception rate.

Because sexed semen is becoming more popular as a means of breeding in many parts of the world, and due to the increase in breedings required per conception with sexed semen, producers will need to either grow heifers more rapidly to account for the increase of approximately 0.77 services per conception (assuming each breeding requires an average of 21 days, this will delay calving by approximately 0.77 x 21 = 16 days) or accept slightly later AFC for heifers bred using sexed semen.

**Current estimates of AFC**

Estimates of AFC are not globally available for many countries. Nonetheless, some countries provide periodic estimates of the average AFC for the dairy herds (or subsets of the herds) within their countries. Some examples are reported in Table 3.

Estimates from other sources are compiled into a global figure, range from 24 to >32 months of age. Although national statistics do not represent the situation on most well managed, modern farms, it is a clear indication that the stated goal of raising heifers to calve at 20-24 months of age is far from achieved in most parts of the world. There is tremendous progress available in most countries.

| Country | AFC (mo) |
|---|---|
| Israel | 24 |
| USA | 25 |
| Ireland | 26 |
| Korea | 26 |
| Netherlands | 26 |
| Canada | 27 |
| Lithuania | 27 |
| Poland | 27 |
| Italy | 28 |
| Sweden | 28 |
| Argentina | 29 |
| China | 29 |
| Spain | 29 |
| UK | 29 |
| Brazil | 30 |
| France | 30 |
| Turkey | 32 |

Table 3. Estimates of age at first calving (AFC) in various countries where data are available.

**Estimating economic cost of suboptimal AFC**

Researchers at the University of Wisconsin reviewed DHIA records from 69,145 Holstein cows that calved in 2005 and compared the effect of AFC on first lactation and lifetime milk production. Milk production records were grouped according to 4 herd management criteria - 1) 3X milking and rolling herd average (RHA) = 12,750 kg (3X-H), 2) 3X milking and RHA = 11,250 kg (3X-M), 3) 2X milking and RHA = 11,250 kg (2X-M), and 4) 2X milking and RHA = 9,250 kg (2X-L).

When first lactation milk production was reviewed, the researchers reported a reduction of 166, 369, and 654 kg for heifers calving at 22, 21, and 20 mo, respectively, compared calving at 24 mo. There were no difference among the four production groups on 1st lactation milk production.

On the other hand, there were important differences between the four groups regarding lifetime milk production. As AFC increased in heifers in the 3X-M and 3X-H groups, there was a linear decline in lifetime milk production. Interestingly, as AFC declined to <24 mo of age, lifetime milk production continued to increase. As can be seen in Figure 6, lifetime milk production in heifers in the 3X-H and 3X-M groups (blue and red lines, respectively) continued to increase as AFC decreased, even below 24 mo of age. Heifers in the 3X-H group that calved at 20 mo of age produced about 2,000 kg more lifetime milk than heifers that calved at 24 mo of age.

Lifetime milk production was affected by AFC differently in heifers in the 2X milking groups (2XM and 2X-L). Rather than a linear increase in lifetime milk with decreasing AFC, there was a curvilinear relationship between lifetime milk and AFC.

Heifers calving at 23 mo (2X-M) and 24 mo (2X-L) produced the most milk; any deviation from these AFC resulted in lower lifetime milk production in these two groups. As can be seen in Table 3, the difference in lifetime milk (labeled as “Diff” in Table 4) compared to the maximum ranged from +1,784 kg of lifetime milk for 3X-H herds, calving at 20 mo of age) to -5,929 kg for heifers in 3X-M herds calving at 30 mo of age.

Why did 3X vs. 2X milking affect the relationship between AFC and lifetime milk production? The authors of the study suggested that differences in longevity between heifers in 3X and 2X herds may have contributed to differences in production. Heifers in 2X herds, reducing AFC by 30 days resulted in a similar reduction (27-28 d) in herd life (heifers left the herd 27-28 d earlier) whereas in 3X herds, reducing AFC by 30 d resulted in only 13-16 d earlier. Thus heifers in 3X herds had nearly 2 weeks additional milk production days for every 30 d reduction in AFC.

Also, the terms of 3X and 2X may have been proxies for many other management practices that altered

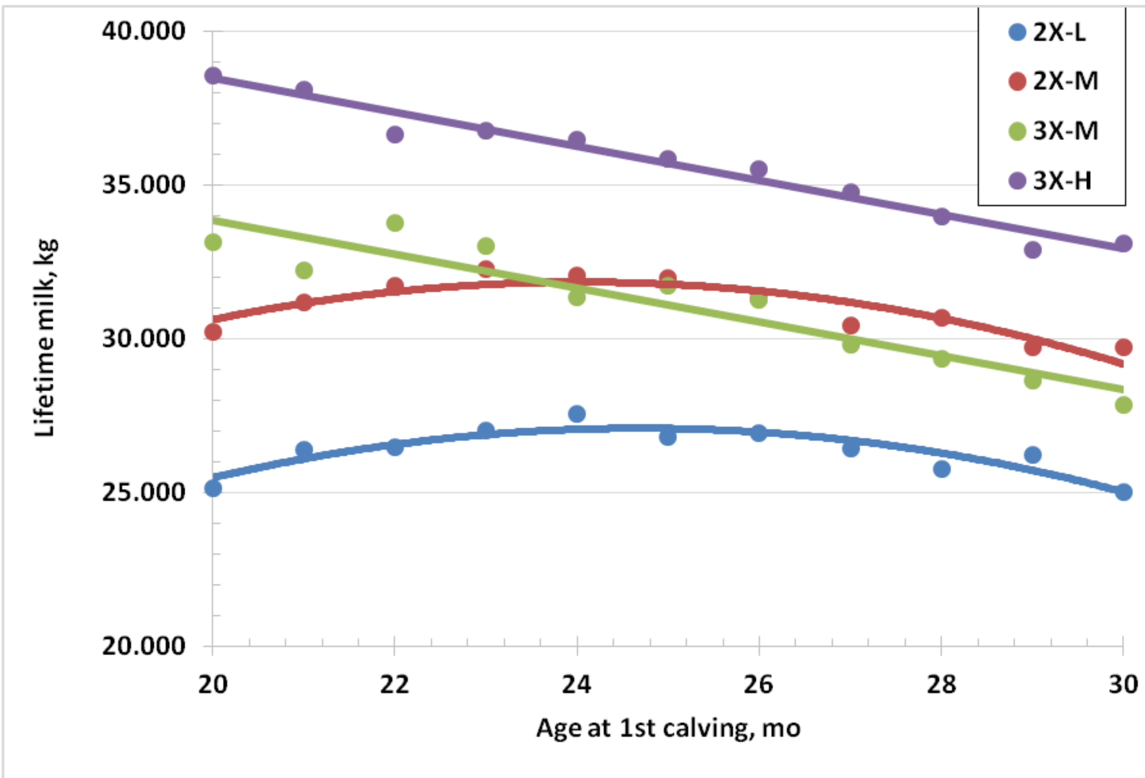


Figure 6. Lifetime milk production in Holstein cows on farms that milked two (2X) or three (3X) times daily and in Low (<9,250 kg; L), Medium (11,250 kg; M) or High (12,750; H) herd average milk production. Adapted from Curran et al., 2013.

heifer management, growth, and longevity.

Data of Curran show clearly the importance of calving at or right around 24 mo of age. Delaying calving to 26, 28 or even 30 mo of age costs money. A lot of money. Let's consider the case of a herd that calves their heifers at an average of 28 mo of age. For the moment, we'll ignore the additional carrying costs – feed, labor, management, capital, etc. – for the heifers. Let's focus in on the cost of lost milk production.

For a 3X-H herd making 12,750 kg of milk per year, calving at 28 mo of age would cost each heifer 2,772 kg of milk during its lifetime. If we assume that milk is worth $0.50/kg then the cost of AFC of 28 mo is 2,772 x 0.50 = $1,386 only in lost future milk production. This cost does not include the cost of additional feed, keeping additional heifers on the farm, capital, labor, etc. These costs can easily double the lost milk, so it's quite possible that producers calving at 28 mo of age could easily lose >$2,000 per heifer when all costs are considered.

What if a herd's milk production doesn't coincide exactly with the averages of Curran et al.? Perhaps we can estimate changes in lifetime milk (the "penalty") as a percentage of the mean. For example, at 26 mo AFC for the 3X-M herds, the loss in lifetime milk is 2,510 kg. Since the maximal lifetime milk for 3X-M herds was 33,764 kg (AFC = 22 mo, see Table 4 and figures in bold), the percent reduction is 2,510 / 33,764 = 7.4% reduction. You can see percent reductions from optimal in Table 5. The key will be to select the appropriate columns to identify which "percent penalty" best represents your operation.

| AFC, mo | 3X-H, kg | Diff, kg | 3X-M, kg | Diff, kg | 2X-M, kg | Diff, kg | 2X-L, kg | Diff, kg |
|---|---|---|---|---|---|---|---|---|
| 20 | 38,545 | 1,784 | 33,142 | -622 | 30,211 | -2,040 | 25,156 | -2,397 |
| 21 | 38,107 | 1,346 | 32,229 | -1,535 | 31,190 | -1,061 | 26,393 | -1,160 |
| 22 | 36,655 | -106 | **33,764** | 0 | 31,709 | -542 | 26,464 | -1,089 |
| 23 | **36,761** | 0 | 33,032 | -732 | **32,251** | 0 | 27,015 | -538 |
| 24 | 36,486 | -275 | 31,332 | -2,432 | 32,078 | -173 | **27,553** | 0 |
| 25 | 35,846 | -915 | 31,714 | -2,050 | 31,978 | -273 | 26,819 | -734 |
| 26 | 35,506 | -1,255 | 31,254 | -2,510 | 31,293 | -958 | 26,917 | -636 |
| 27 | 34,780 | -1,981 | 29,821 | -3,943 | 30,415 | -1,836 | 26,449 | -1,104 |
| 28 | 33,989 | -2,772 | 29,360 | -4,404 | 30,696 | -1,555 | 25,764 | -1,789 |
| 29 | 32,889 | -3,872 | 28,640 | -5,124 | 29,710 | -2,541 | 26,241 | -1,312 |
| 30 | 33,110 | -3,651 | 27,835 | -5,929 | 29,717 | -2,534 | 25,029 | -2,524 |

Table 4. Lifetime milk production and difference from optimal AFC. Adapted from Curran et al., 2013.

Missing on AFC cost producers money. As can be seen in the figures, it can cost a lot of money. Sometimes we can get caught up with "little" details of calf and heifer rearing and lose sight of the big picture. While other aspects of calf rearing are critical, few have the economic ramifications of inadequate (or excessive) growth and delayed (or premature) AFC. We can debate age at weaning, amount of liquid to feed in the first two months of life and the proper serum total protein to achieve at 24 h of age. However, if we do an outstanding job to weaning, but then put heifers into crowded pens and feed them inadequate amounts and concentrations of nutrients, all the investment in early calf rearing will be lost. It's little wonder that many producers with less than optimal post-weaning management have found accelerated milk feeding systems to be an expensive investment that hasn't paid dividends. It may not be the fault of the pre-weaning nutrition – rather, it's post-weaning growth that is the "Achilles heel" of the program. As advisors to producers, it's essential that we consider the entire feeding and growing program to ensure that our recommendations will address the most important economic factors on the farm.

**On-farm calculations**

We (Quigley, unpublished) have developed an economic model of heifer growth from birth to calving based on NRC (2001) estimates of nutrient requirements and nutrient supply, estimates of DM intake (Hoffman et al., 2008 and unpublished) and effects of environment based on the farm location. Using current (January 2017) estimates of feed costs, cull heifer values ($1,500 per heifer) and milk price ($0.25/kg), we estimated the economic penalty associated with extra feed required and lost milk production based on the data of Curran et al. (2013). We assumed in this scenario that the farm in question was producing 9,000 kg milk rolling herd average with a 28% replacement rate, 13.2 month calving interval, 17% calf non-completion rate and 500 cows in the herd. We modeled the loss of milk production based on 2X-M penalties from Curran et al. (Table 5). Also, we calculated the one-time benefit to selling excess heifers when reducing the herd from current levels to the number required for calving at an optimal of 24 mo of age.

| | 3X-H | | 3X-M | | 2X-M | | 2X-L | |
|---|---|---|---|---|---|---|---|---|
| **AFC** | **Diff.** | **%** | **Diff.** | **%** | **Diff.** | **%** | **Diff.** | **%** |
| 20 | 1,784 | 4.9% | -622 | -1.8% | -2,040 | -6.3% | -2,397 | -8.7% |
| 21 | 1,346 | 3.7% | -1,535 | -4.5% | -1,061 | -3.3% | -1,160 | -4.2% |
| 22 | -106 | -0.3% | **0** | **0.0%** | -542 | -1.7% | -1,089 | -4.0% |
| 23 | **0** | **0.0%** | -732 | -2.2% | **0** | **0.0%** | -538 | -2.0% |
| 24 | -275 | -0.7% | -2,432 | -7.2% | -173 | -0.5% | **0** | **0.0%** |
| 25 | -915 | -2.5% | -2,050 | -6.1% | -273 | -0.8% | -734 | -2.7% |
| 26 | -1,255 | -3.4% | -2,510 | -7.4% | -958 | -3.0% | -636 | -2.3% |
| 27 | -1,981 | -5.4% | -3,943 | -11.7% | -1,836 | -5.7% | -1,104 | -4.0% |
| 28 | -2,772 | -7.5% | -4,404 | -13.0% | -1,555 | -4.8% | -1,789 | -6.5% |
| 29 | -3,872 | -10.5% | -5,124 | -15.2% | -2,541 | -7.9% | -1,312 | -4.8% |
| 30 | -3,651 | -9.9% | -5,929 | -17.6% | -2,534 | -7.9% | -2,524 | -9.2% |

Table 5. Lifetime milk production penalty and percent reduction with heifers calving outside optimal AFC. Adapted from Curran et al., 2013.

| AFC (mo) | Feed | Milk | Total | Heifer |
|---|---|---|---|---|
| **24** | 0 | 0 | 0 | 0 |
| **25** | 36 | 36 | 72 | 21,000 |
| **26** | 75 | 26 | 102 | 40,500 |
| **27** | 113 | 98 | 211 | 61,500 |
| **28** | 153 | 209 | 363 | 82,500 |
| **29** | 193 | 360 | 553 | 102,000 |
| **30** | 224 | 551 | 784 | 123,000 |

Table 6. Estimated per heifer cost of additional feed, lost milk production at various months compared to calving at 24 months of age. Also, heifer value is a one-time benefit of reducing heifer herd to number required to calve at 24 months of age. All values are US dollars per heifer. From: Quigley, unpublished.

As can be seen in Table 6, the per-heifer cost of delayed calving increasing with increasing age. From 24 to 26 months of age, the per heifer cost is about $102. However, as AFC increases, predicted lost milk produced increases dramatically, based on the equations of Curran et al. (2013). The one-time value of reducing the heifer herd to the number needed to maintain a supply of heifers (for this example, 409 heifers) is significant. Note that these values do NOT include costs of labor, capital, equipment, additional land required or other factors. It also does not account for increased environmental problems associated with carrying less than optimal heifers on the farm. Fewer heifers on the farm will reduce the amount of manure and methane produced.

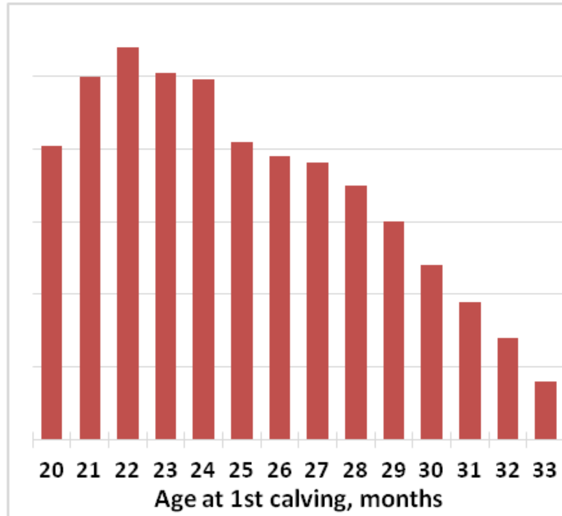


Figure 7. Average profit to 6 years by age at first calving in Holsteins. From: Beavers and Van Doormaal, 2015.

Other calculations, conducted in Canada by the Canadian Dairy Network (Beavers and Van Doormaal, 2015) estimated the lifetime profitability of various ages at first calving. Similar to other calculations, these authors concluded that lifetime profitability is maximized when Holstein and Jersey heifers calve at 22 months of age. The average profit to six years of life is shown in Figure 7. As age at first calving exceeds 22 months, the overall profitability declines.

Finally, Froidmont and coworkers (2013) evaluated the lifetime milk production records of more than 450,000 records of animals born in Belgium between 1990 and 2010. In this dataset, only 24% of heifers calved before 26 months of age, which is typical of many Western European countries. However, animals calving between 22-26 months of age produced more milk in their first and second lactations and in their lifetimes than other groups. The number of productive days in the herd was also longer (Table 7). The authors concluded their article by writing "*Controlling the AFC is a key factor to be addressed to ensure good lifetime milk production and efficient animals able to produce more milk in less time. The implications are both economic and environmental*." Heifers are most profitable and contribute least to environmental problems when they calve between 22 and 26 months of age in this Belgian study.

| | Age at first calving, months | | | | | |
|---|---|---|---|---|---|---|
| **Item** | **18-22** | **22-26** | **26-30** | **30-34** | **34-38** | **38-42** |
| Milk production, kg | | | | | | |
| 1st lactation | 5,824$^{f}$ | 6,539$^{a}$ | 6,462$^{b}$ | 6,363$^{c}$ | 6,211$^{d}$ | 5,914$^{e}$ |
| 2nd lactation | 6,976$^{c}$ | 7,569$^{a}$ | 7,335$^{b}$ | 7,034$^{c}$ | 6,838$^{d}$ | 6,539$^{e}$ |
| Lifetime | 26,565$^{c}$ | 29,340$^{a}$ | 27,869$^{b}$ | 26,138$^{c}$ | 24,690$^{d}$ | 22,566$^{e}$ |
| | | | | | | |
| Animal parameters | | | | | | |
| Number of lactations | 3.84$^{b}$ | 3.95$^{a}$ | 3.85$^{b}$ | 3.73$^{c}$ | 3.60$^{d}$ | 3.44$^{e}$ |
| Calving interval, mo | 13.6$^{a}$ | 13.5$^{b}$ | 13.6a$^{b}$ | 13.6$^{a}$ | 13.6$^{a}$ | 13.7$^{a}$ |
| Life length, d | 2,096$^{f}$ | 2,228$^{e}$ | 2,292$^{d}$ | 2,368$^{c}$ | 2,428$^{b}$ | 2,487$^{a}$ |

Table 7. Production and animal parameters of heifers calving between 18 and 42 mo of age in Belgium between 1990 and 2010. Adapted from Froidmont et al., 2013.

$^{a\text{-}f}P < 0.05$.

**Summary**

Few published data support increasing rates of BW gain to promote calving at less than approximately 22-24 mo of age. Nutrition and management strategies to provide for approximately 800 g/d are adequate to ensure proper rates of BW gain for optimal productivity after calving.

**References**

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

Chester-Jones, H. and J. Linn. 2005. Effect of nutrition and management of dairy heifers on resultant cow longevity. Presented at the 66th Minnesota Nutrition Conference & Technical Symposium: Future of Corn in Animal Feed, September 20-21, 2005, St. Paul, MN.

Curran, R. D., K. A. Weigel, P. C. Hoffman, J. A. Marshall, C. K. Kuzdas and W. K. Coblentz. 2013. Relationships between age at first calving; herd management criteria; and lifetime milk, fat, and protein production in Holstein cattle. Prof. Anim. Sci. 29:1-9.

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

Do, C., N. Wasana, K. Cho, Y. Choi, T. Choi, B. Park, and D. Lee. 2013. The effect of age at first calving and calving interval on productive life and lifetime profit in Korean Holsteins. Asian-Australasian J. Anim. Sci. 26:1511–1517.

Ettema, J. F., and J.E.P. Santos. 2004. Impact of age at calving on lactation, reproduction, health, and income in first-parity Holsteins on commercial farms. J. Dairy Sci. 87:2730–2742.

Froidmont, E., P. Mayeres, P. Picron, A. Turlot, V. Planchon, and D. Stilmant. 2013. Association between age at first calving, year and season of first calving and milk production in Holstein cows. Animal. 7:665–672.

Hare, E., H. D. Norman, and J. R. Wright. 2006. Trends in calving ages and calving intervals for dairy cattle breeds in the United States. J. Dairy Sci. 89:365-370.

Heinrichs, A. J. 2014. Heifer Economics. Pennsylvania State University DAS 99-14. http://extension.psu.edu/animals/dairy/nutrition/heifers/economics/heifer-economics

Heinrichs, A. J., and B. S. Heinrichs. 2011. A prospective study of calf factors affecting first-lactation and lifetime milk production and age of cows when removed from the herd. J. Dairy Sci. 94:336–341.

Hoffman, P.L. 2003. Heifer Management. In: Raising Dairy Replacements (Ed. P.L. Hoffman and R. Plourd), Chapter 12, pp. 93-100, Midwest Plan service, Ames, Iowa.

Hoffman, P. C., N. M. Brehm, S. G. Price, and A. Prill-Adams. 1996. Effect of accelerated postpubertal growth and early calving on lactation performance of primiparous Holstein heifers. J. Dairy Sci. 79:2024-2031.

Hoffman, P. C., K. A. Weigel, and R. M. Wernberg. 2008. Evaluation of equations to predict dry matter intake of dairy heifers. J Dairy Sci. 91:3699-709.

Ishii, T., K. Kawashima, H. Oribe, H. Ueda, T. Hasunuma, K. Akiyama, H. Nakayama, M. Kurihara, F. Terada, and S. Kushibiki. 2011. Effects of growth and dietary crude protein level until first insemination on milk production during first lactation in Holstein heifers. Anim. Sci. J. 82:741–746.

Kuhn, M. T., J. L. Hutchison, and G. R. Wiggans. 2006. Characterization of Holstein heifer fertility in the United States. J. Dairy Sci. 89:4907–4920.

Morrison, S. J., H. C. F. Wicks, A. F. Carson, R. J. Fallon, J. Twigge, D. J. Kilpatrick and S. Watson. 2012. The effect of calf nutrition on the performance of dairy herd replacements Animal. 6:909–919.

Mourits, M.C.M., D. T. Galligan, A. A. Dijkhuizen, and R.B.M. Huirne. 2000. Optimization of dairy heifer management decisions based on production conditions of Pennsylvania. J. Dairy Sci. 83:1989–1997.

Norman H.D., J. L. Hutchison, and R. H. Miller. 2010. Use of sexed semen and its effect on conception rate, calf sex, dystocia, and stillbirth of Holsteins in the United States. J Dairy Sci. 93:3880-3890.

Pecsok, S. R., J. N. Spain, and M. J. Monson. 1992. Optimal heifer growth rates based on forage and concentrate price relationship. J. Dairy Sci. 75:2030-2037.

Pietersma, D., R. Lacroix, D. Lefebvre, R. Cue, and K. M. Wade. 2006. Trends in growth and age at first calving for Holstein and Ayrshire heifers in Quebec. Can. J. Anim. Sci. 86:325–336.

Radcliff, R. P., M. J. VandeHaar, A. L. Skidmore, L. T. Chapin, B. R. Radke, J. W. Lloyd, E. P. Stanisiewski, and H. A. Tucker. 1997. Effects of diet and bovine somatotropin on heifer growth and mammary development. J. Dairy Sci. 80:1996–2003.

Radcliff, R. P., M. J. Vandehaar, L. T. Chapin, T. E. Pilbeam, D. K. Beede, E. P. Stanisiewski, and H. A. Tucker. 2000. Effects of diet and injection of bovine somatotropin on prepubertal growth and first-lactation milk yields of Holstein cows. J. Dairy Sci. 83:23–29.

Sejrsen, K., J. T. Huber, H. A. Tucker, and R. M. Akers. 1982. Influence of nutrition on mammary development in pre- and postpubertal heifers. J. Dairy Sci. 65:793–800.

Sejrsen, K., and S. Purup. 1997. Influence of prepubertal feeding level on milk yield potential of dairy heifers: A review. J. Anim. Sci. 75:828–835.

Swanson, E. W. 1960. Effect of rapid growth with fattening of dairy heifers on their lactational ability. J. Dairy Sci. 377-387.

USDA. 2007. Dairy 2007, Part I: Reference of Dairy Cattle Health and Management Practices in the United States, 2007 USDA-APHIS-VS, CEAH. Fort Collins, CO.

Waltner, S. S., J. P. McNamara, and J. K. Hillers. 1993. Relationships of body condition score to production variables in high producing Holstein dairy cattle. J. Dairy Sci. 76:3410-3419.

Whitlock, B. K., M. J. VandeHaar, L. F. P. Silva, and H. A. Tucker. 2002. Effect of dietary protein on prepubertal mammary development in rapidly growing dairy heifers. J. Dairy Sci. 85:1516–1525.

Zanton, G. I., and A. J. Heinrichs. 2005. Meta-analysis to assess effect of prepubertal average daily gain of Holstein heifers on first-lactation production. J. Dairy Sci. 88:3860–3867.