# Effect Of Nutrition And Management Of Dairy Heifers On Resultant Cow Longevity

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## INRODUCTION

Longevity as defined by the Random House Dictionary is "the duration of an individual's life". Currently dairy cows average 2.8 calvings in a 'lifetime (Cassell, 2005). Raising high quality heifers that will express their genetic potential for milk production and allow optimal duration in the milking herd (longevity) is a priority objective to balance the investment of 15-20% of total costs of milk production with a net return to the dairy (Lormore, 2005). In a study evaluating heifer raising costs to first calving age on eight New York dairy farms, Karzses (2005) found that feed accounted for 49% of the total costs and labor 18%. This suggests a focus on nutrition and management factors are critical with implication to survival in the milking herd. The applied dynamics of the process to attain a balance of investment return and longevity involves attention to many variables.

Hoffman (2003a) outlined a number of management control variables that contribute to meeting management goals including genetics, colostrum feeding; passive immunity transfer; morbidity/mortality; calf weaning criteria; hair coat indices; breeding age/weight; calving age/weight; reproductive efficiency; feeding system management, feed cost control, health programs; and variance factor control. The variance control factors for heifer growth noted were: failure in passive immunity transfer (FPT), health challenges (e.g., pneumonia and respiratory health, digestive pathogens, parasites, BVD, acidosis, trauma/injury, hardware, hoof disease), housing comfort, twins, low birth weight, dystocia, crowding, transitional management, bunk space, diet composition, feed intake. Quigley (2005a) looked at managing variation in a holistic fashion to attain a quality heifer. He emphasized that attention to minimizing biological production input, environmental and managerial variation will help support healthy heifers with a functional immune system, sufficient body capacity for DMI to produce milk, suitable body condition, and enter the milking herd at a young enough age to minimize costs of production..

This paper will look at nutrition and management profiles (including interrelationships between feeding, health, genetics and housing) that have implications to longevity of dairy heifers in the milking herd. Guidelines will be presented within each criteria discussed to reduce variance and increase management consistencies. At each phase of calf and heifer growth as well as during lactation, good record keeping and monitoring tools are paramount.

## TARGET PROFILES

Designing nutrition and management programs for dairy heifers requires some base targets to attain. Body weight of growing heifers and relationships to mature BW are management targets to consider for puberty, breeding, first calving age, and subsequent lactation. Puberty begins at 50-55% of mature BW. This occurs at about 700 lb for large breeds, 500-600 lb for smaller breeds and when heifers reach 60-65% of their mature weight they are usually bred after exhibiting three to five estrus cycles (Hoffman, 2003b). Heifers within breed should reach 85% of mature BW after their first calving, 92% after their 2nd calving, and 96% after their third calving (Van Amburgh, 2005). Target goals for body weight (BW) prior to and post calving are summarized in Table 1, and wither heights by selected ages by breed in Table 2.

Target profiles are averages, and provide no indication as to individual or group variation. Individual animals should be monitored against target growth curves to determine the number of heifers falling within and outside acceptable target ranges. Guidelines for typical genetic variance for a herd of Holsteins are shown in Table 3. Similar age groups of heifers should be managed so that 67% (1 standard deviation) of the heifers have weight and growth within the outlined target (Hoffman, 2003b). A target calving age goal for large breeds is 22-24 and for smaller faster maturing breeds, 22-23 months of-age (Hoffman, 2003c).

**Table 1.** Target pre- and post calving body weights (BW) for first calf heifers by breed[a].

| | Time of measurement | |
|---|---|---|
| **Breed** | **Pre-calving BW, lb** | **Post calving BW, lb** |
| Holstein | 1400 | 1260 |
| Brown Swiss | 1375 | 1240 |
| Ayrshire | 1240 | 1120 |
| Guernsey | 1175 | 1050 |
| Jersey | 900 | 810 |
| Milking Shorthorn | 1300 | 1170 |

[a]Adapted from Hoffman (2003c).

**Table 2.** Target wither height ranges for first calf heifers by age and breed[a].

| | Wither heights, in | | |
|---|---|---|---|
| **Breed** | **10-12 months** | **13-15 months** | **22-24 months** |
| Holstein | 46-47 | 48-50 | 54.5-56 |
| Brown Swiss | 49-51 | 52-53 | 57 |
| Ayrshire | 45-47 | 48-49 | 52-53 |
| Guernsey | 45-46 | 47-49 | 53 |
| Jersey | 44-46 | 47-48 | 52 |
| Milking Shorthorn | 45-46 | 47-49 | 51-52 |

[a] Adapted from Hoffman (2003c).

**Table 3.** Theoretical genetic deviation of body weight (BW) in Holstein replacement heifers[a].

| Age, months | BW, lb | BW Genetic Std | BW low range, | BW high range, |
|---|---|---|---|---|

| | | Deviation, lb | lb | lb |
|---|---|---|---|---|
| 0 | 93 | 19 | 74 | 112 |
| 2 | 185 | 21 | 164 | 206 |
| 4 | 293 | 26 | 266 | 319 |
| 6 | 400 | 32 | 368 | 432 |
| 8 | 507 | 40 | 466 | 547 |
| 10 | 615 | 48 | 567 | 663 |
| 12 | 722 | 54 | 668 | 775 |
| 14 | 830 | 59 | 771 | 889 |
| 16 | 937 | 63 | 874 | 999 |
| 18 | 1045 | 66 | 978 | 1111 |
| 20 | 1152 | 69 | 1083 | 1220 |
| 22 | 1260 | 71 | 1188 | 1331 |
| 24 | 1367 | 73 | 1294 | 1439 |

[a] Adapted from Hoffman (2003d).

## HEALTH MANAGEMENT EFFECTS

### Calf Health and Relationship to Post Calving Survivability

Health management of dairy calves is one of the most critical factors contributing to survivability of dairy heifers and longevity in a dairy herd. Heinrichs et al. (2005) conducted a study of calf factors on 18 Northeastern Pennsylvania dairy farms to look at residual affects of calf management practices from birth to 4 months of age on age, BW, skeletal growth, and body condition score at first calving. They concluded that management, nutritional, health, and environmental factors imposed from birth to 4 months affected age and BW at first calving. An earlier study by Place et al. (1998) on 21 commercial dairy farms in Pennsylvania looked specifically at the affect of disease, nutrition and management on calf average daily gain (ADG). The ADG varied by season, dry matter intake (DMI), housing environment and location after separation from the dam and farm site. Calves born in the winter tended to have the highest ADG. Calves born in the summer had the lowest ADG. Calving location, parity of the dam and delivery score at calving all contributed to variation in calf performance. Faust (2001) noted that more than 20% of all calvings need some sort of assistance and prevalence of dystocia can contribute 70-98% of calf mortality rates.

Rossini (2004) evaluated the effect of calfhood respiratory and digestive diseases on calfhood morbidity and first lactation production and survival rates from 4,635 calf health and 2,556 complete heifer lactation records on a large commercial dairy in western Kansas. During the evaluation period, June 1998 to June 2001, the herd increased from 4,000 to 8,000 cows with a RHA of 22,391 lbs, 814 lb fat, and 691 lb protein. Of the 2,556 first lactation records, 52.4% had no respiratory occurrences and 29.9% had no digestive problems as calves.  For first lactation cows having 1 health occurrence as calves, the most likely occurrence was digestive infections (49.1%) followed by respiratory (30.2%). For animals reported to have 2 health occurrences as calves, the incidence of two respiratory infections was 17.5% and two digestive disorders was 21%.  Heifers calved at an average age of 24.8 months. The average first lactation milk yield was 18,410 lb (3.6% fat; 2.8% protein) and linear somatic cell count score of 2.6. Survivability of the heifers through first lactation was 82.8%.  One occurrence of respiratory infection resulted in an increase in calving age of 0.21 months and 2 or more incidences increased calving age 0.53 months. Seventy-two percent of heifers survived past 2 years from first calving.

The lowest herd survival was noted in heifers that had multiple disease occurrences to 12 months of age. Heifers with no calfhood diseases had 5% greater chance of surviving the first lactation and 8% greater chance of remaining in the herd beyond the 2nd lactation compared to heifers that had 2 or more disease occurrences as a calf. Calfhood diseases did not affect periparturient health disorders and mastitis but overall calfhood diseases affected cow longevity. Miller and Faust (2000) concluded that respiratory disease and digestive disorders in calves affects their first lactation milk yield. Calf health problems caused milk losses of 2.3 to 10 lb/day.

Examples of Heifer Health Variables

In the study by Rossini (2004), of the heifers that left the herd prior to the end of first lactation, culling heifers for feet and legs (14.4%), mastitis (17.4%) and reproduction (27.4%) were the most prevalent and appear to be the main reasons for shortened longevity of cows. The incidences of lameness in calves and heifers is variable and can occur due to congenital defects, infectious diseases, feeding and management systems or environmental factors (Shearer, 2005). Trendel et al. (2005) in a study with 572 Holstein heifers found that presence of claw disorders during heifer rearing increased the risk of developing claw disorders during lactation.

Heifer mastitis is also a concern for first lactation heifers as shown by Rossini (2004). Timms and Ruegg (2003) observed most heifer mastitis problems are subclinical infections and can be contracted as early as the first week after birth through first calving age. These authors cited studies that indicated that > 70% of heifers and 40% of quarters are infected prior to calving and 50% of the heifers and 30% of quarters infected at calving. Subclinical infections can reduce milk production by over 1,000 lbs. Administering a dry-cow intramammary antibiotic to heifers 45 days before calving has been successful in herds with prevalent environmental organisms such as *Staphylococcus aureus.* Udder edema is common in first calf heifers, the severity depending on nutritional management and genetics.

Passive Immunity and Growth Relationships

A sound colostrum management program is one of the most essential aspects of raising strong, healthy, dairy calves. Research has shown that the potential economic benefit for more optimal calf performance, lower mortality, and lower health costs for calves with adequate colostral passive immunity transfer to be $20 to $25/calf during the first 4 weeks of life (Fowler, 1999). Calves with evidence of good passive immunity transfer (serum total protein levels > 5.5 mg/dl or IgG levels > 1000 mg/dl) have lower mortality. Differences in passive immunity transfer can be a significant source of variation affecting calf growth through 6 months of age depending on environmental stressors. About 35% of ingested colostral immunoglobulins are absorbed if colostrum is fed immediately after birth. This declines to < 5% by 20 hours after birth (Chester-Jones and Hoffman, 2003). Feeding high quality maternal colostrum at 12-15% of calf’s birth BW is recommended. Up to four quarts as soon as possible after birth for large breeds and an additional 2 quarts at 8-12 hours after birth. This is modified for small breeds as observed by Jaster (2005), who found that the best approach for Jersey calves is to feed 2 quarts right after birth then an additional 2 quarts within 12 hours. Franklin et al (2003) found that calves fed colostrum from a bottle after birth had greater passive immunity transfer than calves allowed to suckle their dams for 3 days.

Care must be taken not to feed colostrum from Johne's positive cows. Colostrum can become contaminated with bacteria very quickly if left in a warm environment for a number of hours before feeding. Pasteurizing colostrum before feeding will eliminate pathogen concerns but may decrease immunoglobulin availability (Godden et al. 2005). Colostrum replacement products can be useful alternatives but not a substitute for maternal colostrum. Feed additives such as probiotics, oligosaccharides, antimicrobial compounds (lactoferrin, IgG, medium chain triglycerides, essential oils, and garlic), acidification and beta-glucans can help to maintain intestinal health and overall health of calves (Quigley, 2005b).

***What is an acceptable variation in passive immunity transfer among calves managed for growth and minimal infection rates?*** At the University of Minnesota Southern Research and Outreach Center (SROC) heifer calves are being contract raised for 3 commercial dairies. Serum protein (SP) concentrations are taken within 72 hours after birth. Calves are housed in individual pens for a minimum of 56 days in an all-in all-out system and then moved to groups pens. The basic feeding program is 1.25 lbs of a 20:20 milk replacer (MR) reconstituted to 13.9% solids with water fed with an 18% texturized calf starter. Calves are weaned at 42 days and continue on starter through the first 7-10 days in group pens. The basic grower diet has been limit feeding of a 16% concentrate (whole corn and pellet or coarse grain mix) with free choice hay. There have been variations of this program but final heifer growth by 6 to 7 months of age across all groups have been similar. The average SP across all calves between May 2003 and June 2005 was 5 g/dl (Table 4). Only 24% of the calves had SP > 5.5 g/dl although 62.1% had SP > 5 g/dl. Calves with < 5 g/dl represented 37.9%.

**Table 4.** Mean body weight and serum proteins (SP) for 1,156 SROC calves, 2003- 2005[a].

| | Serum protein | | | | |
|---|---|---|---|---|---|
| **Body weight, lb** | **Average, g/dl** | **< 4 g/dl % of calves** | **4-5 g/dl % of calves** | **5-5.5 g/dl % of calves** | **> 5.5 g/dl % of calves** |
| 88.0 | 5.0 | 4.1 | 33.8 | 38.1 | 24.0 |

[a] Suggested failure of adequate passive immunity transfer indicated by serum proteins of < 5.0 g/dl (100 ml); Acceptable between 5 and 5.5 g/dl; Goal is > 5.5 g/dl.

A location affect has been observed across the 3 herds for serum protein level in calves, but all herds have room to reduce the variation of serum proteins. For farm A, average initial serum proteins were 6.7 and 8.4% lower than for farms B and C, respectively. Farm A had the most calves with serum proteins > 5.6 g/dl. The effect of serum protein variation on calf performance from 2 days to 6.4 months of age is summarized in Table 5. The majority of the 897 heifers summarized are Holsteins with about 10% crossbreds. There were no differences in calf gain across serum protein profiles. Location effects were noted for final BW and hip height but the latter was confounded by length of stay at SROC.

**Table 5.** Performance of commercial dairy heifers at the SROC from 2 days to 6.4 months differentiated by initial serum protein (SP) concentrations and farm source.

| **Item** | **No. heifers** | **% by source** | **Init. BW, lb** | **SP, g/dl** | **Final BW, lb** | **Final HH, in** | **Days at SROC** | **ADG, lb** |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***SP, < 4.0 g/dl*** | | | | | | | | |
| Farm A | 4 | 1.5 | 84 | 3.5 | 466 | 45.49 | 199 | 1.91 |
| Farm B | 32 | 6.9 | 89 | 3.5 | 459 | 45.37 | 193 | 1.92 |
| Farm C | 9 | 5.4 | 88 | 3.7 | 479 | 44.81 | 190 | 2.06 |
| ***Sub-total all*** | ***45*** | ***5.0*** | ***87*** | ***3.6*** | ***468*** | ***45.22*** | ***194*** | ***1.96*** |
| ***SP, 4.1 to 4.5 g/dl*** | | | | | | | | |
| A | 36 | 13.6 | 88 | 4.2 | 477 | 45.54 | 194 | 1.96 |
| B | 112 | 24.1 | 90 | 4.2 | 462 | 45.15 | 189 | 1.97 |
| C | 41 | 24.4 | 91 | 4.2 | 467 | 45.00 | 189 | 1.99 |
| ***Sub-total all*** | ***189*** | ***21.1*** | ***90*** | ***4.2*** | ***469*** | ***45.23*** | ***191*** | ***1.97*** |
| ***SP, 4.6 to 5 g/dl*** | | | | | | | | |
| A | 72 | 27.2 | 91 | 4.9 | 486 | 45.53 | 197 | 2.00 |
| B | 145 | 31.3 | 88 | 4.9 | 463 | 45.09 | 188 | 2.00 |
| C | 66 | 39.3 | 89 | 4.9 | 466 | 45.13 | 193 | 1.95 |
| ***Sub-total all*** | ***283*** | ***31.5*** | ***89*** | ***4.9*** | ***472*** | ***45.25*** | ***193*** | ***1.98*** |
| ***SP, 5.1 to 5.5 g/dl*** | | | | | | | | |
| A | 57 | 21.5 | 89 | 5.3 | 478 | 45.32 | 198 | 1.96 |
| B | 78 | 16.8 | 87 | 5.2 | 468 | 45.04 | 188 | 2.02 |
| C | 35 | 20.8 | 93 | 5.3 | 473 | 45.11 | 194 | 1.96 |
| ***Sub-total all*** | ***170*** | ***19.0*** | ***90*** | ***5.3*** | ***473*** | ***45.16*** | ***193*** | ***1.98*** |
| ***SP, > 5.6 g/dl*** | | | | | | | | |
| A | 96 | 36.2 | 91 | 6.0 | 495 | 45.55 | 199 | 2.03 |
| B | 97 | 20.0 | 86 | 6.1 | 457 | 44.38 | 187 | 1.99 |
| C | 17 | 10.1 | 86 | 6.0 | 445 | 44.57 | 192 | 1.87 |
| ***Sub-total all*** | ***210*** | ***23.4*** | ***88*** | ***6.0*** | ***466*** | ***44.83*** | ***193*** | ***1.96*** |
| **Total all heifers** | **897** | **100** | **89** | **5.0** | **469** | **45.14** | **193** | **1.97** |
| A | 265 | | 89 | 5.27 | 480 | 45.49 | 197 | 1.97 |
| B | 464 | | 88 | 4.94 | 462 | 45.01 | 189 | 1.98 |
| C | 168 | | 89 | 4.86 | 466 | 44.92 | 192 | 1.97 |

[a] Location effect for final body weight (A vs B, P <0.04; vs. C, P <.09); final hip height (A vs. B, P <0.02; vs. C, P <0.01); and days at SROC (A vs B and C, P <.01).

The percent distribution of daily gains is summarized in Table 6. Farm A had the lowest number of heifers gaining under 1.7 lb/day. Farm C had the least number of heifers gaining over 2 lb/day to 6.4 months of-age. Given good management conditions with death loss of under 1% for co-mingled calves from 3 dairies, calf performance can be maintained even with a variable range of serum proteins. There is an indication that improving serum protein concentrations decreases the performance variance.

**Table 6.** Percent distribution of daily gain for 897 heifers by farm site.

| | **SP, g/dl** | **Average daily gain from 2 days to 6.4 months** | | | | | |
|---|---|---|---|---|---|---|---|
| **Farm** | **average** | **< 1.2 lb** | **1.2-1.49 lb** | **1.5-1.69 lb** | **1.7-1.89 lb** | **1.9-2.0 lb** | **>2.0 lb** |
| A, % | 5.27 | 0 | 0.7 | 4.5 | 24.4 | 21.0 | 49.4 |
| B, % | 4.94 | 0.2 | 1.3 | 7.4 | 21.9 | 20.4 | 48.8 |
| C, % | 4.86 | 0 | 2.9 | 7.6 | 24.4 | 22.1 | 43.0 |

## NUTRITION AND MANGEMENT EFFECTS

Early Calf Nutritional Management and Effects Through 6 Months of Age

The effect of early calf nutrition is important to the growth, health and immune status of calves, development of milk production potential and metabolic imprinting in early life (Drackley, 2000). Conventional pre-weaning liquid feeding programs encompass individual or group feeding (confinement or access to pasture) using mainly waste whole milk (with or without pasteurization) at a minimum of 8-10 lbs/day with higher levels in some group feeding situations, milk replacers (1 to 1.25 lbs of a 20:20) with access to dry starter feeds and fresh water. Drackley and Van Amburgh (2005) reported the maintenance requirement for a 100-lb calf is 1.75 Mcals of metabolizable energy (ME) per day. Feeding 2/3 gallon of whole milk (2.44 Mcals/lb solids) or 0.84 lb MR powder (2.08 Mcals kcals/lb) will meet the maintenance requirement under thermal neutral conditions (59 to 77 $^{0}$F) of calves < 21 days of age. Maintenance energy requirement increases as temperature incrementally decreases. Calf responses to two MR programs with decreasing ambient temperature is shown in Table 7 (Van Amburgh, 2003). It was observed that calves fed 1 lb of a 20:20 MR did not receive adequate energy adjustment to colder weather compared to feeding 1 lb of a 28:20 MR.
The objectives of recent research and on-farm application work is to enhance the plane of nutrition during the liquid feeding phase and continue with intensive target programs post weaning (Drackley, 2000; Drackley and Van Amburgh, 2005; Van Amburgh, 2005).

Calves will grow faster with increased milk intake above maintenance and protein needs increase at an increasing rate as gain increases. Protein content of the diet approaches a plateau at 28% of DM which is similar to that of whole milk of 26% on a DM basis (Drackley and Van Amburgh, 2005). The premise for intensive feeding is to match the diet with expected growth to optimize lean tissue deposition and takes advantage of the rapid growth potential and efficiency of growth of calves from birth to 2 months of-age and has shown improvement in calf health (Drackley, 2000). Other advantages relate to decreased time to breeding, lower calving age and decreased rearing costs which have implications to herd productivity.

A study conducted at SROC evaluated the effect of varying liquid and dry feeding programs on calf performance and health (Ziegler et al., 2005). Calves were fed 1.25 lb of a conventional 20:20 MR/day with or without acidification and an 18% CP texturized calf starter vs. modified intensive program of 1.5 lbs/day of a 28:16 MR fed at 2 dilution rates and, an intensive program of 2.25 lbs /day MR at 16.67% dilution all with a 22% CP calf starter. Results are summarized in Table 8. Health treatment costs/calf averaged $2.52 for conventional 20:20 programs; $2.44 for the high solids and $2.82 for the low solids modified intensive program and $1.48 for the intensive program.

**Table 7.** Effect of cold stress on growth of a 100 lb calf fed different milk replacers (MR)[a].

| **Temperature °F** | **MR intake, lb/day** | **Energy allowable gain, lb** | **Protein allowable gain, lb** |
|---|---|---|---|
| | | **20:20 milk replacer** | |
| 68 | 1.0 | 0.46 | 0.53 |
| 50 | 1.0 | 0.05 | 0.53 |
| 32 | 1.0 | 0.00 | 0.53 |
| | | **28:20 milk replacer** | |
| 68 | 2.0 | 1.96 | 1.96 |

| | | | |
|---|---|---|---|
| 50 | 2.0 | 1.67 | 1.96 |
| 32 | 2.0 | 1.41 | 1.96 |

[a]Adapted from NRC (2001) and Van Amburgh (2003).

**Table 8.** Performance of heifer calves fed varying milk replacer and starter programs.

| | **Milk Replacer (%CP, %Fat)** | | | | |
|---|---|---|---|---|---|
| **Parameter** | **20:20 Non-Acidified** | **20:20 Acidified** | **28:16** | **28:16** | **28:16** |
| Feed rate lbs/day MR | 1.25 | 1.25 | 1.5 | 1.5 | 2.25 |
| Solids % | 13.88% | 13.88% | 16.67% | 12.50% | 16.67% |
| Calf starter (CS), CP % | 18% | 18% | 22% | 22% | 22% |
| No. heifers | 26 | 28 | 26 | 29 | 24 |
| Init. BW, lb | 90.9 | 91.08 | 89.74 | 87.05 | 88.86 |
| Init. HH, in | 31.80 | 32.00 | 31.78 | 31.73 | 31.81 |
| SP, g/dl | 5.00 | 5.11 | 4.90 | 4.89 | 4.98 |
| Final BW, lb | $171.45^{b}$ | $167.55^{b}$ | $180.09^{c}$ | $169.42^{b}$ | $188.61^{d}$ |
| Final HH, in | $35.87^{b}$ | $35.83^{b}$ | $35.91^{b}$ | $35.71^{b}$ | $36.65^{c}$ |
| ADG 1-42 d, lb | $1.25^{b}$ | $1.19^{b}$ | $1.47^{c}$ | $1.39^{c}$ | $1.74^{d}$ |
| ADG 1-49 d, lb | $1.34^{bc}$ | $1.28^{b}$ | $1.52^{d}$ | $1.45^{cd}$ | $1.78^{e}$ |
| CS DM 42 d, lb | $43.38^{b}$ | $41.62^{b}$ | $43.49^{b}$ | $37.99^{b}$ | $23.61^{c}$ |
| CS DM 49 d, lb | $73.50^{b}$ | $70.64^{b}$ | $74.82^{b}$ | $67.98^{b}$ | $43.85^{c}$ |
| Milk DM, lb | $47.76^{b}$ | $47.45^{b}$ | $57.51^{c}$ | $55.40^{c}$ | $94.89^{d}$ |
| CS 50-56 d, lb | 35.31 | 34.45 | 37.05 | 34.65 | 33.56 |
| CS DM 56 d, lb | $108.81^{b}$ | $105.09^{b}$ | $111.87^{b}$ | $102.63^{b}$ | $77.70^{c}$ |
| Total DM, lb | $156.57^{b}$ | $152.55^{b}$ | $169.38^{cd}$ | $158.03^{bc}$ | $172.59^{d}$ |
| ADG 1-56 d, lb | $1.43^{b}$ | $1.36^{b}$ | $1.61^{c}$ | $1.47^{b}$ | $1.78^{d}$ |
| Total gain, lb | $80.54^{b}$ | $76.47^{b}$ | $90.35^{c}$ | $82.37^{b}$ | $99.75^{c}$ |
| Gain/feed, lb | $0.51^{b}$ | $0.50^{b}$ | $0.53^{b}$ | $0.52^{b}$ | $0.58^{c}$ |

[a]Adapted from Ziegler et al. (2005).
[bcde]Means in the same row with different superscripts differ ($P < 0.05$).

Health costs reflected differences in calf performance. Calf starter intake was the lowest for intensive fed calves. Calves fed the conventional 1.25 lb of a 20:20 MR had good starter intake and an acceptable growth rate. Calves were moved to group pens 1-2 weeks after weaning and remained in their respective pre-weaning groups. Calves fed the conventional programs were offered 6 lb of a 16% CP concentrate with free choice hay and all the other groups were fed 6 lbs of a 18% CP concentrate with free choice hay. Performance is summarized in Table 9. Heifer performance from 9 to 25 weeks post weaning was not affected by the early calf nutrition programs but the BW and skeletal differences observed prior to group feeding were still discernible. There were no health concerns in the group feeding period.

**Table 9.** Effect of pre-weaning feeding program on performance of growing heifers from 9 to 25 weeks post weaning.

| | **Milk Replacer (%CP, %Fat)** |
|---|---|

| Parameter | 20:20 Non-Acidified | 20:20 Acidified | 28:16 | 28:16 | 28:16 |
|---|---|---|---|---|---|
| Grower diet[a] | 1 | 1 | 2 | 2 | 2 |
| Init. BW, lb | 207.10[b] | 209.16[b] | 210.03[b] | 205.80[b] | 229.28[c] |
| Init. BCS | 2.98[b] | 3.06[bc] | 3.06[bc] | 2.99[b] | 3.10[c] |
| Init. HH, in | 37.61[b] | 37.29[b] | 37.34[b] | 37.37[b] | 38.28[c] |
| Final BW, lb | 446.50[b] | 446.36[b] | 454.00[bc] | 448.70[bc] | 466.18[c] |
| Final BCS | 3.77 | 3.80 | 3.77 | 3.78 | 3.80 |
| Final HH, in | 44.80[b] | 44.74[b] | 44.92[bc] | 45.15[bc] | 45.45[c] |
| ADG, lb | 2.14 | 2.12 | 2.18 | 2.17 | 2.12 |
| DMI, lb | 10.20 | 10.35 | 10.31 | 10.37 | 10.48 |
| Hay DM, lb | 4.80 | 4.95 | 4.91 | 4.97 | 5.09 |
| Grain DM, lb | 5.40 | 5.40 | 5.40 | 5.40 | 5.39 |
| Feed DM/gain, lb | 4.77 | 4.89 | 4.74 | 4.79 | 4.95 |
| Gain/Feed DM, lb | 0.210 | 0.205 | 0.212 | 0.210 | 0.202 |

[a] 1 = whole shelled corn mix 16% CP with free-choice hay; 2 = whole shelled corn mix 18% CP with free-choice hay.
[bc] Means in the same row with different superscripts differ (P <.05).

Heifer Nutritional Management Effects

Successful heifer growth requires consistency in feeding and management programs from early calf nutrition through first calving. Hoffman (2003c) offered guidelines for large breed heifers under thermal neutral zone 50 to70 F. He suggested large breed heifers be fed a different ration at every 300 lb change in BW. For small breed heifers it is every 200 lb change in BW. As with calves, it is critical to meet nutrient requirements for growth, use quality feed, and adjust diets for changes in environmental conditions. Feeding an ionophore is a management tool that is an important consideration for both calf and heifer diets to control coccidiosis and improve heifer performance. Feeding programs that cause excessive body condition should be avoided. Feeding guidelines for heifers are shown in Table 10. Examples of diet adjustments for changes in environmental conditions for 300 to 1200 lb heifers are given in Tables 11 and 12. Under excessive heat stress conditions, DMI will suffer. Several studies have evaluated the NRC growth and feed (2001) requirement guidelines for growing heifers. The dietary ratio of protein:energy in heifers does impact growth. A ratio of 0.61 g CP:1 Mcal ME increased growth and feed efficiency in heifers from 28 to 48 weeks of age in a study by Lammer and Heinrichs (2000). Similar ratios were noted by VandeHaar (2004). Attention to pre-partum close-up diets when DMI dramatically decreases was a focus of a study by VandeHaar et al.(1998). They found that increasing energy from 0.59 to 0.73 Mcals $NE_l$/lb and 16% CP during last week prepartum decreased hepatic fat, decreased NEFA levels and reduced postpartum metabolic problems.

**Table 10.** Guidelines for DMI, dietary energy and protein concentrations for large-breed dairy heifers gaining 1.8 lb per day in a thermal neutral environment[a].

| Item | 300 lb heifer | 600 lb heifer | 900 lb heifer | 1200 lb heifer |
|---|---|---|---|---|
| DMI, lb/day | 9.3 | 13.7 | 19.4 | 26.9 |

| | | | | |
|---|---|---|---|---|
| CP, % of DM | 16.9 | 15.0 | 14.2 | 13.3 |
| RUP, % of CP | 39.4 | 33.8 | 30.3 | 26.3 |
| RDP, % of CP | 60.6 | 66.2 | 69.7 | 73.7 |
| TDN, % of DM | 67.4 | 65.3 | 63.3 | 62.3 |
| ME, Mcals/lb | 1.11 | 1.10 | 1.08 | 1.02 |

[a] Adapted from NRC (2001) and Hoffman (2003c).

**Table 11.** Examples of diets for 300 and 600 lb large-breed heifers to maintain 1.8 lb ADG under varying environmental conditions[a].

| | **300-lb heifers** | | | **600-lb heifers** | | |
|---|---|---|---|---|---|---|
| **Season:** | **Summer** | **Winter** | **Winter** | **Summer** | **Winter** | **Winter** |
| **Item** / **Hair coat:** | **Clean** | **Clean** | **Dirty** | **Clean** | **Clean** | **Dirty** |
| ***Diet*** | **% of DM** | | | | | |
| Corn silage | 28.0 | 25.0 | 25.0 | 31.0 | 29.0 | 29.0 |
| Legume silage, bud | 48.0 | 33.0 | 23.0 | 61.0 | 47.0 | 36.0 |
| Shelled corn | 14.3 | 33.0 | 39.0 | 7.2 | 20.6 | 29.3 |
| Soybean meal (SBM) | --- | 2.7 | 12.2 | | --- | --- |
| Expellers SBM | 8.9 | 5.5 | --- | --- | 2.6 | 4.9 |
| TM salt/mineral mix | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| ***Nutrient composition*** | | | | | | |
| DMI, lb/day | 8.5 | 9.2 | 9.2 | 14.7 | 15.4 | 15.5 |
| CP, % of DM | 16.5 | 16.0 | 16.0 | 15.0 | 15.0 | 15.0 |
| RDP, % of CP | 5.9 | 5.4 | 5.0 | 3.5 | 3.8 | 4.1 |
| ME, Mcals/lb | 1.1 | 1.2 | 1.2 | 1.0 | 1.1 | 1.2 |
| ADF, % of DM | 25.7 | 20.4 | 17.3 | 30.5 | 25.4 | 22.3 |
| NDF, % of DM | 39.2 | 32.1 | 27.8 | 45.3 | 38.8 | 34.5 |
| NFC, % of DM | 35.8 | 45.0 | 48.7 | 31.2 | 39.0 | 43.5 |

[a] Adapted from Raising Dairy Heifer Replacements (Hofmann and Plourd, Ed.) Midwest Plan Service (2003).

**Table 12.** Examples of diets for 900 and 1200-lb large-breed heifers to maintain 1.8 lb ADG under varying environmental conditions[a].

| | **900-lb heifers** | | | **1200-lb heifers** | | |
|---|---|---|---|---|---|---|
| **Season:** | **Summer** | **Winter** | **Winter** | **Summer** | **Winter** | **Winter** |
| **Item** / **Hair coat:** | **Clean** | **Clean** | **Dirty** | **Clean** | **Clean** | **Dirty** |
| ***Diet*** | **% of DM** | | | | | |
| Corn silage | 28.0 | 26.0 | 26.0 | 32.0 | 37.0 | 35.0 |
| Legume silage, bud | 71.2 | 58.1 | 57.1 | 66.0 | 61.2 | 58.0 |
| Shelled corn | --- | 13.0 | 14.0 | --- | --- | --- |
| Soybean meal (SBM) | --- | --- | --- | | --- | --- |
| Expellers SBM | --- | 2.1 | 2.1 | 1.3 | 1.0 | 1.2 |
| TM salt/mineral mix | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |

| | | | | | | |
|---|---|---|---|---|---|---|
| ***Nutrient composition*** | | | | | | |
| DMI, lb/day | 21.2 | 22.7 | 22.9 | 26.5 | 28.5 | 29.0 |
| CP, % of DM | 13.5 | 13.5 | 13.5 | 13.0 | 13.0 | 13.0 |
| RDP, % of CP | 3.0 | 3.3 | 3.3 | 3.0 | 3.0 | 3.1 |
| ME, Mcals/lb | 1.0 | 1.1 | 1.1 | 1.0 | 1.0 | 1.1 |
| ADF, % of DM | 33.0 | 28.1 | 28.2 | 33.0 | 32.0 | 30.3 |
| NDF, % of DM | 48.4 | 42.1 | 42.1 | 48.0 | 47.5 | 45.1 |
| NFC, % of DM | 29.8 | 36.7 | 36.7 | 30.4 | 31.0 | 34.1 |

[a] Adapted from Raising Dairy Heifer Replacements (Hofmann and Plourd, Ed.) Midwest Plan Service (2003).

Pasture System Effects

Growing heifers on pasture as part or all of their nutrition program can be an efficient alternative to confinement housing with good pasture management. Pastured heifers do require 12-25% more energy and are more influenced by fluctuations in environmental conditions than those in confinement (James, 2004). The least efficient pasture system is continuous grazing. Rudstrom et al.(2005) indicated comparative performance of 2 lb/day for 400 to 800 lb heifers managed in an intensive rotationally grazing system compared to an open front confinement barn on a commercial custom heifer raiser operation. Heifers on pasture were supplemented with 1-2 lb/day of an ionophore grain mix and offered long hay depending on pasture availability. Average daily costs per heifer were decreased by 39 cents for pastured cattle. Torbert et al. (2002) compared heifer performance in a continuous or intensive rotationally grazed pasture system to an open front feedlot. Feedlot heifers had faster ADG, heavier BW and higher body condition scores than pastured heifers. All heifers remained on their assigned diets until 3 to 4 weeks prior to calving when they were transferred to a tie-stall barn and fed a pre-fresh TMR based on alfalfa hay, corn silage, and grain mix. Heifers managed on pasture systems maintained higher DM intake from 2 weeks pre-partum than those fed in confinement. During lactation, heifers raised on pasture also consumed more DM. Confinement heifers had more dystocia and health problems at calving than pastured heifers. Raising regimen did not affect milk production of healthy heifers that completed first lactation but more pasture raised heifers completed first lactation than confinement heifers. This study indicates raising system can affect heifer survivability during first lactation.

Calf and Heifer Management Control Factors

Implementation of optimal nutritional management for growth and health requires a consistent comfortable and clean environment that meets the criteria of each phase of calf and heifer growth. Facilities or pasture availability should be designed for 15 to 25% above capacity. Herd size, calving interval, conception rate, culling rate, death loss, and seasonal or cyclic patterns will determine the number of animal demographics within each growth phase. An example breakdown of calves and heifers by herd size as a basis to size a facility was discussed by Kammel and Holmes (2003). Assumptions of year-round calving, 12-month calving interval, 30% culling rate, no mortality, 305-day lactation and stable herd size were made (Table 13).

**Table 13.** Heifer replacement numbers by age and herd size as a guide to facility design[a].

| | **Herd size, total cows** | | | |
|---|---|---|---|---|
| **Age of replacements** | **100** | **250** | **400** | **800** |

| | | | | |
|---|---|---|---|---|
| 0 to 2 months | 8 | 20 | 32 | 64 |
| 3 to 5 months | 12 | 30 | 48 | 96 |
| 6 to 8 months | 12 | 30 | 48 | 96 |
| 9 to 12 months | 18 | 45 | 72 | 144 |
| 13 to 15 months | 12 | 30 | 48 | 96 |
| 16 to 24 months | 38 | 95 | 152 | 304 |

[a] Adapted from Kammel and Holmes (2003). Increase groups by 15-25% to size facilities for flexible management and avoid overcrowding.

Grouping of calves and heifers by age and weight range with appropriate resting space, bunk space, good bunk management and adequate access to water will help to improve the consistency of growth and overall health. Managing housing facilities year round to take advantage of a photoperiod (PHP) affect is a variance that can be controlled (Dahl, 2000, Dahl and Petitclerc, 2003). A PHP program of exposing first calf heifers to a short day PHP (e.g, 8 hours light (L),:16 hours darkness (D)) during the last 60 days of gestation followed by natural PHP or controlled 16 L:8 D PHP during lactation can elicit a milk production response of about 8 % or 5 lb of milk per cow per day average.

## PRE- AND POST PUBERTY GROWTH, CALVING AGE AND MILK YIELD

A numbed of studies have taken a systems approach to evaluate the effect of pre- and post pubertal growth nutritional management on calving age, milk production and longevity balanced against economic assessments. Recent research suggest that heifers on a high plane of nutrition (to support 2 lb or more ADG) does not impair normal mammary cell growth but there are less parenchyma DNA at puberty (Myer and Van Amburgh, 2005). It was noted that only 2% of total parenchyma DNA found at the initiation of lactation can be accounted for in the prepubertal period and as such is not correlated to first lactation milk yield. In a study with 734 pre-pubertal heifers at 4 sites, Vicini et al (2003ab) fed three dietary regimens with or without POSILAC® for 20 weeks to attain variable growth rates and evaluate heifer performance (Table 14). Increasing pre-pubertal gain, increased BW, enhanced skeletal growth and decreased age of calving. POSILAC® increased skeletal growth but not ADG. Heifers fed the high energy and high protein pre-pubertal diets had lower milk yields than those fed the control diet.

**Table 14.** Effect of varying feeding management systems and POSILAC® on pre-pubertal growth of dairy heifers[a].

| **Item** | **CECP[b]** | | **HECP[b]** | | **HEHCP[b]** | |
|---|---|---|---|---|---|---|
| CP, % | 16.98 | | 14.69 | | 18.38 | |
| ADF, % | 25.57 | | 19.71 | | 21.35 | |
| $NE_g$ Mcals/lb | 0.44 | | 0.51 | | 0.49 | |
| | **CECP** | **+POSILAC** | **HECP** | **+POSILAC** | **HEHCP** | **+POSILAC** |
| ADG, lb[c] | 1.69 | 1.78 | 2.49 | 2.49 | 2.66 | 2.84 |
| DMI, lb[c] | 10.67 | 10.71 | 15.16 | 15.03 | 16.59 | 16.46 |
| Final BW, lb[c] | 593.8 | 609.6 | 707.3 | 704.2 | 730.8 | 752.2 |
| BCS[c] | 3.1 | 3.1 | 3.7 | 3.5 | 3.8 | 3.7 |
| WH, in[cd] | 44.8 | 45.2 | 45.4 | 45.9 | 45.9 | 46.3 |
| Heart girth, in[c] | 59.5 | 60.0 | 63.0 | 63.0 | 63.8 | 64.5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| % Pregnant | 90.6 | 95.9 | 89.1 | 90.8 | 88.4 | 94.9 |
| Calving age, mo[c] | 25.2 | 24.9 | 22.4 | 22.6 | 21.9 | 21.7 |
| Milk yield, lb[e] | 62.5 | 62.7 | 59.4 | 61.4 | 60.5 | 57.4 |

[a] Adapted from Vicini et al. (2003ab); 734 heifers, 4 sites (AZ, ID, MN, NY) 128-215 days of-age (297-427 lb).

[b] CECP = limit fed control energy and protein for 1.3-1.8 lbs ADG; HECP = ad libitum high energy; HEHCP = ad libitum high energy and high metabolizable protein. Diets fed for 20 weeks then all heifers fed the CECP diet; heifers bred at pen group average of 823 lb. POSILAC = 500 mg/heifer every 14 days.

[c] Diet effect ($P < .03$).

[d] POSILAC effect ($P < .02$).

[e] Average of 252 day lactations for 615 heifers. No affect of POSILAC. CECP > HEHCP heifers ($P < .05$).

Earlywine (personal communication) evaluated the impact of pre-pubertal intensive feeding programs for 748 dairy heifers vs. 1602 conventionally fed on 5 commercial dairies. Calving age was reduced by 2.5 months and there was a trend towards more milk production later into lactation. Effect of feeding level pre and post puberty and BW at first calving in grazing Holstein and Jersey dairy cows was evaluated by Macdonald et al.(2005). Increasing rate of gain decreased age of puberty, age at first calving (AFC) and BW. Pre- and post pubertal feeding level and BW at first calving did not affect reproductive performance or cow longevity. Average survivability to 2nd and 3rd lactation for all heifer breeds were 88 and 73% for 2nd and 3rd lactation, respectively. Meyer et al. (2004) summarized selected studies evaluating the effect of prepubertal growth on AFC and milk yield (Table 15). Across all studies, heifers fed for faster growth rate and lower AFC ( 21.9 months) calved 2.8 month earlier and had 4.8% lower first lactation milk yields than those fed a more conventional program (24.7 months AFC).

Meyer et al.(2005), looked at the impact of AFC on milk production, longevity and farm profitability. They evaluated over 2.5 million 1st lactation records from 937 herds in CA and the Northeast US from 1985-2002. Heifers were differentiated by AFC, 23.3, 24.3, 25.6, 27.2, and 30.3 months. Reduced calving age increases production per year of life. Longevity and health of cows were not influenced by reduced AFC as long as 1st calf heifers freshen at an adequate BW. Financial advantage of reduced AFC offset reduced milk production (Table 16).

**Table 15.** Selected studies evaluating the effect of prepubertal growth and younger age at first calving (AFC) on milk yield[a].

| | **AFC, months** | | **Prepubertal ADG, lb** | | **BW post calving, lb** | | **1st lactation milk yield, lb** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Reference[b]** | **Late AFC** | **Early AFC** | **Late AFC** | **Early AFC** | **Late AFC** | **Early AFC** | **Late AFC** | **Early AFC** | **% change** |
| 1 | 26.1 | 22.9 | 1.63[c] | 1.63[c] | 1,107 | 997 | 9,797 | 9,189 | - 6.2 |
| 2 | 23.0 | 21.9 | 1.50 | 1.84 | 1,115 | 1,197 | 20,176 | 21,173 | + 4.9 |
| 3 | 24.5 | 21.3 | 1.50 | 2.07 | 1,210 | 1,144 | 21,721 | 20,651 | - 4.9 |
| 4 | 23.6 | 20.7 | 1.69 | 2.46 | 1,186 | 1,133 | 18,962 | 16,507 | - 12.9 |
| 5 | 25.4 | 22.4 | 1.69 | 2.49 | NR[d] | NR | 15,745 | 14,969 | - 4.9 |
| 6 | 25.9 | 22.3 | 1.65[c] | 1.65[c] | 1,327 | 1,256 | 23,665 | 22,779 | - 3.7 |
| Mean | 24.7 | 21.9 | ------ | ------ | ------ | ------ | ------ | ------- | - 4.8 |

[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.

**Table 16.** Average percent survival of commercial heifers from 937 dairy herds across 5 ages of first calving (AFC) through six lactations and eight years of age[a].

| Age, years | 23.3 AFC | 24.3 AFC | 25.6 AFC | 27.2 AFC | 30.3 AFC |
|---|---|---|---|---|---|
| 3 | 80.2 | 81.5 | 82.6 | 85.5 | 90.1 |
| 4 | 56.6 | 61.0 | 62.3 | 64.6 | 66.8 |
| 5 | 39.9 | 40.9 | 41.9 | 43.4 | 44.2 |
| 6 | 25.5 | 25.0 | 25.7 | 26.6 | 27.1 |
| 7 | 13.9 | 14.1 | 14.6 | 15.3 | 15.4 |
| 8 | 7.4 | 7.4 | 7.7 | 8.2 | 8.2 |

[a] Adapted from Meyer et al.(2004).

## REPRODUCTION AND GENETIC FACTORS

Using calving ease bulls for heifer AI is critical and use of sires that are less than 10% for percent difficult births has been recommended (Fricke, 2003). This author noted that with good management, conception rates should be between 50 and 70%. Pregnancy rates (service rate x conception rate) can vary between 25 and 50%. Synchronized programs are used extensively to manage heifer reproduction groups. Breeding age should be within BW and height target goals for different breeds (Tables 1 and 2). Genetic selection is an important management factor that can contribute to cow variance and longevity. Faust (2001) observed that 25-30% of variability among cows for yield traits is attributable to genetic merit. It also was noted that important factors for genetic selection for future herd profitability should be traits that can be measured accurately such as yield traits; health, durability (longevity), and reproduction.

Crossbreeding between Holstein and other breeds has become prevalent in the dairy industry. Reasons for crossbreeding are improved calving ease, fertility, longevity and milk composition (Wiegel, 2003). The other concern is increased inbreeding within the main dairy breeds which should not exceed 6.25%. Crossbreeding provides an opportunity for hybrid vigor of 6.5% for production and 10% for fertility as long as the top AI sires within breeds are used (Hansen et al., 2005). These authors reported on 692 pure Holsteins and 1,554 crossbred first lactation heifers from 7 California dairies from June 2002 to October 2004. Survival during first lactation is shown in Table 17. A further comparison of 118 Normande-Holstein crossbreds with 283 pure Holsteins indicated that 66% of the latter and 82% of the crossbreds calved a 2nd time within 20 months of their first calving. First service conception rate was 22%, 35%, 31%, and 30% for pure Holsteins, Normande-Holsteins, Montbeliarde-Holstein and Scandinavian Red-Holstein crossbreds, respectively. Crossbreeding is not a genetic improvement program and continuous use of high-ranking progeny tested A.I. sires within breeds is critical for genetic improvement (Hansen et al., 2005).

**Table 17.** Comparative survival of 692 purebred Holstein and 1,554 crossbred first lactation heifers from seven California Dairy Herds between June 2002 and October 2004[a].

| Breed | Number | 30 day survival, % | 150 days survival, % | 305 days survival, % |
|---|---|---|---|---|
| Pure Holsteins[b] | 692 | 95 | 91 | 86 |
| Normande-Holstein | 465 | 98 | 96 | 93 |
| Montbeliarde-Holstein | 655 | 98 | 96 | 92 |
| Scandinavian Red-Holstein | 434 | 98 | 96 | 93 |

[a] Adapted from Hansen et al. (2005).
[b] Pure Holsteins vs. other breeds (P<0.05).

Selecting for large cows may affect cow longevity and profitability. In a classic study at the University Northwest Research and Outreach Center in Crookston a herd of Holstein cows has been selected since 1966 for large vs. small body size. Heifers and cows are managed identically except for sire selection. Data from 1983 to 1994 were evaluated by Hansen et al. (1999). Mean calf body weights for the large line were 5.7, 5.1, and 5.5 lb greater than the small line in parities 1, 2, and 3 respectively. First calving age averaged 25.5 months, with large line heifers averaging 1340 lb and small line heifers 1128 lb post calving. Differences at the withers of 2.8 to 3.0 inches for the large heifers were observed.

Milk production comparisons between large and small body size selected cows during lactations 1, 2 and 3 were 18,682 vs.18,770; 21,072 vs. 21,604 and 21,899 vs. 21,311 lb respectively. Small line cows had higher income over feed costs as they used their feed more efficiently (6%). Productive life to a maximum of 6 years was 87.7 days (15.4%) longer for cows in the small vs. large lines. Comparing large vs. small lines, reproduction was the most predominant factor for disposal (33 vs. 34.5%) followed by mastitis16.3 vs 15.3%) and udder conformation (5.3 vs. 11.9%). Hansen et al. (1999) concluded that “over the long term, selection for economically important traits other than those related to body size should result in cows of near optimum size.”

## SUMMARY

Nutrition and management programs for dairy heifers have been described with implications to cow longevity. Understanding the interrelationships between management factors that can be controlled to reduce variation in heifer growth and health are important steps for a productive life. Optimizing metabolic, physiological and structural health of dairy heifers are keys to longevity.

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