# Optimum Growth Rates for Holstein Replacement Heifers

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## Introduction

Replacement heifer management has received considerable attention in recent years, most likely due to an increased emphasis on business management by dairy producers. Replacement heifers are expensive to raise, are labor intensive, and return on investment is relatively slow. Accompanying this interest has been a rise in the amount of printed recommendations and press on replacement heifer growth rates. This information is used by consultants, feed dealers, and veterinarians as base recommendations for dairy producers. This information is sometimes conflicting, confusing, and can lead to enormous errors in recommendations to producers by industry professionals. Problems with published recommendations result from two factors. First, research on replacement heifers is limited and is spread out over many years. This creates problems when old, outdated information is used as the basis for recommendations. Secondly, current research is often misinterpreted and in the haste to use "something new", impractical field recommendations are made. This paper will discuss fundamentals of replacement heifer growth and development as best as current research can define it. The discussion will be limited to the growth and development of Holstein replacements.

## Defining Growth Rates - Factors to Consider

In order to define optimum growth rates of replacement heifers, three factors need to be considered. They are: 1) What is the optimum age at first calving, 2) What is the optimum body size at first calving, and 3) What is the genetic variance associated with body size? The following discussion is devoted to current research which also addressed these issues.

### Optimum Calving Age

The long-standing age of first calving recommendation has been 24 mo. Past research projects evaluating early calving (< 22 mo) replacement heifer management programs have observed reduced milk yield (20, 23) or increased dystocia (6). Due to genetic selection and advancement in nutritional management, it has been hypothesized (15) that acceptable milk yield and levels of dystocia can be achieved in modern Holstein heifers when calving at ages < 22 mo. Van Amburgh et al. (27) fed prepubescent replacement heifers 3 levels of energy and achieved calving ages of 24.2, 22.0, and 21.0 mo. Milk yield was lower, but not significantly different for replacement heifers calving at 22.0 and 21.0 mo as compared to 24.0 mo. Hoffman et al. (14) evaluated first lactation performance of Holstein heifers calving at 20.6, 22.7, 23.6, and 25.6 mo.

The different calving ages were achieved by feeding control or accelerated diets containing 62.5 or 68.5% TDN from 10 mo of age until parturition. Breeding was initiated at 14 and 10 mo for heifers fed control or accelerated diets, respectively. Heifers fed control and accelerated diets were subdivided into two breeding groups based on normal A.I. breeding efficiencies (1 service/conception = target; > 1 service/conception = delayed). Combination of feeding (control, accelerated) and breeding regimen (target, delayed) resulted in the four calving ages (20.6, 22.7, 23.6, 25.6 mo). Results from the study are presented in Table 1.

Table 1. Effect of early calving on development and lactation performance of Holstein replacement heifers.

| | Treatment | | | |
|---|---|---|---|---|
| | Accelerated | | Control | |
| Item | Target | Delayed | Target | Delayed |
| Calving age, mo | 20.6 | 22.7 | 23.6 | 25.6 |
| ADG, lb/d | 2.1 | 1.9 | 1.7 | 1.7 |
| Prepartum BW, lb | 1371 | 1462 | 1407 | 1464 |
| Postpartum BW, lb | 1215 | 1294 | 1279 | 1327 |
| Height, in | 53 | 53 | 54 | 54 |
| Body condition | 3.5 | 3.7 | 3.4 | 3.6 |
| Prepartum pelvic area, $cm^2$ | 259 | 274 | 269 | 291 |
| Dystocia index[1] | 2.7 | 4.2 | 2.8 | 3.4 |
| Lactation performance | | | | |
| Milk yield, lb/d | 55.1 | 57.3 | 60.0 | 58.6 |
| Milk fat, % | 3.80 | 3.77 | 3.93 | 3.78 |
| Milk protein, % | 3.23 | 3.16 | 3.24 | 3.25 |
| Milk yield, lb/305d | 16583 | 17346 | 18278 | 17791 |

[1] 1-5 system: 1 = unassisted, 2 = some assistance, normal birth, 3 = difficult birth, 4 = extremely difficult birth, 5 = veterinarian required.

Heifers fed accelerated diets had higher average daily gain (2.1 vs. 1.7 lb/d) and calved 2.9 mo earlier than heifers fed control diets. Heifers fed accelerated diets and calving earlier had similar prepartum (10 d) body weights as heifers fed control, but true body size as indicated by wither height and postpartum body weight (7 d) indicated early calving heifers were smaller. Heifers fed accelerated diets and calving earlier maintained lower body weight throughout first lactation. Heifers calving at older ages had larger pelvic areas than younger heifers, but increased pelvic area in older heifers was not related to dystocia. Increased days on feed caused by delayed breeding resulted in increased body condition score and dystocia. Data suggest dystocia is related to body condition score of replacement heifers at calving. Early calving heifers had lower milk yields than heifers calving at older ages, but milk fat and protein % were not influenced by early calving.

The data of Van Amburgh et al. (27) and Hoffman et al. (14) to recommend early calving (< 22 mo) should be used with caution for the following reasons: 1) No economic analysis has been conducted; 2) Hoffman et al. (14) observed the need for increased breeding efficiency of accelerated heifers, otherwise dystocia may occur; 3) Milk yields were reduced in both studies at ages 20 mo; and 4) Neither study evaluated a complete management scheme to calve replacement heifers < 24 mo.

The data of Van Amburgh et al. (27) and Hoffman et al. (14) do, however, demonstrate that acceptable first lactation performance can be obtained when replacement heifers calve from 22 to 24 mo. From these data it appears that calving replacement heifers at 22 mo could be successful under intensive management programs. Additional data are required before recommending calving ages < 22 mo.

**Optimum Body Size**

Assimilation of replacement heifer body size criteria is necessary so commercial dairy producers have a reference to evaluate replacement heifer management. Recent research has greatly aided the ability to define optimum body size criteria of replacement heifers. In a review of literature, Hoffman et al. (13) defined optimum body size criteria of Holstein replacement heifers at first calving (Table 2).

Table 2. Optimum body size criteria of Holstein replacement heifers at first calving.

| | Genetic Range | | |
|---|---|---|---|
| Criteria | Average | Lower | Upper |
| Body weight, lb (7 d postpartum) | 1231 | 1182 | 1280 |
| Body weight, lb (30 d postpartum) | 1148 | 1102 | 1193 |
| Wither height, in | 54.9 | 54.2 | 55.5 |
| Body length[1], in | 67.3 | 66.5 | 68.0 |
| Pelvic area, $cm^2$ | > 260 | > 260 | > 260 |
| Body condition score | 3.5 | 3.5 | 3.5 |

[1] Measured from the point of shoulder to the ischium.

The mechanisms used by Hoffman et al. (13) to define these criteria will not be re-examined in this paper, but a general overview is as follows. Optimum prepartum (14 d) body weight was determined to be 1366 lb. Prepartum body weights < 1366 have been demonstrated to reduce first lactation milk yields (18) and prepartum body weights > 1366 lb have been demonstrated to be of no predictive benefit (9, 19). Parturition induced body weight loss (7 d postpartum) was determined to be 9.9% of prepartum body weight. Replacement heifers loose 16.1% of prepartum body weight by 30 d postpartum.

Hoffman et al. (13) also emphasized the use of skeletal measurements to define

replacement heifer size. Optimum wither height, body length, and pelvic areas at first calving are also listed in Table 2 and were determined to be 54.9 in, 67.3 in, and > 260 $cm^2$, respectively. Optimum body condition score at calving was determined to be 3.5. Body condition scores > 3.5 have been demonstrated to increase the probability of metabolic problems (9) and dystocia (14) and to reduce milk yield (29).

**Genetic Variation**

Replacement heifer growth recommendations are commonly based on single body weight or wither height criterion at a corresponding age. These recommendations are useful, but do not incorporate genetic differences of body size. To account for genetic variation of body size, authors (4, 12) have proposed acceptable body weight and wither height ranges for Holstein replacement heifers at corresponding ages. Body weight and wither height ranges defined by Crowley et al. (4) were estimated and were not based on research data which evaluated genetic variance (W. T. Howard, personal communication, Madison, WI). Heinrichs and Swartz (12) suggested genetic variance of body weight at first calving (precalving) to be between 1137 and 1296 lb.

Body size parameters at first calving from a herd of Holstein cows bred for either high production and large size of high production and small size were examined by Yerex et al. (30). After three generations, breeding for size had no effect on first lactation milk yield, but primiparous cows (7 d postpartum) differed in body weight (110 lb), wither height (2.2 in), and length (2.5 in). The data of Yerex et al (30) is supported by Tveit et al. (26), who observed the genetic and phenotypic SD of body weight at calving to be 65.5.

Establishment of a normal genetic range of body size parameters for the current genotype of Holstein replacement heifers raised under ideal management conditions is important for two reasons. First, genetic variance of body size is normal and variance of body size at first calving due to genetics has not been demonstrated to influence first lactation milk yield (21, 30). Second, establishment of a normal genetic range of body size parameters for replacement heifers by default defines an abnormal range. An abnormal range of body size parameters defines less than ideal replacement heifer management. Genetic variance of body size parameters of Holstein replacement heifers at first calving is also presented in Table 2.

**Optimum Growth**

In this paper the term "optimal" is somewhat misnamed because a specific set of growth criteria for Holstein replacement heifers may not be applicable to all management situations. Optimal growth can only be defined in the context research measurements provide. Body size criteria for the current genotype U.S. Holstein replacement heifers were determined by the following methods and are presented in Table 3.

Table 3. Upper and lower ranges of body size parameters and growth rates for Holstein replacement heifers under ideal management.

| Body Size Criteria[1] |
|---|

| | Upper Range | | | | | Lower Range | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Age, mo | BW | ADG | WH | BL | BCS | BW | ADG | WH | BL | BCS |
| 0 | 93 | . . . | 30 | 32 | . . . | 93 | . . . | 30 | 32 | . . . |
| 1 | 139 | 1.5 | 32 | 34 | . . . | 139 | 1.5 | 32 | 34 | . . . |
| 2 | 185 | 1.5 | 34 | 37 | . . . | 185 | 1.5 | 34 | 37 | . . . |
| 3 | 242 | 1.8 | 36 | 39 | 2.2 | 236 | 1.7 | 36 | 39 | 2.2 |
| 4 | 298 | 1.8 | 39 | 41 | . . . | 287 | 1.7 | 38 | 41 | . . . |
| 5 | 355 | 1.8 | 40 | 43 | . . . | 339 | 1.7 | 40 | 43 | . . . |
| 6 | 410 | 1.8 | 41 | 46 | 2.3 | 390 | 1.7 | 41 | 45 | 2.3 |
| 7 | 467 | 1.8 | 43 | 48 | . . . | 441 | 1.7 | 42 | 47 | . . . |
| 8 | 522 | 1.8 | 44 | 50 | . . . | 491 | 1.7 | 43 | 48 | . . . |
| 9 | 580 | 1.8 | 44 | 52 | 2.4 | 544 | 1.7 | 44 | 50 | 2.4 |
| 10 | 635 | 1.8 | 46 | 53 | . . . | 595 | 1.7 | 45 | 52 | . . . |
| 11 | 692 | 1.8 | 46 | 55 | . . . | 646 | 1.7 | 46 | 54 | . . . |
| 12 | 747 | 1.8 | 47 | 56 | 2.8 | 696 | 1.7 | 46 | 55 | 2.8 |
| 13 | 804 | 1.8 | 48 | 58 | . . . | 749 | 1.7 | 47 | 56 | . . . |
| 14 | 860 | 1.8 | 49 | 59 | . . . | 800 | 1.7 | 48 | 58 | . . . |
| 15 | 917 | 1.8 | 50 | 61 | 3.0 | 851 | 1.7 | 49 | 59 | 3.0 |
| 16 | 972 | 1.8 | 50 | 62 | . . . | 901 | 1.7 | 50 | 60 | . . . |
| 17 | 1029 | 1.8 | 51 | 63 | . . . | 952 | 1.7 | 50 | 61 | . . . |
| 18 | 1084 | 1.8 | 52 | 64 | 3.2 | 1005 | 1.7 | 51 | 62 | 3.2 |
| 19 | 1142 | 1.8 | 52 | 65 | . . . | 1056 | 1.7 | 52 | 63 | . . . |
| 20 | 1197 | 1.8 | 53 | 65 | . . . | 1106 | 1.7 | 52 | 64 | . . . |
| 21 | 1254 | 1.8 | 54 | 66 | 3.4 | 1157 | 1.7 | 53 | 65 | 3.4 |
| 22 | 1309 | 1.8 | 54 | 67 | . . . | 1210 | 1.7 | 53 | 66 | . . . |
| 23 | 1366 | 1.8 | 55 | 67 | . . . | 1261 | 1.7 | 54 | 66 | . . . |
| 24 | 1422 | 1.8 | 56 | 68 | 3.5 | 1311 | 1.7 | 54 | 67 | 3.5 |
| 7-d postpart. | 1281 | | | | | 1181 | | | | |
| 30-d postpart. | 1192 | | | | | 1102 | | | | |

[1] WH = wither height, BL = body length from the point of shoulder to the ischium, BCS = body condition score.

[2] Pelvic area > 260 $cm^2$.

The breed average optimal prepartum body weight was determined to be 1366 lb. The premise for this determination (1366 lb) was as follows: It is representative of prepartum body weight (1369 lb) observed in recent experiments, it is the approximate mid-point of the body weight range (1300 to 1400 lb) which optimized first lactation milk yield (18), and it is representative of prepartum body weight (1358 lb) of Holstein heifers in high producing dairy herds (16). A genetic range of prepartum body weight was determined to be 100 lb (30). Calf body weight was determined to be 93 lb (3) and weaning was assumed to occur at 2 mo of age at 185 lb (4). To determine optimum growth, growth rates were calculated for both genetic ranges from weaning (2 mo, 185 lb) to 1422 (upper) and 1311 (lower) lb. Linear growth rates were used because there is no evidence from field surveys

(10, 16) to suggest that high yielding first lactation cows are reared on non-linear growth planes. This approach ignores the potential to improve prepuberty secretory tissue development by decreasing prepuberty growth rates (28). Prepuberty growth rates (2 to 10 mo) are 1.84 and 1.74 lb/d for upper and lower genetic ranges. Average daily gains of approximately 1.75 lb/d have not been demonstrated to be detrimental to milk yield or mammary development in recent experiments (22, 24, 25).

Wither height criteria of Holstein replacement heifers were calculated (Table 3) by the equations of Heinrichs et al. (11). Predicted wither heights in Table 3 are in close agreement with measured (10, 16) wither heights. Body lengths were calculated using the best fit equation defined by Hoffman (13) and are in agreement with body lengths observed in controlled studies (2, 5).

Body condition scores (16), pelvic area, 7 d and 30 d postpartum body weights (Table 2) are also presented in Table 3.

## Heifer Growth - Theory vs. Application

Many replacement heifer growth recommendations are made with a theory or concept in mind. Many of these recommendations, while theoretical, give specific guidelines for growth which are difficult to apply under field conditions. Listed below are some common theory vs. application paradoxes.

### Mammary Development

Numerous research projects (20, 23) have demonstrated a negative relationship between prepuberty growth rate and milk yield. The scientific literature (28) contains numerous trials and recommendations suggesting lactation performance of replacement heifers is enhanced at low prepuberty growth rates (1.3 lb/d).

The recommendation generally is not applicable under field conditions. Replacement heifers with prepuberty average daily gains of 1.3 lb/d will not reach puberty (650 lb) until 14 mo of age or would not reach a sensible breeding weight (850 lb) until 19.0 mo. Prepuberty growth rates of 1.3 lb/d eliminate the possibility of achieving a 24 mo calving age. Prepuberty average daily gains of 1.75 to 2.0 lb/d have not been demonstrated to depress secretory tissue development (13) and represent prepuberty growth rates of high producing first lactation cows (16).

### Growth Rate/Laminitis

It has been suggested that replacement heifers gaining > 1.75 lb/d are predisposed to laminitis and sole hemorrhages (8). The modern Holstein replacement heifer has the potential to gain 1.75 lb/d fed all baled hay of reasonable quality provided the replacement heifer is in a quality environment. A diet of all long stem forage would not likely result in laminitis. While laminitis of replacement heifers is a concern, causes should be expressed in diet energy content or lack of dietary fiber and not correlated to growth rate.

**Protein Level/Stature Growth**

It is theorized that NRC protein requirements for replacement heifers are insufficient and limit stature growth (17). It is true that protein (quality and quantity) must be adequate to optimize growth and frame development. It, however, has been demonstrated (1, 28) that oversupplying protein will not further enhance growth or frame development. Recent research on protein nutrition of replacement heifers has not clearly defined strategies to consistently improve growth or frame development.

**Hindsight Recommendations**

Objectives of heifer growth are often expressed at some point in the future. For example, replacement heifers should weigh 1200 lb after calving, replacement heifers should weigh 82.0% of their mature weight at calving. These recommendation only allow a hindsight evaluation of replacement heifer management. Guidelines should be available to monitor the replacement heifer growth at any stage of growth and if deficient, corrective management programs can be implemented.

## Monitoring Heifer Growth

Monitoring actual heifer performance is important so that adjustments in management can be made. Replacement heifer monitoring programs based on periodic weighing (or measuring) of replacement heifers almost always fail at the farm level due to the time commitment involved.

Replacement heifer monitoring programs should be simple and minimize labor. Two monitoring systems best meet these criteria.

**Breeding/Calving**

Birth dates of replacement heifers are recorded, heifers are identified. Heifers are measured (heart girth, wither height, body condition scored) at breeding and 14 d prepartum. Growth rate, age/weight relationships, etc., can be calculated.

**Single Time Measurement**

All replacement heifers on the farm are measured (heart girth, wither height, body condition scored) on the same day. Data are plotted and compared to objectives. Galligan and Ferguson (7) have proposed enhancements for this method and have demonstrated acceptable accuracy.

## Conclusions

Recent research has given us the ability to define replacement heifer growth to a greater degree of accuracy. In the past, growth has always been defined as weight gain per day. Other body size criteria such as wither height, body condition score, body length, and pelvic area are now available to aid growth definitions. Where possible, these measurements should be used because they are as related and often more related to lactation performance and animal health than body weight.

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