**Holstein heifer growth and body composition from 100 to 770 lb body weight**

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Growth with body composition data on Holstein heifers are limited. I briefly previously reviewed principles involved and a specific recent study in that area (Kertz 2025). The most comprehensive study was done at Cornell University (Meyer 2005) and portions previously published (Meyer et al., 2006a,b). The growth and body composition data have been published (Van Amburgh et al., 2026) and will be addressed in this article.

The study used a modified serial slaughter technique (Fortin et al., 1982) with multiple intervals, rather than baseline and endpoint composition (most of the following protocol was taken verbatim from the paper).

- The diet composition (**Table 1**) was modified throughout the study to maintain the target rates of gain, ensuring that protein was not limiting growth.
- This study was conducted from October 2001 to July 2003 with 78 Holstein heifers purchased within 1 week of birth from dairy farms near Ithaca, New York, from October 2001 to June 2002.
- The average mature body weight (BW) among the 4 farms was 1447 ± 258 lb. Heifer calves averaged 97.3 lb, 9.9 days old, and were randomly assigned to either an elevated (E) or restricted (R) level of nutrient intake and were fed to achieve 1.43 lb (R) or 2.1 lb (E) daily gain.
- R-heifers received a 22% CP (all milk protein) and 20% fat milk replacer on a DM basis of 0.20 Mcal intake energy per kg of BW0.75 (**Table 1**).
- Heifers were weighed once weekly, and the amount of milk replacers offered was adjusted accordingly to maintain the target growth rates.
- Weaning was initiated after approximately 42 days of treatment by reducing the amount of milk replacer provided to 50% the preweaning amount for 7 days and then removing all milk replacer by approximately 50 days. To achieve a BW at weaning as similar as possible between treatments, the R-heifers were offered milk replacer for 7 days longer than the E-heifers.
- Calves had access to water throughout the entire treatment period. A commercially available 26% CP textured starter was offered starting at approximately 1 week on study until 2 weeks after weaning. These diets met the CP requirements for the expected ADG, as calculated by Van Amburgh and Drackley (2005), and were further confirmed by the NASEM (2021) recommendations.
- To maintain target growth rates by stage of maturity, 3 TMR common to both treatments were formulated using the Cornell Net Carbohydrate and Protein System such that predicted ME and MP allowable daily gains were similar within the BW range in which they were offered and across the 2 treatments.

- For the 2 weeks following weaning (weeks 8 and 9), all heifers were offered the starter to ensure adequate feed intake to meet the growth objectives (this is a good practice on-farm too). From 10 to 13 weeks of age, heifers received TMR 1 (**Table 2**), after which they were switched to TMR 2 (**Table 2**). The heifers were fed TMR 2 until they reached approximately 200 kg BW. From 200 kg BW until slaughter, TMR 3 (**Table 2**) was offered to the remaining heifers. The amount of feed offered was adjusted to achieve the target growth rate of gain using the CNCPS to formulate the diet. The TMR were formulated to facilitate the transition of heifers from a starter to a forage-based diet (TMR 1) and to meet their nutrient requirements during a BW gap of more than 200 kg (TMR 2 and 3). According to NASEM (2021), these diets provided protein adequate to sustain 980 g of daily gain for all BW ranges, which supports that protein was not limiting growth in this study.
- From the initiation of treatment to 150 kg BW, all heifers were housed and fed in individual pens within a greenhouse structure at the Cornell Dairy Teaching and Research Center (Harford, NY). Upon reaching 150 kg BW, heifers were moved to a freestall barn, group housed and individually fed via the Calan gate system at the Teaching and Research Center. Throughout the study, heifers were weighed, and hip height (HH) was measured once per week.
- Once heifers reached 225 kg, blood was collected twice weekly via jugular venipuncture, and plasma progesterone concentration was determined.
- Heifers were slaughtered every 50 kg from 100 to 350 kg BW to evaluate mammary epithelial cell proliferation and total parenchymal accumulation, and these data were previously published (Meyer et al., 2006a,b).

**Table 1.** Milk replacer and texturized calf starter composition for R (restricted) and E (elevated) daily gains.

| % of dry matter | R-milk replacer | E-milk replacer | Calf starter |
|---|---|---|---|
| DM, % | 96.0 | 96.0 | 90.8 |
| CP | 22.0 | 29.3 | 26.7 |
| Fat | 21.2 | 18.9 | 4.2 |
| Ca | 0.95 | 0.99 | 1.41 |
| P | 1.04 | 0.97 | 0.65 |
| NDF | NA | NA | 18.3 |
| ADF | NA | NA | 16.2 |

- There was no indication of how texturized the starter was.
- Calf starter CP was quite high at 24.2% as-fed.

**Table 2.** Total mixed ration (TMR) DM and nutrient composition.

| Item | TMR-1 | TMR-2 | TMR-3 |
|---|---|---|---|
| Ingredients, % of DM | | | |
| Alfalfa hay | 10.3 | --- | --- |
| Alfalfa silage | 15.1 | 31.8 | 31.8 |
| Corn silage | 13.8 | 31.8 | 31.8 |

| | | | |
|---|---|---|---|
| **Soybean meal (SBM)** | --- | --- | 4.2 |
| **Heat-treated SBM** | 10.3 | 18.0 | 8.4 |
| **Starter grain mx** | 50.3 | --- | --- |
| **High-moisture corn** | --- | 15.9 | 23.1 |
| **Monensin mix** | --- | 1.6 | 1.7 |
| **Vitamin E** | 0.12 | 0.12 | 0.10 |
| **Mineral mix** | 0.12 | 0.90 | 1.40 |
| **Nutrients, % of DM** | | | |
| **DM, %** | 60.3 | 45.3 | 46.7 |
| **CP** | 24.3 | 19.0 | 17.2 |
| **ADF** | 18.1 | 21.1 | 20.2 |
| **NDF** | 35.5 | 34.0 | 31.4 |
| **NSC** | 34.3 | 35.9 | 40.0 |
| **Fat** | 1.91 | 3.93 | 3.45 |
| **Ash** | 8.48 | 7.41 | 7.21 |
| **ME, Mcal/kg DM** | 2.43 | 2.45 | 2.47 |

- TMRs were formulated for different growth stages.
- TMRs were formulated to meet metabolizable energy (ME) and protein requirements when fed at the various growth stages and daily gain treatment targets.
- Nonstructural carbohydrates (NSC) is an estimate of starch and sugar as calculated = 100- (% ash + % CP + % NDF + % ether extract).

**Table 3.** Body weight (BW) and hip height (HH) at various times for elevated (E) and restricted (R) daily gain treatments.

| Item | Elevated | Restricted | SEM | *P*-value |
|---|---|---|---|---|
| **Initial age, days** | 10.4 | 9.4 | 0.74 | 0.30 |
| **Initial BW, lb** | 96.2 | 95.1 | 2.62 | 0.85 |
| **Initial HH, inch** | 32.6 | 32.2 | 1.33 | 0.24 |
| **BW at weaning, lb** | 184.7 | 162.4 | 2.18 | <0.01 |
| **HH at weaning. inch** | 37.0 | 36.4 | 0.17 | <0.01 |
| **Preweaning BW gain, lb/day** | 1.94 | 1.30 | 0.06 | <0.01 |
| **Preweaning HH gain. inch/day** | 0.10 | 0.08 | 0.01 | 0.01 |

- Initial BW and HH were similar between treatments.
- BW and HH at weaning were greater ($P$ <0.01) for the Elevated (E) versus Restricted (R) treatments as were daily increases in BW and HH.
- The Dairy Calf and Heifer Association's goal at 2-months old weaning is to double birth weight. These calves were 10 days old at the initiation of the experiment. But a daily gain of 1.94 lb (E) would likely have doubled birth weight at 2 months old but not the daily gain of 1.30 lb daily gain on the R-treatment.

**Table 4.** Body weight (BW) and composition as % of empty body weight (EBW) of the baseline heifers before being fed elevated (E) or restricted (R) treatments.

| Item | Elevated | Restricted |
|---|---|---|
| **Pre-transport BW, lb** | 100.4 ± 1.54 | 101.5 ± 3.52 |

| | | |
|---|---|---|
| **EBW, % of preweaned BW** | 95.1 ± 1.8 | 93.8 ± 2.1 |
| **Blood/organs, % of BW** | 19.9 ± 0.6 | 19.6 ± 0.7 |
| **Carcas, % of BW** | 60.1 ± 0.6 | 60.9 ± 0.9 |
| **HHFT[a], % of BW** | 20.0 ± 0.1 | 19.5 ± 0.2 |
| **CP, % of BW** | 16.9 ± 0.1 | 16.5 ± 0.2 |
| **Fat, % of BW** | 6.1 ± 0.8 | 6.2 ± 0.6 |
| **Ash, % of EBW** | 3.8 ± 0.5 | 3.9 ± 0.2 |
| **Water, % of EBW** | 73.2 ± 0.9 | 73.4 ± 0.8 |

**[a]** Head, hide, feet, and tail.

- Composition as % of EBW was similar between treatments.
- Note fat as % of EBW was about 6%. That is typical for young calves as it usually falls within a range of 5 to at most 10% for newborn or very young calves. Thus, they have little body fat to mobilize when they encounter health problems such as diarrhea or respiratory.
- Likewise, % water in EBW is at its greatest due to the inverse relationship between body fat and water.

**Table 5.** Dry matter intake (DMI) and days on feed for Holstein heifers fed either elevated (E) or restricted (R) milk replacer treatments and then postweaning TMR for up to 6 slaughter weights.

| Item, lb/day | E-DMI | R-DMI | E-days | R-days | E n = | R n = |
|---|---|---|---|---|---|---|
| **Milk replacer** | 2.64[a] | 1.67[b] | 45.9[a] | 51.5[b] | 36 | 36 |
| **Starter** | 2.29[a] | 1.56[b] | 57.3[a] | 63.4[b] | 36 | 36 |
| **TMR 1** | 6.25[a] | 4.74[b] | 16.7[a] | 19.1[b] | 36 | 36 |
| **TMR 2** | 9.23[a] | 6.54[b] | 58.8[a] | 118.9[b] | 30 | 34 |
| **TMR 3** | 14.80[a] | 10.11[b] | 59.3[a] | 93.8[b] | 20 | 18 |

[ab]Means within a category differ ($P < 0.05$) if designated with different superscripts.

- To reach similar body weights, due to elevated (E) versus restricted (R) feeding levels, resulted in greater DMI and less days ($P < 0.05$) for E versus R.
- With more milk replacer intake by E-heifers, why did they also eat more starter (Kertz 2019)? Most likely because their greater BW compelled them to eat more of what was available--the starter.
- Number of heifers between treatments remained similar.

**Figure 1.** At slaughter, body weight (BW), empty body weight (EBW), gut fill, and average daily gain (ADG-lb) for each category of slaughter by elevated (E 2.1 lb) versus restricted (R 1.43 lb) daily gain.

- Body weights (BW) between treatments for the various slaughter groups were remarkably similar as planned.
- Empty body weights (EBW) were also similar between treatments except for lower ($P < 0.05$) EBW for R versus E at 350 kg BW.
- Gut fill tended to be greater for R versus E, and was greater ($P < 0.05$) for R versus E at both 300 and 350 kg BW categories.

- Averaged daily gains (ADG) were remarkedly close to targets of 1.43 for R (average of 1.47 with a range of 1.36 to 1.51 for various BW categories) and 2.10 for E (average of 2.04 with a range of 1.87for first BW category to 2.11) for various BW categories.

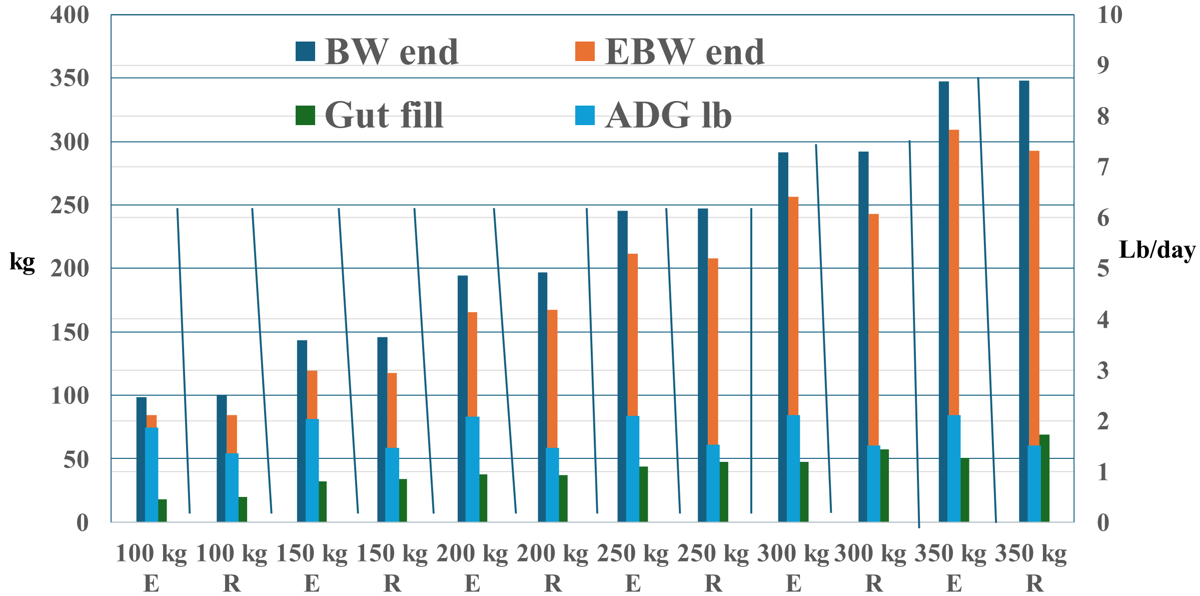
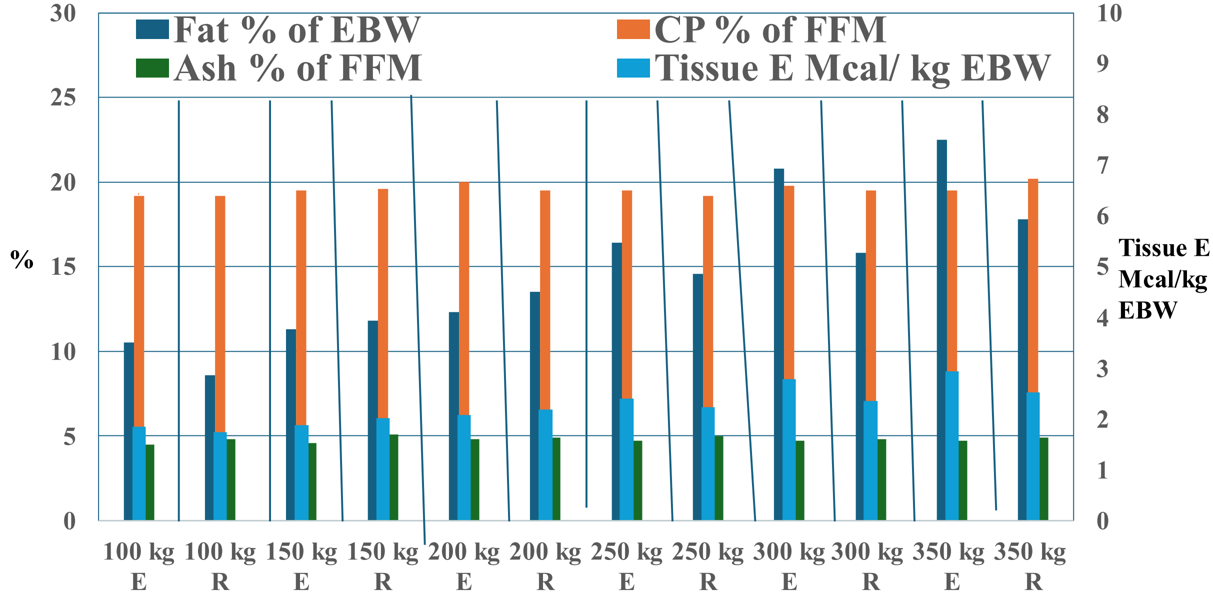
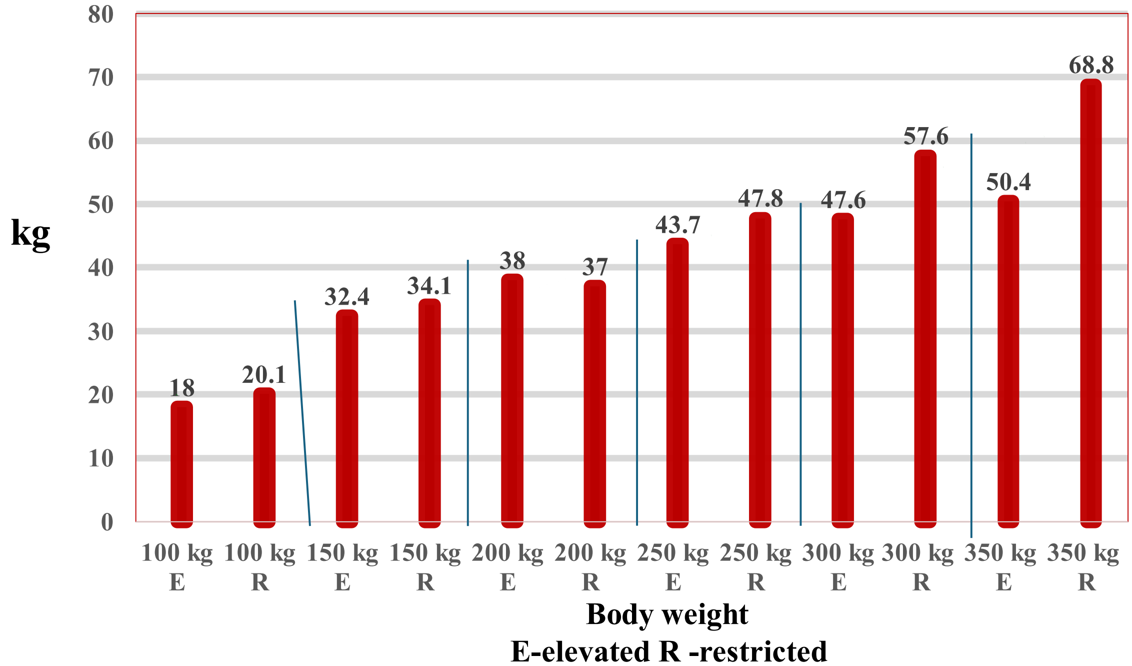



**Figure 2.** At slaughter, fat as a % of empty body weight (EBW), protein (CP) and ash as a % of fat free body mass (FFM), and tissue energy concentration (Mcal/kg EBW) for various slaughter BW with average daily gain by elevated (E of 2.1 lb) versus restricted (R of 1.43 lb) daily gain.




- Not shown is water as a % of fat free matter (FFM) and which did not differ within a range of 75.1 to 76.5 %.
- Fat as % of EBW progressively increased from 10 and 8.6% at 100 kg BW for E and R respectively, to 22.6 and 17.8% at 350 kg BW. Differences between E and R did not differ ($P < 0.01$) until 300 and 350 kg BW categories when E was greater than R.
- CP and ash as % of FFM did not differ between treatments and across BW slaughter categories.
- Tissue energy concentrations in Mcal/kg EBW progressively increased with BW slaughter categories. At 250, 300, and 350 kg BW categories E heifers had greater ($P <$ 0.01) tissue energy concentration than R heifers.

**Figure 3.** Gut fill for Holstein heifers at various BW when fed either R-restricted or E-elevated TMR**.**




- Gut fill was similar among body weight categories for E- and R- fed heifers until 250 kg.
- At and above 250 kg body weight gut fill was greater ($P < 0.05$) for R- versus E-fed heifers.
- ***Why when they were fed the same TMR and fed less?*** Most likely because this parallels Fat as a % of EBW seen in **Figure 2**. And this fat is primarily internal with the age and body weight as seen in Fortin et al. (1980) and Kertz et al. (1982). This most likely reduced rumen volume due to fat taking up more internal space in these heifers. Thus, gut fill was lower for E- versus R- heifers .

E-heifers reached puberty at 107 days earlier than R-heifers in this study. In general other beef and dairy studies have shown that one kg daily gain is about the maximum for protein deposition.

- Daily gain in this study did not reach one kg. Greater fat deposition for E versus R heifers at 250, 300, and 350 kg BW is most likely due to the earlier onset of puberty. Beyond puberty and especially after conception is when excess fat deposition is of greater concern because, if nothing else, it decreases pelvic canal space for calving. That is why fatter heifers, and cows too, have more difficulty calving. And that also increases the probability of the fat cow syndrome with metabolic problems.
- In the prior study (Fortin et al., 1980; Kertz et al., 1982). Holstein heifers had greater internal fat deposition and lipogenic activity than bulls and steers. Subcutaneous fat deposition occurred last after internal fat deposition, which means body condition scoring of Holstein heifers is likely to underestimate internal fat deposition which has already occurred,. But that is better than ignoring the possibility of excessive fattening.

Lastly, but most certainly not least, this study is a major contribution in this area. And it was done with creativity, close management and coordination, and much work. I know because as a graduate student I was involved as the coordinator of a similar study (Fortin et al., 1980; Kertz et al., 1982).

I also want to acknowledge the review by Dr. Rodrigo Molano of this article. He spotted several errors I would have made and sharpened some of the final discussion and conclusion.

**The Bottom Line**

Feeding Holstein heifers to gain 2.1 versus 1.43 lb daily gain decreased days to first puberty by 107. The major difference at and above 250 kg (550 lb) to 350 kg (770 lb) body weight was increased fattening but not with decreased protein deposition. However, at least until one-third of maturity, the more rapid gain did not affect body composition while increasing feed efficiency and reducing time to puberty. After that point, a lower daily gain could be targeted to avoid excessive fat accumulation during pregnancy.

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