Iowa Beef Industry Council
Iowa State Checkoff Research Program
Final Report

I. COVER PAGE

Title:

Heifer development using carcass ultrasound as an indicator of heifer reproductive performance.

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Project Period:

Initiation:	October 2023
Live animal completion:	September 2024
Completion:	December 2024

Budget:

Awarded:	$ 70,730.80
Spent	$ 50,746.91
Remaining Funds	$ 19,983.89

II. NONTECHNICAL SUMMARY

The objective of this study was to gain a preliminary understanding of pre-pubertal heifer growth, the development of body composition traits, and how these traits could affect pregnancy status. At weaning, 124 spring 2023-born Angus heifers from the Iowa State University McNay Memorial Research and Demonstration farm were selected for this study. Heifers were divided into two treatment groups stratified by age and weight at weaning. The first group of heifers was assigned a lower energy ration to reach 55% of their mature body weight by breeding time (restricted). The second group was assigned a moderate energy ration to reach 65% of their mature body weight at breeding (non-restricted).

Measurements were collected over seven time points during the study, with initial observations collected at weaning in October 2023. Data recorded included body weight, body condition score, hair shedding score, and carcass ultrasound measurements for ribeye area, backfat, intramuscular fat, and rump fat. Heifers were estrous synchronized before artificial insemination (AI) using the 7-day CO-Synch+CIDR protocol. All heifers were bred AI in May 2024 and managed as one group within a single breeding pasture following initial breeding. Ten days following AI, bulls were turned out with heifers for a 45-day breeding season. Pregnancy status for heifers bred AI was determined 30 days following initial breeding. A final pregnancy diagnosis was conducted 30 days following bull removal.

Results indicate treatment group significantly influenced the development of body composition measurements. A statistical difference between groups was found for response to the estrus synchronization but not AI or final pregnancy rates. Although not statistically different, the number of heifers bred AI was higher for the non-restricted group. Statistical modeling indicated backfat and group were significant indicators of pregnancy status. When both groups of heifers were managed together on pasture, heifers from the non-restricted group, on average, lost backfat and ribeye area more drastically compared to the restricted group. No statistical difference was found in pregnancy loss between the two treatment groups.

III. TECHNICAL REPORT

a. Impact

Reproductive performance is an economically relevant trait, and failure to calve results in revenue loss for cow-calf operations. Heifer reproductive success is particularly critical since a calf has yet to be produced to recover the investment of the female's development costs. Understanding the mechanisms that affect heifer pregnancy can improve heifer development practices and increase profitability for cow-calf operations. Traditional practices use body condition scores (BCS) and body weight as indicators of puberty onset. However, BCS can be subjective, and weight may not accurately reflect body composition. The objectives of this study were to understand the pre-breeding development of body composition traits, identify the variation in body composition measurements within BCS, determine the association between body composition and heifer pregnancy, and evaluate the effect of fat and muscle deposition from different diets on pregnancy status. The results from this study contribute to the understanding of the development of body composition traits from weaning until breeding and could potentially identify indicators for heifer pregnancy.

b. Methods and Results

Methods

A total of 124 purebred Angus heifers from the Iowa State McNay Memorial Research and Demonstration farm were used in this study. Heifers were divided into two dietary groups based on age and weight at weaning: a lower average daily gain (restricted; n=61) and a moderate average daily gain group (non-restricted; n=63). The mean age of heifers in both groups was 185 ± 18 days, and the mean weight for the restricted and non-restricted groups was 430.5 ± 7.2 and 437.4 ± 7.0 pounds, respectively. Table 1 presents the rations fed to each group up to breeding. Both treatment diets consisted of the same feed ingredients, differing only in proportions. The treatment diets were developed for heifers to reach a target body weight of 55% and 65% mature body weight for the restricted and non-restricted groups, respectively. The restricted group was intended to be maintained on pasture throughout development, but there was no grass availability due to drought conditions. As a result, the restricted group was maintained in a large open area but fed in bunks. At the third measurement, heifers in both groups were predicted to be overdeveloped at breeding. Therefore, a new diet was developed for both groups starting on Day 178 to reduce the ADG of heifers to meet the target body, as shown in Table 1.

Table 1. Treatment group rations for developing heifers from weaning (Day 0) until breeding (Day 231)

	Day 0 to 178		**Day 178 to 231**	
	Restricted[1]	**Non-restricted**[2]	**Restricted**[1]	**Non-restricted**[2]
Ingredient, % DM basis				
Ground Hay	43.98	22.89	71.17	38.01
Mod Distillers	12.00	21.80	9.80	19.70
Corn silage	42.50	54.50	17.80	41.30
Grower mineral	1.60	0.80	1.20	1.00
Analyzed Composition				
NE m Mcal/lb	0.64	0.80	0.47	0.71
NE g Mcal/lb	0.38	0.52	0.23	0.44
Crude Protein %	10.80	13.60	9.10	13.20
Programmed Gain				
Daily Gain	0.62	1.11	0.65	2.04
Feed:Gain	14.45	7.46	22.69	8.29

[1]Restricted: ration to develop heifers to 55% of mature body weight at time of breeding.
[2]Non-restricted: ration to develop heifers to 65% of mature body weight at time of breeding.

Data collected over all seven time points included BCS, weight, and carcass ultrasound measurements for ribeye area (REA), backfat (FAT), and intramuscular fat (IMF). Collection dates were as follows: October 2023 (Day 0), December 2023 (Day 55), February 2024 (Day 123), April 2024 (Day 178), May 2024 (Day 231), July 2024 (Day 274) and September 2024 (Day 338). A certified ultrasound technician collected ultrasound measurements, and the CUP Lab in Ames, Iowa, processed and quantified the ultrasound images. Artificial insemination pregnancy diagnosis was determined in July (Day 274), and no carcass measurements were collected at this time. Rump fat (RUMP) measurements were not collected at weaning due to the heifers' small size.

Before breeding, pelvic area measurements and reproductive tract scores (RTS) were measured in May 2024. Eleven heifers did not meet farm management criteria for pelvic area and RTS and were subsequently culled. Heifers were synchronized for AI using the 7-day CO-Synch+CIDR protocol. Gonadotropin-releasing hormone (GnRH) was administered, and a controlled internal drug release (CIDR) was inserted the last week of May. Day 231 carcass ultrasound measurements were taken during CIDR placement in heifers. Seven days following insertion, the CIDR was removed, a prostaglandin injection was administered, and an Estrotect heat detection patch was placed on the tailhead of heifers to monitor estrus response. A response outcome was assigned by abrasion of the heat patch. Heifers that expressed estrus before timed AI breeding were bred 12 hours following expression. All other heifers were bred at timed AI and administered a GnRH injection. Bulls were released with heifers 10 days following AI for natural service. Four weeks post-AI, pregnancy status was determined via transrectal ultrasound to determine heifers bred AI. The final pregnancy diagnosis was determined 12 weeks after initial AI and 30 days following bull removal in September. Data was analyzed using R Statistical Software 4.41.

Results and Discussion

Pre-breeding Development

One week following weaning (Day 0), heifers were randomly assorted into two groups stratified by age and weight. Independent two-sample t-tests were performed to compare mean measurements between the two treatment groups. Results indicate significant differences in weight, FAT, and REA between the restricted and non-restricted groups were observed on days 55, 123, 178, and 231. Significant differences in average IMF measurements between groups were identified on days 123 through 231. Measurements collected up to the breeding date are presented in Table 2 with significant differences ($P<0.05$), denoted by an asterisk.

Table 2. Group means for observations of body weight (Wt), backfat thickness (FAT), ribeye area (REA), intramuscular fat (IMF), and body condition scores (BCS) for Angus beef heifers from weaning (Day 0) to breeding (Day 231) when developed to different percentages of mature weight

		Day 0	Day 55	Day 123	Day 178	Day 231
Wt (lbs)	**Restricted[1]**	430.50 ± 7.42	517.67 ± 8.24*	623.41 ± 9.34*	719.33 ± 71.88*	749.00 ± 74.74*
	Non-Restricted[2]	437.42 ± 6.97	539.21 ± 7.40*	691.70 ± 8.43*	836.11 ± 66.52*	876.38 ± 68.25*
FAT (in)	**Restricted[1]**	0.09 ± 0.004	0.13 ± 0.004*	0.14 ± 0.006 *	0.17 ± 0.05*	0.14 ± 0.06*
	Non-Restricted[2]	0.08 ± 0.004	0.15 ± 0.005*	0.18 ± 0.007*	0.27 ± 0.06*	0.26 ± 0.07*
REA (in^2)	**Restricted[1]**	6.64 ± 0.12	7.18 ± 0.12*	8.64 ± 0.13*	9.50 ± 1.06*	9.37 ± 1.04*
	Non-Restricted[2]	6.71 ± 0.11	7.79 ± 0.13*	9.85 ± 0.13*	10.69 ± 1.20*	11.23 ± 1.14*
IMF (%)	**Restricted[1]**	3.79 ± 0.95	4.10 ± 0.99	4.54 ± 1.33*	4.89 ± 1.47*	4.43 ± 1.38*
	Non-Restricted[2]	3.60 ± 0.77	3.86 ± 0.79	4.75 ± 1.10*	6.03 ± 1.63*	5.83 ± 1.60*
BCS	**Restricted[1]**	5.32 ± 0.47	5.14 ± 0.41	4.98 ± 0.37*	5.01 ± 0.38*	5.42 ± 0.35*
	Non-Restricted[2]	5.12 ± 0.49	5.21 ± 0.44	5.38 ± 0.40*	5.42 ± 0.35*	6.06 ± 0.16*

[1]Restricted: ration to develop heifers to 55% of mature body weight at time of breeding.
[2]Non-restricted: ration to develop heifers to 65% of mature body weight at time of breeding.
* P-value < 0.05

Figure 1 is a visual depiction of the mean differences between treatment groups during pre-breeding development. Spearman rank correlations for each trait were calculated within dietary groups between each measurement point. A rank correlation close to 1 indicates a strong positive association between ranks, meaning animals that ranked high for one measurement also ranked high for the second (and vice versa). In contrast, a low rank correlation indicates significant reranking of animals occurred between one data point and the next. This study compared the ranks of individual animals between consecutive measurement points (i.e., Day 0-55, 55-123, 123-178, and 178-231) to generate four rank correlations per group and trait. Red values correspond to the restricted group, and blue values correspond to the non-restricted group. A strong positive association for Spearman rank correlations for each group and collection point was found for weight and REA. This suggests that within each group, heifers that were heavier initially tended to maintain heavier weight through development relative to the rest of the group cohort. Additionally, heifers with larger REAs relative to their group at the beginning of this study maintained larger REAs at each collection point.

Backfat Spearman rank correlations were marginally lower than weight and REA rank correlations but still indicated a strong positive association between animal measurements across measurement points. Measurements for FAT for the non-restricted group between Day 0 and Day 55 had the most amount of reranking. Significant reranking was also observed for IMF between Day 0 and Day 55 for both groups, with a greater degree of reranking observed for the non-restricted group. For each consecutive IMF measurement interval, the degree of reranking lowered.

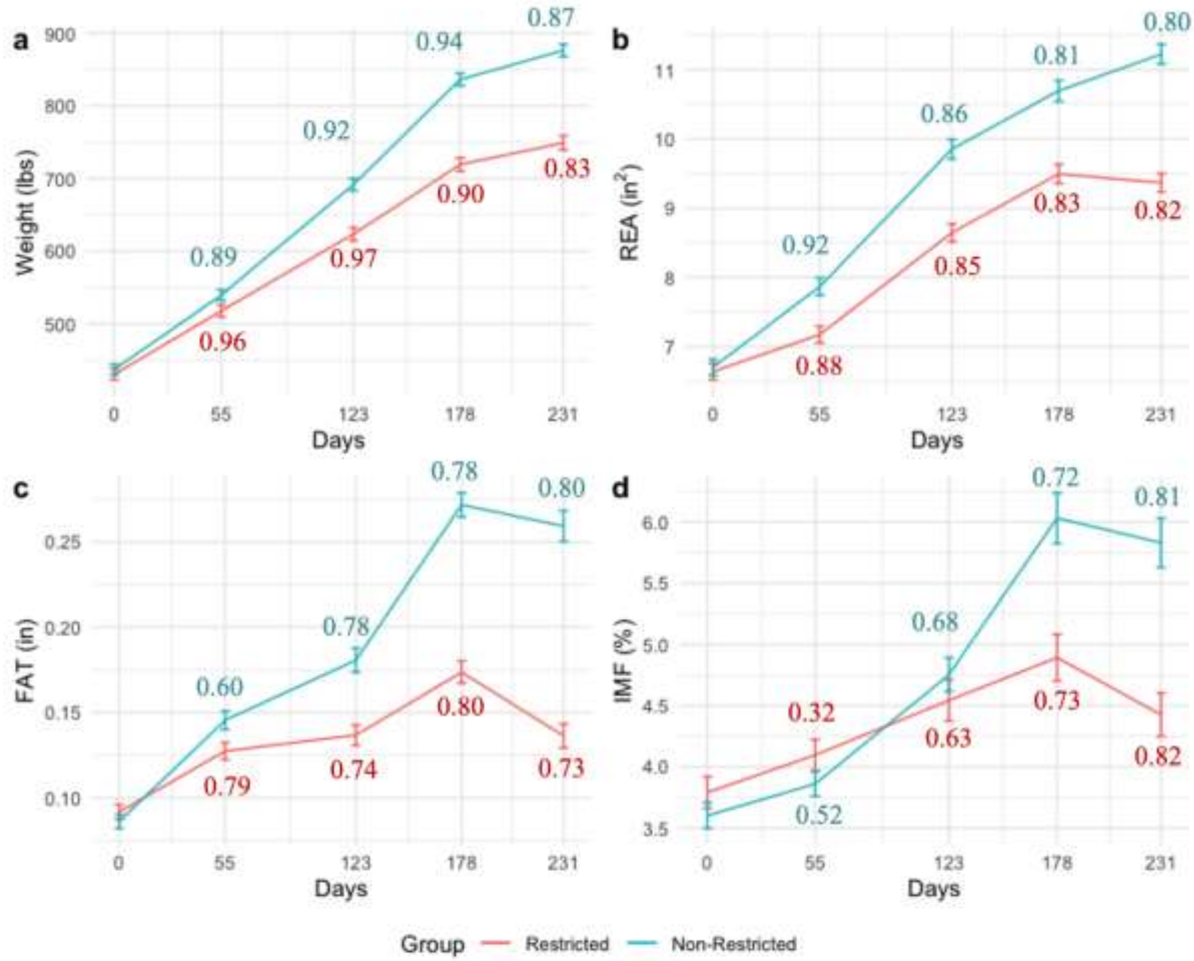

Figure 1a-d: Illustration of heifer development from weaning (Day 0) to breeding (Day 231) for when developed to different percentages of mature weight. Graphs represent mean differences and Spearman rank correlations for body weight (a), ribeye area (REA; b), backfat thickness (FAT; c), and intramuscular fat (IMF; d)

A commonly used indicator of puberty onset is BCS, a visual appraisal of fat coverage. The BCS scale ranges from 1 to 9, with 1 being emaciated and 9 being obese. Traditional guidelines recommend developing heifers to a BCS of 5 or 6 to ensure enough energy reserves to withstand growth demands and establish pregnancy. Figure 2 depicts the variation in body composition measurements as measured by carcass ultrasound within BCS at the time of breeding (Day 231). The red dots represent individuals in the restricted group, and blue represents the non-restricted group. The dot size represents the number of individuals with that particular measurement. While the variation in weight, REA, and IMF within BCS is expected, the variability in FAT measurements within BCS is particularly noteworthy. Overall, FAT tends to increase with BCS, but there are visual deviations from this trend observed in BCS 5 and 6. The variation for FAT between animals assigned a BCS of 6 across both groups is 0.38 inches. This highlights the subjectivity of BCS, as factors like increased hair coat and variations in body metrics can influence the scoring.

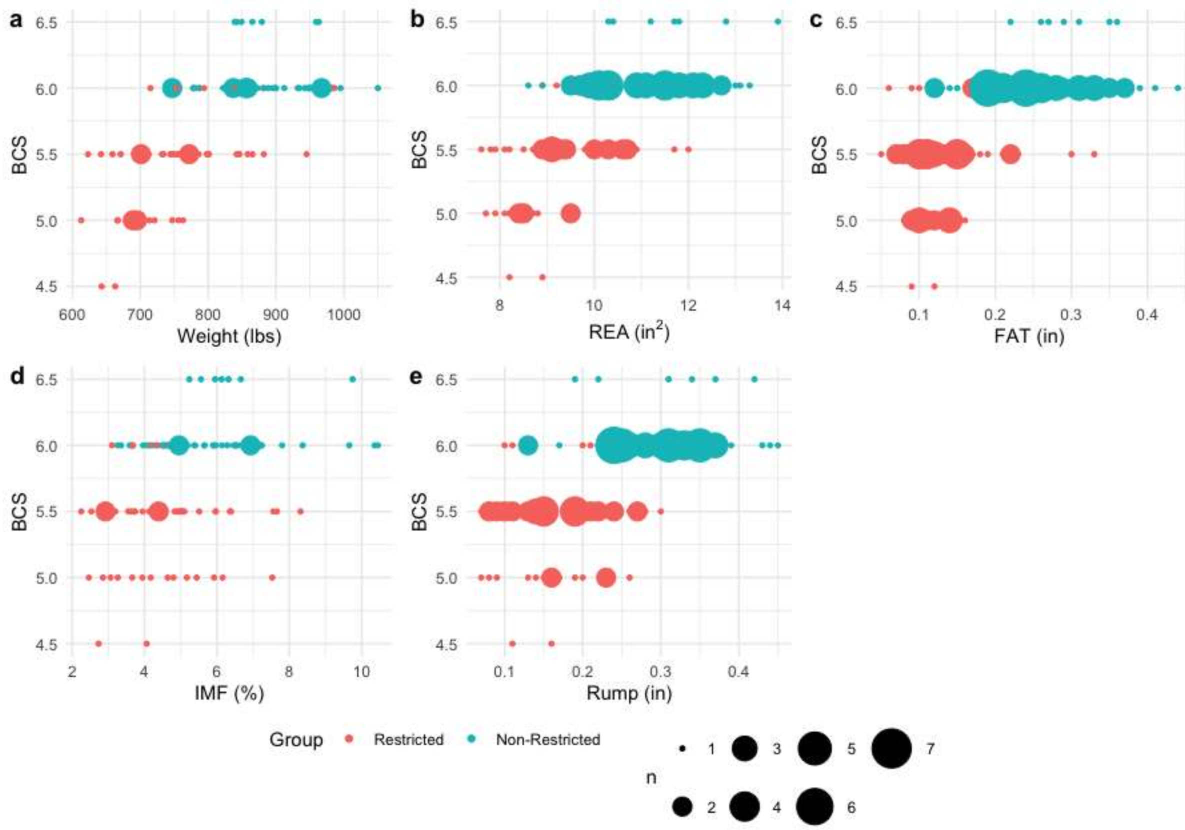

Figure 2a-e: Variability of body weight (Weight) and carcass ultrasound measurements for ribeye area (REA), backfat thickness (FAT), intramuscular fat (IMF), and rump fat (RUMP) within body condition scores (BCS) in two dietary groups (restricted vs non-restricted) of Angus heifers at breeding (Day 231). Dot size increases proportionally to the number of animals represented in each measurement.

The relationship between carcass ultrasound measurements and weight for Days 0 and 231 is illustrated in figure 3. Initial carcass ultrasound measurements (figure 3a) illustrate no distinct group separation. At the time of breeding (figure 3b), there is a clear distinction between dietary groups and body weight and carcass ultrasound measurements. This indicates diet is likely an influential factor in the development of body composition traits in beef heifers. A strong positive association between REA and weight and between FAT and weight is observed in figure 3. Weight is a commonly used metric of heifer selection, and although it can be an indicator of REA and FAT, it appears to have a more variable relationship with IMF.

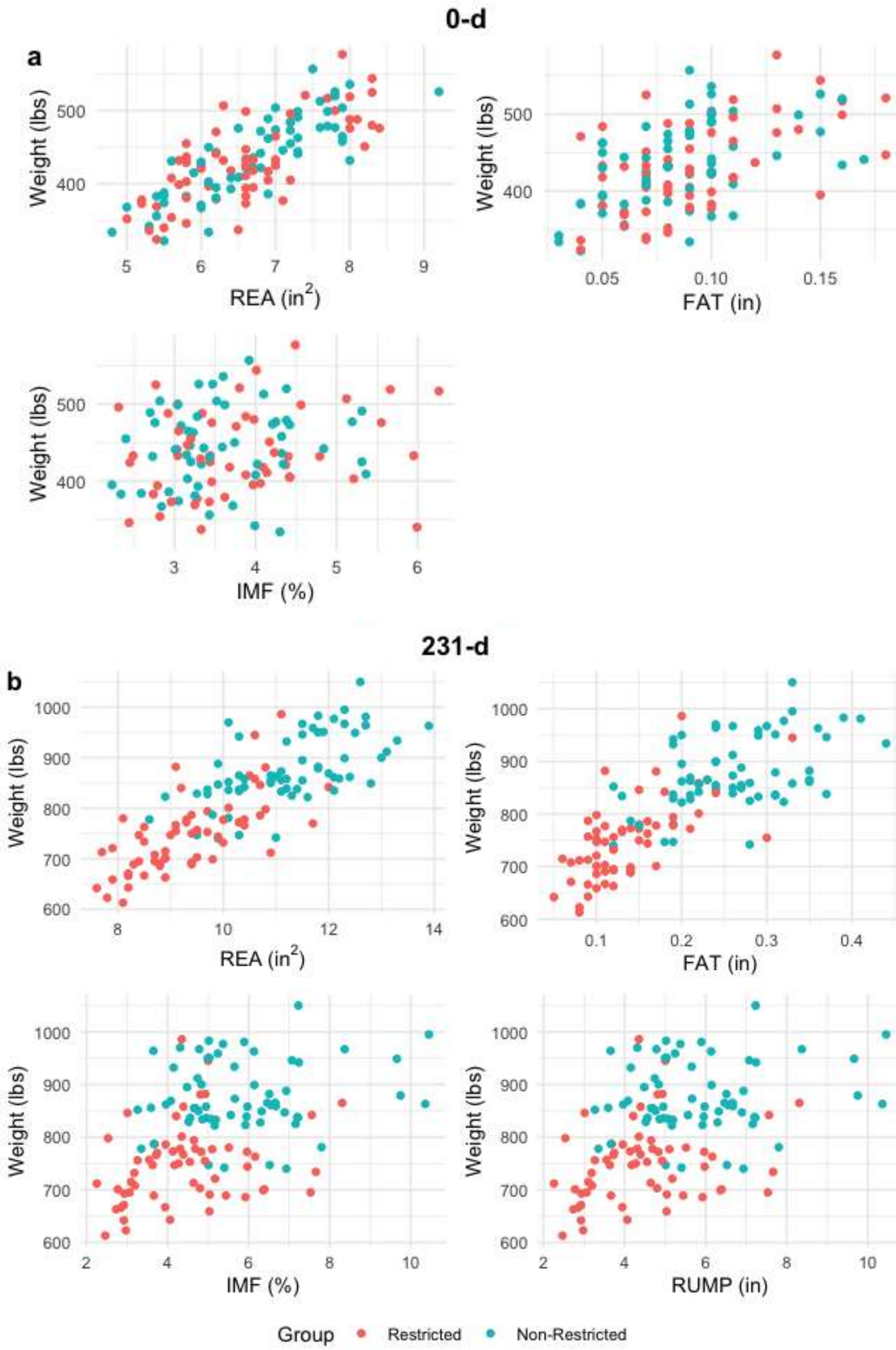

Figure 3a-b. Association between body weight (Weight) and carcass ultrasound measurements for ribeye area (REA), backfat (FAT), intramuscular fat (IMF), and rump fat (RUMP) in two dietary groups (restricted vs non-restricted) of Angus heifers at breeding (Day 231). NOTE: Ultrasound measurements for RUMP were not taken on day 0.

Pearson correlations were estimated to measure the strength and direction of the linear relations between numerical variables and are shown for all pairs of measurements in figure 4. A positive Pearson correlation indicates that as one trait increases, the other also increases, while a negative correlation means that as one trait increases, the other decreases. The magnitude of the Pearson correlation would indicate the strength of the relational change between traits, with 1 indicating a perfect relationship between variables. Most observations in this study demonstrated moderate correlations of 0.3 to strong of 0.7. Very strong correlations of 0.76 or greater were observed between FAT and RUMP, weight and REA, and weight and FAT.

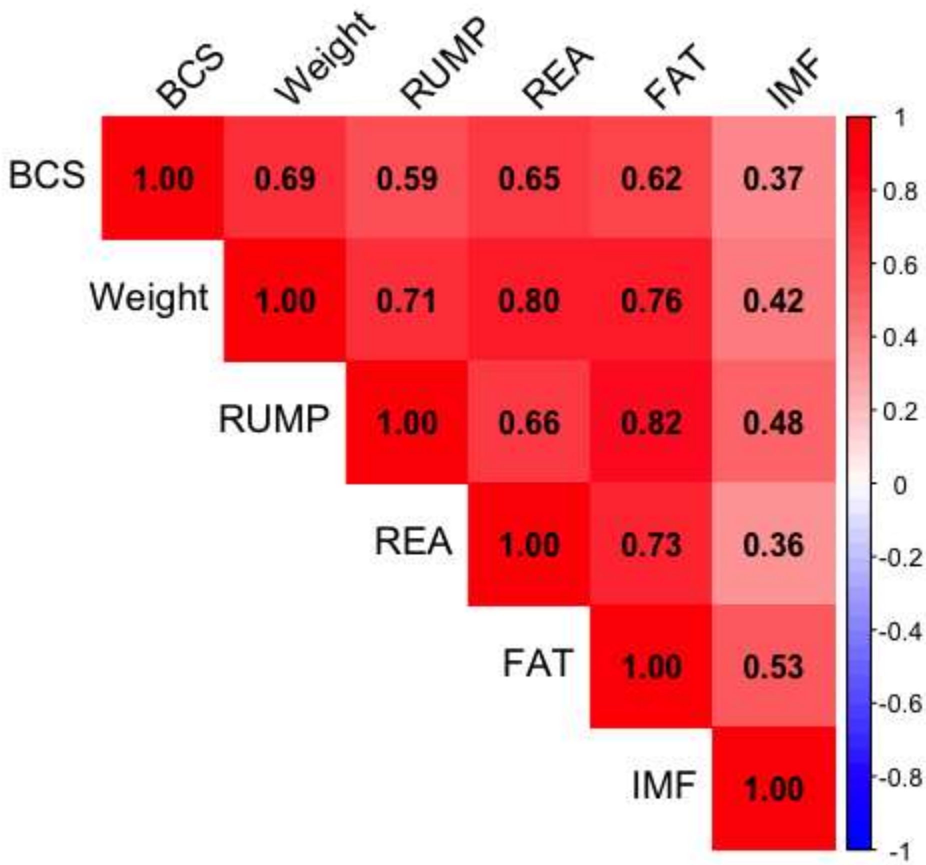

Figure 4: Pearson correlations between body condition scores (BCS), body weight (Weight), rump fat (RUMP), ribeye area (REA), backfat thickness (FAT), and intramuscular fat (IMF) in Angus heifers at breeding.

Heifers with small pelvic areas and low reproductive tract scores (RTS) were culled before breeding. Seven heifers were culled from the restricted group and four from the non-restricted group. Group average RTS and pelvic area measurements before culling are shown in Table 3. A statistical difference (P<0.005) was observed for RTS, pelvic area, and pelvic ratio.

Table 3: Pre-breeding mean measurements for reproductive tract score (RTS), pelvic area, and pelvic ratio in heifers from different dietary groups (restricted vs non-restricted).

	Restricted[1]	**Non-Restricted[2]**
N	61	63
RTS	3.75	4.15
Pelvic Area	162.24	174.09
Pelvic Ratio	96.50	103.55

[1]Restricted: Heifers developed to 50 to 55% of mature body weight at time of breeding.
[2]Non-restricted: Heifers developed to 60 to 65% of mature body weight at time of breeding.

Estrotect heat detection patches were used to monitor the response to estrus synchronization. Heifers were assigned a “response" or "no response" status based on whether the Estrotech patch abrasion was observed. The percentage of estrous response status in each group was recorded at time of AI (Table 4). In the restricted group, 75.47% of heifers responded to estrous synchronization, compared to 100% of non-restricted heifers, resulting in a statistically significant difference in estrus response between the groups ($P < 0.001$).

Table 4: Mean response to estrus synchronization by dietary group at the time of artificial insemination (AI). Estrous response was recorded as a binary trait of either “response” if the Estrotect patch was abraided or “no response” if no abrasion was observed.

	Restricted[1]	**Non-Restricted[2]**
N	53	59
Response	75.47%	100%
No Response	24.53%	0%

[1]Restricted: Heifers developed to 50 to 55% of mature body weight at time of breeding.
[2]Non-restricted: Heifers developed to 60 to 65% of mature body weight at time of breeding.

Post- AI Performance

After AI breeding, all heifers were managed as one group on pasture. The restricted group was managed throughout the development period in a large area to mimic pasture, but the non-restricted group was maintained in a smaller dry lot area. Carcass and body weight measurements were taken during final pregnancy determination to monitor changes in body composition after moving heifers onto the spring breeding pasture. Group means and standard deviations are reported in Table 5. Statistically significant differences were found between the two groups in all five measurements. However, the magnitude of the significance decreased for Fat, REA, IMF, and BCS from Day 231 to Day 338.

Table 5: Body weight (WT), body condition score (BCS), and carcass ultrasound measurements for backfat thickness (FAT), ribeye area (REA), and intramuscular fat (IMF) collected at AI breeding (Day 231) and final pregnancy determination (Day 338) in heifers.

		Day 231	**Day 338**
WT (lbs)	**Restricted**[1]	749.00 ± 74.74	796.79 ± 84.33*
	Non-Restricted[2]	876.38 ± 68.25*	864.19 ± 65.93*
FAT (in)	**Restricted**[1]	0.14 ± 0.06*	0.13 ± 0.05*
	Non-Restricted[2]	0.26 ± 0.07*	0.16 ± 0.06*
REA (in^2)	**Restricted**[1]	9.37 ± 1.04*	8.67 ± 1.06*
	Non-Restricted[2]	11.23 ± 1.14*	9.31 ± 1.04*
IMF (%)	**Restricted**[1]	4.43 ± 1.38*	5.99 ±1.98*
	Non-Restricted[2]	5.83 ± 1.60*	7.02 ± 1.93*
BCS	**Restricted**[1]	5.42 ± 0.35*	5.01 ± 0.61*
	Non-Restricted[2]	6.06 ± 0.16*	5.35 ± 0.44*

[1]Restricted: Heifers developed to 50 to 55% of mature body weight at time of breeding.
[2]Non-restricted: Heifers developed to 60 to 65% of mature body weight at time of breeding.
* P-value < 0.05

Figure 5 displays the group mean measurements with the final carcass measurements for Day 338 (final pregnancy diagnosis). The effect of heifers managed on pasture on carcass and body weight measurements resulted in a decrease in mean weight for the non-restricted group while the restricted group continued to gain weight on pasture. Both groups experienced a decline in REA and FAT, with a more pronounced decrease for the non-restricted group. Interestingly, IMF increased for both groups while on pasture for Days 231 to 338.

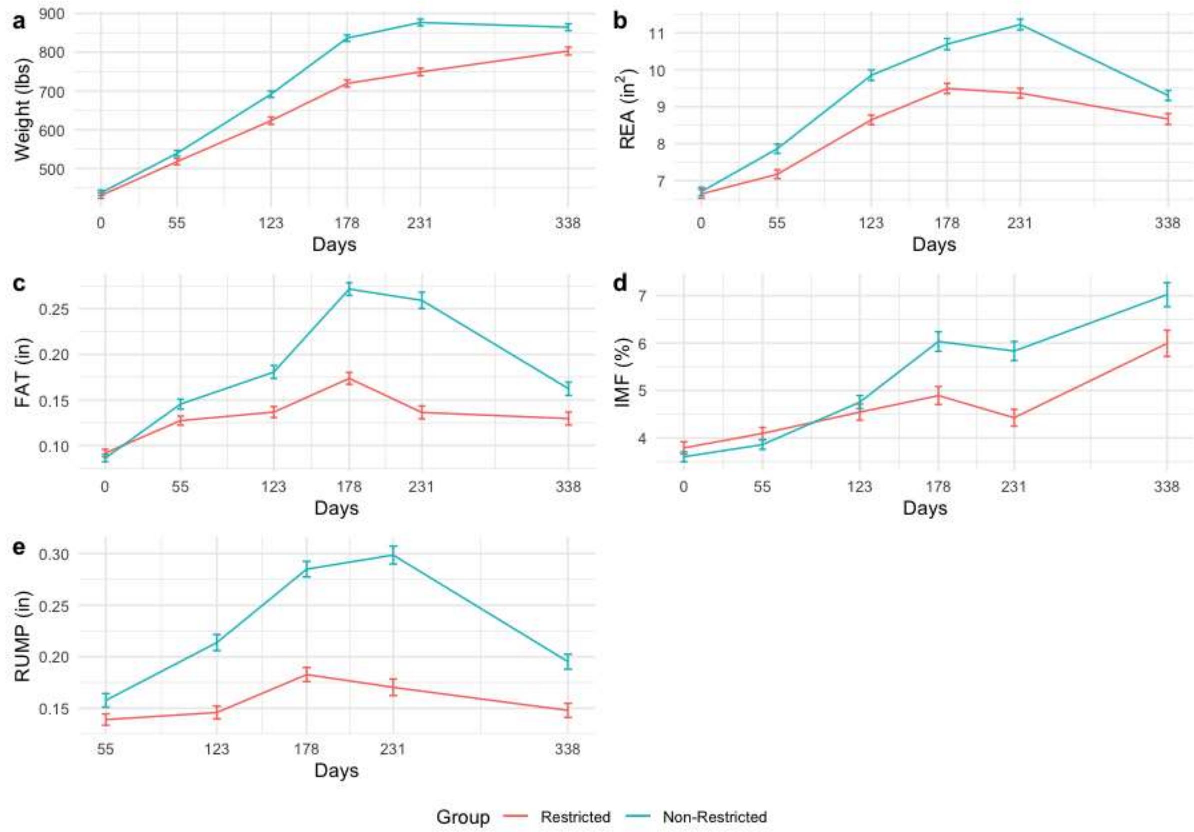

Figure 5: Illustration of heifer development from weaning (Day 0) to final pregnancy determination (Day 338) when developed to different percentages of mature weight. Graphs represent mean differences for body weight (a), ribeye area (REA; b), backfat thickness (FAT; c), intramuscular fat (IMF; d), and rump fat (RUMP; e). The blue line corresponds to the group of heifers developed to 55% of their mature body weight at the time of breeding (restricted) and the red line corresponds to the group of heifers developed to 65% of their mature body weight at breeding (non-restricted).

Figure 6 utilizes boxplots to illustrate the change in group mean values for carcass measurements from AI breeding to final pregnancy determination after managing heifers on pasture. Note the y-axis is scaled based on each measurement to represent the average change in the trait measured. Values below zero indicate animals that lost body composition during this timeframe. On average, heifers lost REA and gained IMF during this period, regardless of group (figure 6a-b). Heifers in the non-restricted group lost more FAT and RUMP compared to the restricted group.

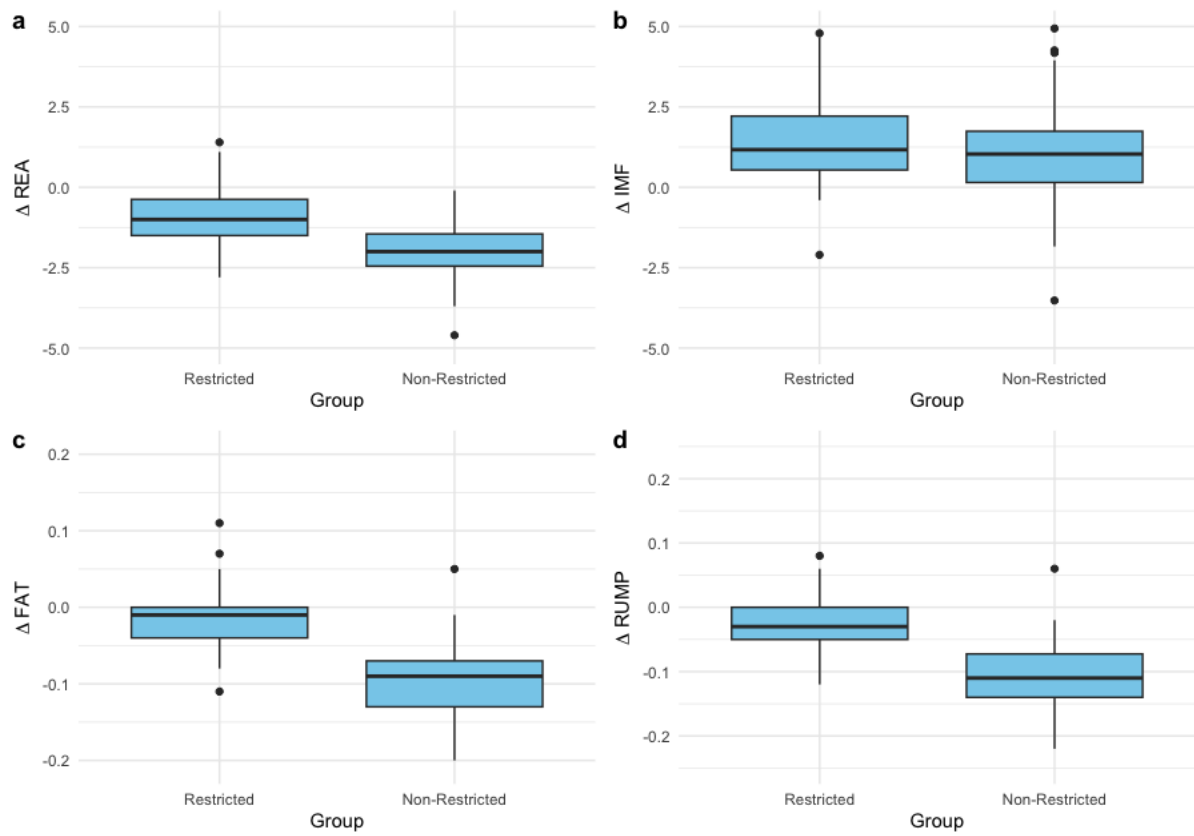

Figure 6: Change (Δ) in heifer ultrasound carcass measurements for ribeye area (REA), intramuscular fat (IMF), backfat thickness (FAT), and rump fat thickness (RUMP) from artificial insemination (AI) to final pregnancy determination, split by dietary group (restricted vs non-restricted). The restricted group are heifers developed to 55% of mature body weight at time of breeder while the non-restricted heifers were developed to 65% of mature body weight.

Reproductive performance

Pregnancy rates by group are presented in Table 6. One heifer was missing at time of AI pregnancy determination but was later located in another pasture and was included in the final pregnancy diagnosis in September. This explains the decreased number of heifers in the restricted group for this time point. Pregnancy determination for AI-bred heifers was conducted 30 days post-insemination by rectal ultrasound. The pregnancy percentage in the non-restricted group was 10.61% higher compared to the restricted group. Although numerically different, no statistically significant difference was found for AI pregnancy rates between the two groups. Final pregnancy diagnosis was determined by rectal ultrasound 30 days after bull removal. In both groups, AI pregnancy percentages dropped due to some pregnancy loss from the initial and final pregnancy diagnosis. AI pregnancy loss was observed in both groups, with two losses in the non-restricted group and four in the restricted group. The final pregnancy percentage was 1.85% higher in the restricted group compared to the non-restricted group. No statistically significant difference was found between groups at final pregnancy determination.

Table 6: Pregnancy rates for heifers 30 days following artificial insemination (AI) and 30 days following bull removal. Pregnancy rates were categorized as AI bred (AI Pregnant), bull bred or natural service (NS Pregnant), and not bred (Open).

	Pregnancy rates 30 days following AI		**Final pregnancy rates 30 days following bull removal**	
	Restricted	**Non-Restricted**	**Restricted**	**Non-Restricted**
N	52	59	53	59
AI Pregnant	38.54%	49.15%	30.19%	45.76%
NS Pregnant	NA	NA	54.72%	37.29%
Open	61.46%	50.85%	15.09%	16.95%
Total Pregnant	38.54%	49.15%	84.91%	83.05%

[1]Restricted: Heifers developed to 50 to 55% of mature body weight at time of breeding.
[2]Non-restricted: Heifers developed to 60 to 65% of mature body weight at time of breeding.

Binary pregnancy model

Two logistic regression models were considered to best capture the relationship between heifer pregnancy and carcass ultrasound measurements. The first model (M1) included yearling carcass ultrasound measurements as explanatory variables, while the second model (M2) used the change (denoted as Δ) in carcass measurements from weaning until breeding. Data was analyzed using R Statistical Software 4.4.1. During initial modeling, highly correlated variables (>0.75) were filtered to reduce collinearity in the model.

Following data filtering, a stepwise model selection process was used to determine the final models. The explanatory variables for M1 was comprised of group, FAT, and IMF, while M2 included group and the change in weight, FAT, and IMF.

For both M1 and M2, final models for heifer pregnancy indicated that diet group and FAT were significant predictors in this study. At the time of the report submission, the logistic regression results were preliminary. Model diagnostics indicate low confidence for model fit to the data, which suggests that additional factors not captured in this analysis may also influence the outcome of heifer pregnancy. Further model analysis is warranted and will continue after report submission.

c) Conclusions

The energy concentration of the diet appears to influence body weight and body composition measurements in heifers. On average, the non-restricted group had higher values for carcass measurements and weight compared to the restricted group. While some animals consistently ranked similarly between collection dates regarding carcass values, there was reranking throughout the development period. Variation in carcass composition measurements within BCS reflected the inherent approximation of BCS, even when considering backfat.

The non-restricted group had higher mean values for RTS and pelvic area compared to the restricted group. The number of heifers culled due to RTS and pelvic area in the restricted group was twice that of the non-restricted group. All heifers in the non-restricted group responded to estrus synchronization, and only 75% responded in the restricted group, resulting in a statistically significant difference between the two groups. A numerical difference but no statistical difference in AI pregnancy rates was observed between the two groups. No pregnancy rate difference was found between the two groups at final pregnancy determination. The non-restricted group overall had higher AI rates while the restricted group had higher NS rates. Statistical modeling identified FAT and group as significant indicators of pregnancy response. Intramuscular fat was included in the best-fit model but was not found to be significant.

After AI breeding, all heifers were managed as one group on pasture. Changes in carcass measurements and weight post-AI suggest the non-restricted group lost body condition more rapidly than the restricted group. Specifically, a sharp reduction in FAT and REA was observed in the non-restricted group on pasture, whereas the reduction was smaller in the restricted group. Pregnancy loss was slightly higher in the non-restricted group but not statistically significant.

These results illustrate the effect of development practices on heifer pregnancy. Developing heifers to a lower percentage of mature weight of 50 to 55% at breeding could result in more culling prior to breeding and lower conception rates to AI compared to heifers developed to larger body weight. Heifers developed to a larger body weight (60 to 65% of mature weight) at the time of breeding had a better response to estrus synchronization and AI conception, but when transitioned from the dry lot to pasture, these heifers lost weight and condition compared to their lighter contemporaries.

d) Project challenges

Heifers in this study were culled due to health status, small size, or reproductive scoring. At the initiation of the project in October, twelve heifers were culled due to pink eye and small body size. One heifer was culled in December due for poor health. Before breeding in May, the bottom 10% of heifers with low RTS and pelvic ratios were culled. Removing heifers based on small body size and poor reproductive indicators are standard practices at McNay. Drought conditions in 2023 prevented the restricted group of heifers from being on pasture for the duration of this study. Therefore, the heifers were fed in concrete feed bunks with additional space to mimic pasture area. It was intended to develop each group of heifers on their respective diets throughout the pre-breeding period. However, it was observed in February that heifers were developing to a higher percentage of their mature body weight than intended for this project, so a new diet was formulated to reduce the rate of gain.

e) Publications

Phelps, S., G.R. Dahkle, M.E. Reynolds, P.B. Wall, M.M. Culbertson. *Analysis of maternal influence on phenotypic ultrasound measurements of weaned Angus calves*. Journal of Animal Science, Volume 102, Issue Supplement 2, May 2024, Page 269. https://doi.org/10.1093/jas/skae102.305.

Phelps, S.L., G. Dahlke, M.E. Reynolds, P.B. Wall, M. Culbertson. *Differences in body composition measurements for developing Angus heifers*. Journal of Animal Science, Volume 102, Issue Supplement 3, September 2024, Pages 83–84. https://doi.org/10.1093/jas/skae234.093.

f) Personnel Support

Sarah Phelps: A portion of Sarah Phelps Master's program was supported by this grant for the summer and fall 2024 ($15,434.95)
Patrick Wall committed 0.03 FTE of his time on the project ($3,846.96)
Garland Dahlke committed 0.01 FTE of his time on the project ($1,710.02)

g) Final Budget

Expense	**Budget**	**Spent**	**Remaining**
Salary & Stipend	$30,722.00	$20,991.93	$9,730.07
MS Tuition	$8,249	$5,878.38	$2,370.62
Fringe Benefits	$5,189.76	$4,082.83	$1,106.97
Travel	$7,030	$7029.74	$0.26
Materials, Supplies, Printing	$10,516	$5819.21	
Services & Fees	$9,024	$6,944.82	$2,079.18
Total Cost	**$70,730.80**	**$50,746.91**	**$19,983.89**

h) Acknowledgements

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