THE EFFECT OF A TRANSITIONAL DIET ON STOCKER HEIFERS GRAZING WHEAT PASTURE

By

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Abstract:

Cattle on wheat pasture require an acclimation period before significant body weight gains occur. Weight loss is often observed during the adaptation period. The effect of energy supplementation while grazing wheat has been tested, and the effect of high energy diets during preconditioning before grazing wheat has also been tested. However, the strategy of designing a feeding program that continues from drylot through the transition to wheat pasture has not been explored. Therefore, a three-year study of three different diet strategies, including a combined (transitional) strategy was conducted and weights recorded daily using GrowSafe® technology. A mixed model is estimated and, a partial budget is prepared for each diet strategy. Average daily gain differed significantly by treatment in the drylot phase ($P < 0.05$). On pasture, total weight-gain for cattle under the transitional strategy differed significantly from the other two treatments ($P < 0.05$) in the first 14 days. However, average daily gain did not differ significantly between treatments overall ($P < 0 .05$). This study reveals that the weight loss cattle experience during the transition period occurs during the first two days of wheat pasture grazing. Given that the transitional-diet strategy yielded no additional benefit overall, the net returns to such a strategy are negative. This study uniquely uses GrowSafe technology to reveal that cattle on wheat pasture lose weight quickly but rebound slowly.

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CHAPTER I

INTRODUCTION

Cattle transitioning to wheat pasture from a drylot require an acclimation period before significant body weight gains can occur (Lippke et al., 2000; Phillips et al., 2006; Phillips and Horn, 2008). Substantial weight loss is often observed during the drylot to pasture adaptation period. Energy supplementation during the grazing period is shown to allow increased stocking rates, but research has not focused on individual animal gain during the transition period (Horn et al., 2005). Other research concludes that weight loss can be decreased by altering the diet fed before turn out on to wheat pasture. Feeding a high energy diet to calves during the drylot phase before turnout increased average daily gain (ADG) by 1.63 lbs per day in the first 14 days compared to calves fed hay-based diets (Beck et al., 2005a).

Previous studies have typically focused on altering diet fed before turn out on to wheat pasture or providing animals supplemental feed after turnout. No research on cattle adaptation to wheat pasture has yet examined a combination of both strategies. Therefore, further research on cattle adaptation to wheat pasture by altering diet in drylot before turnout and also providing an energy supplement during the grazing period is warranted. Objectives for this study were to determine the effect of a combined (transitional diet) strategy on stocker heifer average daily gain during the grazing period, determine the treatment effect on total weight gain across both feeding segments, and determine the net return of a transitional diet strategy to a stocker enterprise. With the transitional diet strategy, cattle receive both a high energy feed in drylot during backgrounding and an energy supplement during the transition period on pasture.

CHAPTER II

DATA AND METHODS

All animal procedures in the following experiments were conducted per the recommendations of the Guide for Care and Use of Agricultural Animals in Research and Teaching and were approved by the Noble Research Institute's Animal Care and Use Committee (IACUC). The 307 heifers used in this experiment were purchased directly from farms and ranches in Oklahoma from 2015 to 2017. Descriptive statistics, including the number of heifers purchased each year, are in Table 1. Regardless of the year of purchase, all heifers received the same treatments upon arrival at Noble Research Institute facilities. All heifers were treated for internal parasites (Safe-guard®, Merck & Co. Inc., Madison, NJ), with a clostridial (Clavary® 9, Merck & Co. Inc., Madison, NJ), given a zeranol implant (Ralgro®, Merck & Co. Inc., Madison, NJ), and tested for persistent infection upon arrival at the Noble Research Institute's Oswalt Ranch cattle handling facilities in Love County, OK. Heifers were randomly assigned to one of six preconditioning pastures (two pastures per treatment), stratified by weight. The average starting weight of the heifers in each treatment group was 235kg. Table 1 shows the mean starting body weight in drylot by year as well as the standard deviation of weights. There were 120 head used in 2015 (BW ± SE = 207 ± 1.79 kg), 92 head used in 2016 (241 ± 3.72 kg), and 95 head used in 2017 (265 ± 3.85).

Diets fed to the heifers during the drylot period are shown in Table 2. Each treatment has a drylot feeding segment and a wheat pasture grazing segment as seen in Table 3. The low energy

(LP) diet is fed in drylot at a rate of 1% of body weight (BW) and the high energy (HP) and transitional (HS) diet groups are fed at 2% BW. During the pasture segment, LP and HP treatment heifers were provided with only pasture to graze. Heifers on the HS diet were provided a supplement during the first 21 days on pasture. Heifers were fed in concrete bunks. The target ADGs for cattle on the 1% diet and 2% diets were 0.68kg and 0.90kg, respectively. The diet fed during the drylot phase contained (DM basis) 37% soybean hulls, 32.5% DDG 26.5 corn, 17.5% corn gluten feed, 10% wheat middlings, 1.5% molasses cane, 0.8% calcium carbonate, 0.35% Rumensin 10, 0.25% salt (sodium chloride), and 0.1% R350 Ruminant VTM Premix. Medium quality bermudagrass hay in round bales was offered ad libitum using hay rings in addition to grass that already existed in the paddocks. Additionally, a 12% calcium, 12% phosphorus mineral (Stillwater Milling Co., Stillwater, OK) was offered ad libitum.

A drought in the fall of 2015 greatly reduced forage availability. As a result, 96 heifers, 32 from each treatment, were randomly removed from the study after the drylot phase and did not participate in the pasture phase. Each pen of the remaining heifers then was placed onto one of six pastures seeded with wheat (Triticum aestivum L.). The forage availability target for cattle placement was 1.13 kg of forage per kg of bodyweight. On pasture, all cattle had free access to a monensin block (Stillwater Milling Co., Stillwater, OK). A loose mineral supplement was provided on pasture which contained 12.5% calcium and 6% phosphorus (Stillwater Milling Co., Stillwater, OK). Monensin was removed from the feed that was supplied to the treatment which received feed on pasture (Table 2) because it was provided in the loose mineral for each treatment. Each pasture had a GrowSafe Beef® individual animal weighing unit (GrowSafe Systems, Alberta, Canada). Radiofrequency identification (RFID) ear tags were used to identify heifers when they stepped on the scales as they approached the system to drink water from its troughs. One water trough in each GrowSafe unit was drained in each pasture and a bloat block was placed in the trough to act as another way to entice the heifers to approach the machines because the water content of wheat pasture is often high enough that cattle may not need to consume any additional water. This step was taken to help prevent incomplete observations due to cattle not approaching the scales to drink water.

Statistical analysis

The data collected during the drylot period were analyzed as a completely randomized design using pen within year as a random effect. The effects of diet fed in drylot as well as supplementation during the pasture phase were estimated with analysis of covariance using Proc Mixed of SAS (SAS Inst., Inc., Cary, NC). Stocker heifers were the experimental units and average daily gain was the dependent variable. For a detailed explanation of model estimation, refer to Appendix A.

Average daily gain is calculated as the difference between the ending weight and the beginning weight divided by the number of days the heifer was on feed. The beginning weight of each heifer was calculated as the average of the weights measured on two consecutive days before feeding began. Taking the average of two consecutive weight measurements allows for a more accurate measure of weight because factors affecting the measurement, such as gut-fill, can change overnight. Likewise, the ending weight was calculated as the average of weights measured on two consecutive days at the end of the feeding period and just before placement on pasture. The number of days heifers spent in drylot differed by year because they were kept in drylot until the forage availability target for wheat pasture was met. For 2015, 2016, and 2017 heifers remained in drylot for 84, 39, and 44 days, respectively. The number of days in drylot is much greater in 2015 due to the drought in the fall of 2015.

Average daily gain on pasture was modeled using a similar though more complex process due to missing data points. Daily weight measurements were taken for each heifer. However, there are many days for which the daily weight data is missing for multiple consecutive days, though not for each animal in each pasture concurrently. Table 4 shows the minimum, maximum, and average percentage of observations missing each day by year and by treatment. The percentage of observations missing on the first day on pasture is displayed as well. While there was at least one day for each treatment in each year that all of the observations were missing, most days had less than ten percent of the observations missing. Overall, the greatest percentage of observations missing occurs in the first three days and the average is only 16%.

The missing weights during the first three days are most likely due to cattle being unfamiliar with the GrowSafe system. Missing weights later in the grazing period are most likely due to a technical problem such as GrowSafe being unable to read a heifer's RFID tag when it stepped on the scale. Therefore, each weight measurement in the data set was identified by the value of the ordinal day on pasture on which it was taken, i.e. the first day on pasture is identified with the number 1. Even if a measurement was missing, it was still assigned a number based on the day on pasture. Average daily gain was calculated as the difference in consecutive available weight measurements, divided by the number of days for which data were missing. Although, calculating average daily gain in this way introduces heteroscedasticity. To account for heteroscedasticity, the variance of each measurement was weighted by the number of consecutive days the calculated average daily gain represented. However, missing values during the first day on pasture were not used in the model estimation because accurate estimation of first day changes in weight was considered to be important. As a result, 163 first-day observations on pasture were not available[1]. The last day on drylot was not used as a proxy for the first day on pasture because doing so would obscure the true change in weight from the last drylot measurement to the first measurement on wheat pasture.

[1] The cumulative weight gained on pasture in the first 10 days by heifers with missing first-day observations was not different from heifers with a recorded weight on the first day ($P = 0.38$).

Economic Analysis

A partial budget was prepared using the parameter estimates to determine the effect of each treatment diet on the profitability of a stocker enterprise. The partial budget is used to compare the HP and HS diets to the LP diet.

The cost analysis assumes a cost of $0.318 per kg for the feed. The price of good quality Bermudagrass hay in Oklahoma in early winter is assumed to be $0.116 per kg based on the Oklahoma Hay Market Report (2020) for the week ending January 10, 2020. The cost of pasture is assumed to be $0.099 per kilogram (Tumusiime et al., 2010). The value of additional gain was determined using the Oklahoma combined average April prices from 2010 to 2019 of medium to large frame feeder heifers with a yield grade of 1 (Livestock Marketing Information Center, Lakewood, CO). No yardage fee is considered in the costs because the fees would be the same for each treatment and would not have an impact in a partial budget analysis. The most current prices were used, when possible, because they are more useful in producing the expected revenues from the results of the statistical analysis.

The difference in revenue in the partial budget is estimated by comparing the ending value of a representative animal in the HP and HS diets with the ending value of a representative animal in the LP diet. A representative animal, for all treatments, has a starting weight of 235 kg and an ending weight determined by the parameter estimates of the growth models. The ending value of each representative animal is calculated by multiplying its ending weight, converted to hundred-weight units, multiplied by the price the animal would receive for its weight. The price received is calculated using the Livestock Marketing Information Center prices and adjusting for the animal's weight using a price slide as described in appendix B. The value of additional gain is also determined and is calculated as the difference in ending value divided by the difference in ending weights.

The difference in costs of the HP and HS treatments relative to a representative animal on the LP diet occurs due to the differences in the amount of feed, hay, and wheat pasture consumed. The amount of hay and wheat pasture consumed by each representative animal is calculated using the parameter estimates of the models in conjunction with net energy equations provided by the Nutrient Requirements of Beef Cattle (Nutrient Requirements of Beef Cattle: Seventh Revised Edition: Update 2000, 2000). A more detailed explanation of these calculations is included in Appendix B.

CHAPTER III

RESULTS

Statistical

The ADG least-squares means by treatment diet strategy during the drylot feeding period are shown in Table 5. The effect of diet fed in drylot was significantly different ($P < 0.0001$) with cattle being fed at 2% of BW having the highest ADG. Average daily gain was less than expected for both feeding levels in drylot. Heifers fed at 1% of BW in drylot had an average daily gain of 0.66 kg while heifers fed at 2% of BW in drylot had an average daily gain of 0.86 kg. Cattle fed at 2% of their BW gained an average of 7.75 kg more than those fed at 1% of their BW.

The main effect of treatment on heifers grazing wheat pasture was statistically insignificant ($P = 0.49$). Treatment had no long-term impact on the BW heifers gained during the entire grazing period. However, the interaction effect of treatment and number of days on pasture was significant ($P < 0.0001$). Although BW gain on pasture did not differ by treatment, the pattern of weight gain was different. The number of days on pasture and year were also significant ($P < 0.0001$), indicating that ADG was affected by differences in each year the experiments were conducted, such as weather. The least-square means effect of year in the pasture model (Table 7) shows that 2015 had lower ADG most likely due to the drought and decreased forage availability.

Figure 1 shows the daily weight pattern for the first 21 days. The first 14 to 21 days are of interest because previous works have only measured bodyweights every 2 weeks and shown that the adaptation period is within the first 14 to 21 days and positive weight gains are not seen until the second weighing period (Phillips et al., 2006). After 14 days on pasture heifers on the HS diet had gained 3.71 kg more ($P < 0.001$) than heifers that received the HP diet and 4.00 kg more ($P < 0.001$) than heifers that received the LP diet. For day 14 on pasture, the amount of weight gained was not significantly different ($P = 0.77$) between the HP and LP heifer groups. Notably, body weight decreased greatly during the first day on pasture rather than decrease slowly over time before beginning to rebound.

Table 6 displays the cumulative weight gain of the heifers while on pasture. Heifers that were targeted for 0.90 kg ADG in drylot (the HP and HS diet groups) lost less body weight than did those on the LP diet ($P < 0.001$). Heifers on the HP diet lost 9.11 kg ($P <.001$) of body weight on the first day on wheat pasture and heifers receiving the HS diet lost 9.90 kg ($P < 0.001$). Heifers on the LP diet in drylot lost 12.87 kg of body weight on the first day on wheat pasture.

Figure 2 shows the daily pattern of weight gain by treatment for the entire 119-day grazing period. Although the HS diet strategy group performed better than the other two groups in the transition period, by the end of the grazing period there was no significant difference in the amount of weight gained on wheat pasture ($P > 0.10$). The results show that heifers in the HP diet group had the highest ADG, the LP group had the next highest, and cattle in the HS diet strategy group had the lowest ADG, though these differences are not statistically significant. Including the weight gained previously in drylot, the representative heifer, one who's starting weight is the average starting weight of 235 kg, in the HP and HS diet strategies remained 12.28 kg and 4.88 kg, respectively, greater in weight than heifers in the LP diet strategy group at the end of the grazing period.

Economic

The ending weight, value, and cost per animal in each treatment are shown in Table 8. The ending value ($/head) assumes that the cattle are sold in April because April was the average month of removal from wheat pasture. The price received for the cattle, calculated according to the steps provided in Appendix B, assumes that the base price received is $131.57/cwt at a base weight of 825 lb and a price slide of -$7.75/cwt (or $2.89/kg at a base weight of 374 kg and price slide of $0.17/kg). The ending weights are 389.84 kg for the LP diet, 402.11 kg for the HP diet, and 394.72 kg for the HS diet. The corresponding ending values per animal are $1107, $1124, and $1114 respectively.

Table 8 also reports the cost of feed, hay, and wheat pasture consumed per animal in each treatment. Notably, all of the energy requirements for the HP and HS diet cattle in drylot could be met with the feed provided. As a result, there was virtually no consumption of hay by the representative animal in those two groups and, therefore, no cost of hay consumed. The HS diet heifer had the highest cost of feed and the lowest cost of wheat pasture consumed. The HP heifer consumed the most pasture and therefore has the highest cost of pasture consumed. In terms of total cost, the LP diet had the lowest cost and the HS diet had the highest cost.

Table 9 shows a partial budget of the HP and HS diet strategies compared to the LP diet strategy. The value of additional gain is $1.33/kg for the HP diet and $1.36/kg for the HS diet. The cost of additional gain is $3.03/kg for the HP diet and $12.07/kg for the HS diet. The overall net returns per animal in the HP and HS diets are $20.96 and $52.34 less than the LP diet.[2]

[2] Reducing the cost of the supplement by half does not change the ranking of the net revenue of the diets.

CHAPTER IV

DISCUSSION

Beck et al. (2005a) fed cattle in drylot using ADG targets of 0.57 kg and 0.91 kg, which is similar to cattle fed at 1% BW and 2% BW. Their cattle gained less than expected. They also found that cattle fed for the higher rate of gain had a lower cost of gain in drylot. In the present study, however, the group fed for a higher ADG had a higher total cost as seen in the partial budget in Table 8. This is likely because heifers in this study fed at 2% BW had a less desirable gain:feed ratio than those fed at 1% BW. In Beck et al., cattle fed more feed had a more desirable gain:feed ratio (2005a).

One reason for the difference in net returns to weight gain in drylot is due to the quantity of feed given compared to the additional weight that was gained. Heifers fed at 2% BW (HP and HS)received twice as much feed as those in the LP group, while ADG increased by about one-third. Costs could have been reduced slightly in both groups if check weights had been taken during the drylot period in each year to adjust the feed if necessary.

Phillips et al. (2006) found that by day 14 on wheat pasture cattle had lost weight as indicated by a negative ADG over the 14 days. In this experiment, ADG was also negative during the first 14 days for the LP and HP diet groups. Only the HS diet strategy group showed a positive ADG across the first 14 days. Previously, however, Tolley et al (1988) found that less.

frequent measurements can obscure the true pattern of growth for cattle that were switching from low or high energy concentrate diets to fescue-clover pasture with low or high energy supplementation. Due to the use of GrowSafe systems, the results of this study show that cattle do not lose weight slowly over time but rather the loss is quite dramatic beginning on the very first day of pasture transition. Positive daily gains are observed for all groups by day three showing that while the weight loss is quick and dramatic, the recovery also begins quickly.

Beck et al. (2005a) found that cattle fed at a higher level of BW in drylot had a lower ADG on wheat pasture; however, cattle fed for a lower ADG in drylot never made up the difference on pasture. Our results similarly showed that although ADG on wheat pasture was not significantly different, the gap in total weight gain across both feeding segments was never eliminated.

Although the results from the pasture grazing model indicate that the heifers given the additional supplement on wheat pasture performed better while being fed, it was most likely due to them exhibiting a preference for the feed and therefore consuming very little wheat forage. Noble Research Institute personnel conducting the experiment indicated that all of the feed supplement provided on pasture was consumed each day. Previous research indicates that regardless of what type of high-energy supplementation is provided, as the level of supplementation increases the consumption of wheat forage decreases (Horn et al., 2005). This implies that giving a supplement on wheat pasture did not serve to biologically affect adaptation to wheat forage. Rather, the supplement merely delayed the adaptation.

Previous research by Phillips and Horn (2008) has shown that cattle that are immediately placed on winter wheat pasture and do not face a transition period in the winter perform better during spring grazing than those who are backgrounded on warm-season grasses and supplements. This indicates that the transition to a new diet does significantly affect animal performance when grazing wheat. Further, a lower ADG during the first 14 days is most likely due to decreased dry matter intake (DMI) rather than directly caused by any problem endogenous to the wheat forage itself (Phillips and Horn). However, the decreased DMI can be largely explained by changes that occur in the rumen that occur when cattle are faced with an abrupt change in diet (Lippke and Warrington, 1984; Beck et al., 2005b).

Despite much previous research showing that cattle undergo an adaptation period when transitioning to wheat pasture, some detractors argue that the adaptation period simply does not exist. Experiments conducted by Fieser et al. (2006) show that the adaptation period may not exist at all. They assert that because the residuals of measurements taken during the first two weeks do not significantly differ from zero that the adaptation period is non-existent (Fieser et al.). Put another way, they believe none of their measurements differ significantly from the overall trend. Counter to their point however, the results of our study show that the daily pattern of growth was significant. Inherently this means that the weight loss and daily gains which cattle experienced during the transition are significantly different from the overall trend.

Additionally, the only weight measurement which differed significantly for Fieser et al. (2006) was the measurement at day 0, i.e. the initial measurement before being placed on pasture. They ignore this measurement, attributing its difference to using different scales and different time periods of feed and water withdrawal. The results of our pasture growth model show a similarly large drop in weight at the beginning of the grazing period (Figures 1 and 2). Further, our daily weight gain model shows that weight loss occurs rapidly and that positive daily gains are observed by the third day. Additionally, the growth charts of cattle switching diets by Tolley et al. (1988) also suggest an underlying pattern of growth similar to our model as well as the observations of Fieser et al. The implication then is that while the concerns of Fieser et al. for the measurement of weight at day 0 are legitimate, they likely do not have a significant enough impact to warrant throwing out that observation altogether. If our pasture model ignored the measurement at day 0, we would find very similar results. Therefore, the reason Fieser et al. conclude that the adaptation period does not exist is that they ignored the one observation in their data that indicates that it does.

CHAPTER V

CONCLUSION

The results of the drylot model and pasture model, as they pertain to the weight gain of cattle in these two feeding segments, concur with and confirm much of what has already been established by previous research on cattle adapting to wheat pasture in the Great Plains Region. The drylot model shows that cattle fed more feed will gain more weight. However, the pasture model uniquely reveals that all of the weight loss which cattle may experience occurs almost immediately as they transition to pasture. Positive daily gains begin by the third day after transitioning rather than slowly over time. Although previous work has attributed the change in weight to what is often referred to as a two-week adaptation or transition period, the results of this study indicate that the transition period is much shorter.

Although providing a high-energy supplement to cattle transitioning to pasture affected their weight gain during the first two weeks, the gains were not sustained in the long run. Cattle fed at 1% of their body weight in drylot and provided no supplement during the first two weeks would be more profitable than the other two feeding strategies considered. The additional cost of feed in drylot and the additional cost of feed on pasture outweighed any additional revenue that was received by cattle gaining more weight than their contemporaries which were fed the LP diet. The most economically sound practice is to not provide any supplement with the intent of aiding cattle transition to wheat pasture. Hence, providing energy supplementation to aid cattle in adapting to wheat pasture for grazing is not recommended.

CHAPTER VI

SUGGESTIONS FOR FURTHER RESEARCH

In light of the results of this study, there are a few suggestions for further research that can be made. When conducting future experiments, the standard deviation of the weight of the cattle that are being used should be kept as small as possible. Cattle gain weight differently depending largely upon their weight. Using cattle closer to one another in weight can reduce the variance of the treatment data from the outset. Care should also be taken to ensure that scales used in separate locations are calibrated to each other so that weight loss (or gain) can be verified. Cattle should also be conditioned to using the GrowSafe scales, if possible, so that they approach the system with ease from the first day on pasture.

A future topic of interest is the impact of changing locations versus changing diets. Do cattle on wheat pasture who are moved to another wheat pasture lose as much weight as those changing from a drylot diet to a pasture diet? Another interesting topic for future research is the use or development of a direct-fed microbial (DFM) or another type of supplement that would quickly allow the gut of transitioning cattle to adapt to their new diet. Ruminal acidosis is hypothesized to inhibit the ability of gut microbes to function properly, so could a daily dose of a DFM improve digestion performance? Alternatively, could a DFM be developed that has greater digestive efficacy in the acidic gut environment cause by ruminal acidosis?

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Table 1. Descriptive Statistics of Cattle by Year

	Year		
Item	2015	2016	2017
Number of head	120	92	95
Mean body weight, kg	207	241	265
Standard deviation, kg	19.63	35.69	37.52
Standard error, kg	1.79	3.72	3.85

Table 2. Composition of Diets Fed During the Drylot Phase (%, DM Basis)

Item	%, DM Basis
Soybean hulls	37.00
DDG 26.5 corn	32.50
Corn gluten feed dry 20%	17.50
Wheat middlings 16%	10.00
Molasses cane	1.50
Calcium carbonate	0.80
Rumensin 10	0.35
Salt (sodium chloride)	0.25
R350 Ruminant VTM Premix	0.10

Table 3. Treatment Design

	Diet Received	
Treatment (acronym)	Drylot Phase	Pasture Phase
Low energy (LP)	1% of BW	wheat pasture only
High energy (HP)	2% of BW	wheat pasture only
Transitional (HS)	2% of BW	wheat pasture + supplement

Table 4. Percentage of First Day Observations Missing by Year and Treatment

Year	Treatment	First Day	Minimum	Maximum	Average
2015	LP	100%	0%	100%	22%
	HP	100%	0%	100%	21%
	HS	100%	0%	100%	22%
2016	LP	97%	0%	100%	15%
	HP	57%	0%	100%	13%
	HS	79%	0%	100%	20%
2017	LP	78%	0%	100%	17%
	HP	47%	0%	100%	16%
	HS	97%	0%	100%	16%
	Overall	78%	0%	78%	16%

Table 5. Average Daily Gain in Drylot

Experiment Group	Treatment Diet	Target ADG, kg	Actual ADG, kg
LP	1% BW	0.68	0.66 A[a]
HP, HS	2% BW	0.90	0.86 B

[a] Items with different letters are statistically different (P>.0001) using a t-test calculated using the Estimate statement of SAS Proc Mixed.

Table 6. Cumulative Heifer Weight Gain on Pasture, kg

Treatment	Day 1	Day 14	Day 119	ADG for Entire Period
LP	-12.87 A[a]	1.15 D	116.31 F	0.99 G
HP	-9.11 B	1.43 D	117.17 F	0.99 G
HS	-9.90 C	5.14 E	109.78 F	0.93 G
Contrasts				
LP vs HP	<0.0001	0.77	0.82	0.82
LP vs HS	<0.0001	0.0001	0.08	0.08
HP vs HS	0.0025	0.0002	0.051	0.051

[a] Values within a column with different letters are statistically significant (P >.05) using a t-test calculated using the Estimate statement of SAS Proc Mixed.

Table 7. Least Squares Means Effect of Year on ADG in Pasture

Year	Estimate	P-value
2015	0.7804	< 0.0001
2016	0.9298	< 0.0001
2017	0.9680	< 0.0001

Table 8. Ending Weight, Value, and Cost per animal for Animals in Each Treatment

	LP	HP	HS
Revenue			
Ending weight, kg/hd	389.84	402.11	394.72
Price received[a], $/kg	2.84	2.80	2.82
Ending value, $/hd	1107.84	1124.13	1114.46
Costs			
Feed, $/hd	47.79	98.05	134.30
Hay, $/hd	14.33	0	0
Wheat pasture, $/hd	80.07	81.39	66.85
Total cost, $/hd	142.19	179.44	201.15

[a]Assumes a 10-year Oklahoma combined average price of $131.57/cwt in April for medium and large frame heifers ranging from 800-850lbs (midpoint of 825lbs is used for calculation of price received). The price slide is -$7.75/cwt.
For example, the price slide of the LP heifer (389.84kg or 859.45lbs) is: (859.45-825)/100*(-7.75) = -2.67. Therefore, the price received is: 131.57-2.67 = $128.90/cwt ($2.84/kg). In metric units, the price slide is: (389.84-374.21)/45.36*(-7.75)=-2.67/45.36kg. The price received is: 131.57-2.67=$128.90/45.36kg ($2.84/kg).

Table 9. Partial Budget of Net Revenue of HP Diet and HS Diet Versus LP Diet per animal

	Diet Strategy	
	HP	HS
Change in costs, $		
Feed	50.26	86.51
Hay	-14.33	-14.33
Wheat pasture	1.32	-13.22
Total change in cost,$	37.26	58.96
Cost of additional gain, $/kg	3.03	12.07
Change in revenue		
Total additional gain, kg	15.80	8.62
additional gain in drylot, kg	11.42	11.42
additional gain on pasture, kg	0.86	-6.54
Total change in revenue[a], $	16.30	6.62
Value of additional gain, $/kg	1.33	1.36
Net revenue, $	-20.96	-52.34

[a]Assumes a 10-year Oklahoma combined average price of $131.57/cwt in April for medium and large frame heifers ranging from 800-850lbs (midpoint of 825lbs is used for calculation of price received).

Figure 1: Heifer Body Weight Gain During First 21 Days of Grazing

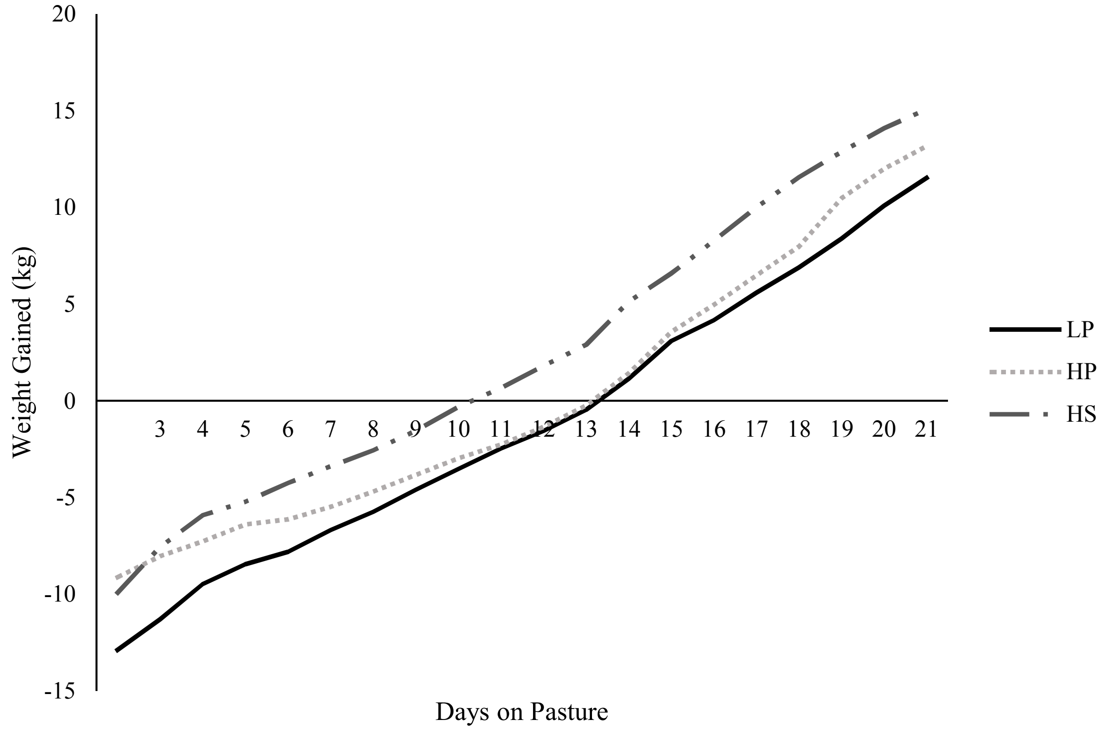
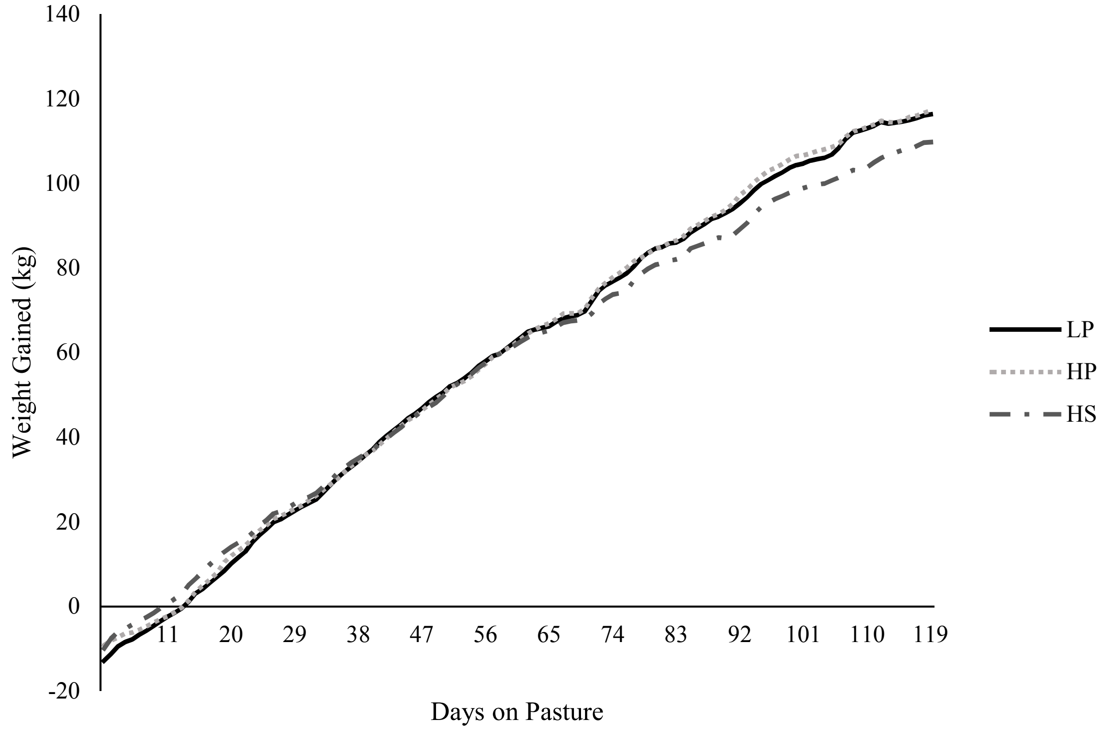


Figure 2: Heifer Body Weight Gain Over 119-Day Grazing Period



APPENDICES

APPENDIX A

This appendix outlines in detail the models used to determine the effect of the diet treatments on average daily gain in drylot and on pasture. The drylot model will be outlined first and the pasture model will be second.

The following equation is estimated to model growth in drylot using ADG as the dependent variable:

$$ADG_{ijt} = \beta_0 + \beta_1 starting\ weight_{ij} + \lambda_i + \gamma_{tp_{ij}} + e_{ijt}, \tag{A.1}$$

where ADG_{ijt} is the average daily gain of the j^{th} animal of treatment i in year t, β_0 is the intercept, β_1 is the coefficient of the starting weight of the j^{th} animal of treatment i at day 0 in drylot, λ_i is the fixed effect of treatment i, and e_{ijt} is the error term. Starting weight is chosen as a covariate because larger cattle will eat more and, therefore, gain more weight than smaller cattle. Treatment effect is also considered because determining the treatment effect is one objective of this study. Pen within year was considered as a random effect ($\gamma_{tp_{ij}}$).

The model estimated for growth on pasture using ADG as the dependent variable is

$$ADG_{ijkt} = \beta + \beta_3 starting\ weight_{ij} + \gamma_i + \delta_k + (\lambda\delta)_{ik} + \rho_t + \nu_j + e_{ijkt}, \tag{A.2}$$

where ADG_{ijkt} is the average daily gain of the j^{th} animal of treatment i in year t on day k, β is an overall intercept, β_3 is the coefficient of the starting weight of the j^{th} animal of treatment i at day 0 in drylot, γ_i is the effect of treatment i and δ_k is the effect of day k on pasture so that $(\gamma\delta)_{ik}$ is the treatment by time period interaction, ρ_t is the effect of year t, and ν_j is the random effect of the j^{th} animal of treatment i. Starting weight in drylot is used as a covariate instead of starting weight on pasture because the starting weight on pasture is an effect of the treatment in drylot. The treatment effect would, therefore, be endogenous to the starting pasture weight. Treatment, year, and day on pasture are estimated as fixed effects. A day on pasture and treatment interaction is also included. Individual heifer identification is considered as a random effect. The error variance will be weighted $\frac{1}{D}$ so that $e_{ijkt} \sim N\left(0, \ \frac{\sigma^2}{D}\right)$, where D is the number of consecutive days that an average daily gain observation represents. Year fixed effects are used as a nonparametric estimate of the year random effect. Fixed effects are still best linear unbiased even when the true effect is random. Due to 2015 being an outlier, the normality assumption that is usually made when estimating random effects would be inappropriate here.

APPENDIX B

This appendix provides more detail on how costs and revenue are calculated for the partial budget. This appendix is divided into five sections. The first section shows how the quantity of feed given and hay consumed in drylot is calculated. The second shows the steps used to calculate the quantities of feed and forage consumed in drylot. The third explains the net energy calculations used to determine the net energy available in the hay and wheat forage. The fourth section shows how drylot and pasture costs are calculated using the quantities of feed, hay, and forage consumed. The final section shows how revenue is calculated for the representative heifer of each group treatment.

Drylot feed and hay consumption

Costs are incurred during the drylot period due to the consumption of feed and hay. The amount of feed and hay consumed was determined based on the feeding program used in the experiment. The quantity of feed given each day is calculated by adding the target weight gain, which is either 0.68 kg or 0.90 kg, to the assumed weight of the previous day and multiplying by 1% or 2% depending on the treatment. The sum of the feed given each day for 58 days is the total quantity of feed given for each treatment:

$$Total\ Feed_i = \sum_{n=1}^{58} [(AW_{i-1} + TWG_i) * BWP_i], \qquad \text{(B.1)}$$

where $Total\ Feed_i$ is the total amount of feed given in treatment i for a representative heifer, AW_{n-1} is the assumed weight of a heifer the previous day, TWG_i is the target daily weight gain for treatment i, and BWP_i is the scalar which represents the amount of feed provided for a heifer in treatment i based on its body weight, either 0.01 or 0.02. When $n = 1$ then AW_0 represents the average weight of heifers at the start of drylot. The average starting weight for both diet treatments is 235 kg. The heifers spent an average of 58 days in drylot each year.

Next, hay consumption in drylot is estimated. Hay is consumed assuming that all of a heifer's net energy requirements for maintenance of body weight and weight gain are met first by the consumption of feed. Hay fulfills any energy requirements not met by the feed. Therefore, the amount of hay consumed each day can be found by subtracting the net energy provided by feed for gain from the total net energy required for gain and then dividing by the amount of net energy for gain provided per kg of hay. The total quantity of hay consumed is the sum of the quantity of hay consumed each day during the 58-day drylot period:

$$Total\ Hay_i = \sum_{n=1}^{58} \left[\frac{TNEg_{in} - FNEg_{in}}{NEg_{hay}} \right], \tag{B.2}$$

where $Total\ Hay_i$ is the total quantity of hay consumed by the representative heifer in treatment i in drylot, n is the day in drylot from 1 to 58, $TNEg_{in}$ is the total net energy required for weight gain on day n for treatment i measured in Mcal, $FNEg_{in}$ is the net energy for weight gain that is provided by the feed consumed on day n for treatment i measured in Mcal, and NEg_{hay} is the net energy available for gain in hay measured in Mcal per kg. The net energy available for gain in the feed is 1.39 Mcal/kg. Hay consumption is assumed to be different by treatment due to the different energy requirements needed for each treatment.

The total net energy for gain required each day is calculated based on net energy calculations from Nutrient Requirements of Beef Cattle (2000). The total net energy for gain required each day is a function of the weight of the heifer and the amount of weight gained each day, which is the least-square means effect of treatment on average daily gain:

$$TNEg_{in} = \left[\frac{WG_{in}}{13.91 * W_{in}{}^{-0.6837}} \right]^{1/0.9116}, \tag{B.3}$$

where W_{in} is the actual weight of the heifer on day n for treatment i. It is a function of the actual weight of the heifer each day and the least-square means effect of treatment on average daily gain according to the results of the model of ADG in drylot (A.1).

The amount of net energy provided by the feed for weight gain is also estimated for use in equation B.4. The net energy for gain available from the feed is the amount of feed remaining after maintenance requirements are met multiplied by the net energy for gain available per kg of feed. The amount of feed remaining after maintenance requirements are met is the total net energy required for maintenance minus the amount of net energy for maintenance available in all of the feed given then divided by the net energy available per kg of feed. The amount of net energy available for maintenance in the feed is itself calculated as the amount of feed provided multiplied by the net energy for maintenance available per kg of feed. The amount of feed given each day is calculated using the same steps in equation B.1 but for a single day only. All of these steps combine in a single function to calculate the net energy available for gain from the feed:

$$FNEg_{in} = \left[\frac{TNEm_{in} - \left[[(AW_{n-1} + TWG_i) * BWP_i] * NEm_{feed}\right]}{NEm_{feed}}\right] * NEg_{feed}, \tag{B.4}$$

where $TNEm_{in}$ is the total net energy needed for maintenance of the heifer's weight on day n for treatment i, NEm_{feed} is the net energy available in the feed for maintenance measured in Mcal per kg, NEg_{feed} is the net energy available in the feed for gain measured in Mcal per kg. The net energy for maintenance available in the feed is 2.02 Mcal/kg.

The total net energy required for maintenance, which is one component of equation B.4, is a function of the weight of the heifer and is calculated using formulas from Nutrient Requirements of Beef Cattle (2000):

$$TNEm_{in} = 0.077 * (0.891 * W_{in})^{0.75}. \tag{B.5}$$

Pasture feed and forage consumption

During the pasture phase, feed is only consumed by cattle on the HS diet. Feed was provided for 21 days at a rate of 2% of body weight of the ending weight in drylot. The amount of feed given on pasture for the HS diet each day for the first 21 days is the ending weight of the HS diet in drylot, 285 kg, multiplied by 0.02 which is 5.70 kg. Therefore, the total quantity of feed supplement given for the representative heifer on the HS diet is 114 kg.

The total amount of pasture consumed each day is the sum of the quantity of pasture consumed for net energy requirements for maintenance and net energy requirements for weight gain. Pasture is consumed to meet net energy requirements for maintenance and gain that are not met by the feed, if feed is provided. The pasture consumed each day then is:

$$PC_{ik} = \frac{TNEm_{ik} - FNEm_{ik}}{NEm_{wheat}} + \frac{TNEg_{ik} - FNEg_{ik}}{NEg_{wheat}}, \tag{B.6}$$

where PC_{ik} is the pasture consumed on day k for treatment i measured in kg, $TNEm_{ik}$ is the total net energy needed for maintenance on day k for treatment i measured in Mcal, $FNEm_{ik}$ is the net energy for maintenance provided by the feed supplement on day k for treatment i measured in Mcal, $TNEg_{ik}$ is the total net energy needed for gain on day k for treatment i measured in Mcal, $FNEg_{ik}$ is the net energy provided by feed on day k for treatment i measured in Mcal, NEm_{wheat} the net energy available for maintenance in the wheat forage measured in Mcal per kg, and NEg_{wheat} is the net energy available for gain in the wheat forage measured in Mcal per kg.

The amount of feed provided on pasture for the HS diet each day was more than enough to cover the total net energy maintenance requirements. After day 21, the net energy from feed for maintenance and gain becomes 0 because the feed is no longer being provided. Therefore, the following two restrictions are imposed on equation B.9:

$$FNEm_{ik} = \begin{matrix} TNEm_{ik} & \forall\, k \leq 21 \\ 0 & \forall\, k > 21 \end{matrix}, \tag{B.7}$$

$$FNEg_{ik} = 0 \qquad \forall\, k > 21, \tag{B.8}$$

Next, the components of equation B.6 are calculated. The total net energy required for maintenance on pasture is calculated using a similar process to drylot. A distinction, however, is that the calculation on pasture is adjusted due to possible weight loss. Because dry matter intake accounts for most of the decrease in weight, it is assumed if cattle lose weight it is because they did not consume enough forage to cover their maintenance energy requirements. Therefore, the total net energy required for maintenance each day is the net energy required to maintain weight minus the amount of maintenance energy not consumed due to weight loss. Total net energy for maintenance is a function of weight and weight loss as described in the equation:

$$TNEm_{ij} = 0.077 * (0.891 * W_{ik})^{0.75} - 0.077 * (0.891 * WL_{ik})^{0.75}, \tag{B.9}$$

where W_{ik} is the weight of the heifer on day k for treatment i measured in kg and WL_{ik} is the amount of weight lost on day k for treatment i measured in kg. Weight loss is 0 for any day on pasture for which positive gains were estimated according to the least-square means effect of the treatment-day interaction of the wheat pasture growth model (A.2).

The total net energy needed for gain is also estimated to be included in equation B.6. Total net energy is calculated using the same formula as in drylot. The weight gain for each day is the least-square mean of the treatment-day interaction of the wheat pasture growth model (A.2). Total net energy for gain each day is:

$$TNEg_{ik} = \left[\frac{WG_{ik}}{13.91 * W_{ik}{}^{-0.6837}}\right]^{1/0.9116}. \tag{B.10}$$

The final remaining component needed to calculate pasture consumption is the net energy for gain provided by feed. It is the amount of feed not used for maintenance multiplied by the net energy for gain available per kg of feed. All of these components make up the equation:

$$FNEg_{ik} = \left[\frac{\left[TNEm_{ik} - \left[Feed_i * NEm_{feed}\right]\right]}{NEm_{feed}}\right] * NEg_{feed}, \tag{B.11}$$

where $Feed_i$ is the amount of feed provided each day for treatment i, measured in kg. The amount of feed provided is 5.70 kg for the HS diet and 0 kg for the other two diets.

Net energy calculations

The net energy for maintenance and gain available in the feed was given by an analysis of the feed. The available net energy for maintenance in the feed is 2.02 Mcal/kg and net energy available for gain is 1.39 Mcal/kg. However, the net energy for maintenance and gain available in the hay and wheat forage was determined by converting the total digestible nutrients (TDN) of the hay and wheat into estimated values of net energy for gain and maintenance measured in Mcal per kg (Nutrient Requirements of Beef Cattle, 1984). The TDN of a good quality Bermudagrass hay was assumed to be 60 (Philipp and Jennings, 2015). The TDN of wheat pasture was assumed to be 73 (Nutrient Requirements of Beef Cattle, 1984). TDN was converted to net energy for maintenance and gain using equations from Garrett and the NRC (Garrett, 1979; Nutrient Requirements of Beef Cattle, 1984).

Net energy for maintenance is a function of metabolizable energy. It is estimated using the equation:

$$NEm = 1.37 * ME - 0.138 * ME^2 + 0.0105 * ME^3 - 1.12, \tag{B.12}$$

where NEm is net energy for maintenance measured in Mcal per kg, and ME is metabolizable energy measured in Mcal per kg.

Net energy for gain is also a function of metabolizable energy and is calculated:

$$NEg = 1.42 * ME - 0.174 * ME^2 + 0.0122 * ME^3 - 1.65, \tag{B.13}$$

where NEg is the net energy available for growth measured in Mcal per kg.

Metabolizable energy is a function of digestible energy, calculated as:

$$ME = 0.82 * DE, \tag{B.14}$$

where DE is digestible energy measured in Mcal per kg.

Digestible energy is a function of total digestible nutrients (TDN), calculated as:

$$DE = TDN * 0.04409, \tag{B.15}$$

where DE is digestible energy measured in Mcal per kg, and TDN is total digestible nutrients measured as a percentage.

The estimated net energy content of hay is 2.02 Mcal/kg for maintenance and 1.39 Mcal/kg for gain. The estimated net energy of wheat pasture forage is 1.73 Mcal/kg and 1.30 Mcal/kg.

Costs

The total cost of a representative heifer in drylot is the sum of the cost of the feed given and the cost of the hay consumed. Total cost in drylot for each treatment is:

$$Total\ Drylot\ Cost_i = P_{feed} * Total\ Feed_i + P_{hay} * Total\ Hay_i \tag{B.16}$$

where $Total\ Drylot\ Cost_i$ is the total cost in drylot per animal in treatment i, P_{feed} is the price of the feed used, and P_{hay} is the price of hay. The price of the feed is \$0.318/kg and the price of the hay is \$0.116/kg.

The total cost on pasture is the sum of the cost of the feed given (HS diet only) and wheat forage consumed, calculated as: $Total\ Pasture\ Cost_i = P_{feed} * Supp_i + P_{wheat} * \sum_{k=1}^{119}[PC_{ik}]$, (B.17) where $Total\ Pasture\ Cost_i$ is the total cost of pasture consumed of treatment i, P_{feed} is the price of the feed used measured in dollars per kg, $Supp_i$ is the total amount of supplemental feed provided measured in kg, P_{wheat} is the cost of the wheat pasture measured in dollars per kg. The average number of days on pasture is 119. $Supp_i$ is 114.0 kg for the HS diet group and 0 kg for the other because the HS diet strategy group is the only one that received the supplement on pasture.

Revenue

To determine the difference in revenue for the partial budget, the total revenue per animal in each treatment is determined. The total revenue per animal in each treatment is the ending weight times the price:

$$Total\ Revenue_i = \left[235 + \sum_{n=1}^{58} WG_{in} + \sum_{k=1}^{119} WG_{ik}\right] * \frac{Cattle\ Price_i}{45.35924}, \quad \text{(B.18)}$$

where $Total\ Revenue_i$ is the total revenue received at the end of a grazing period for the sale of an individual animal in treatment i, 235 is the starting weight of the representative animal in each treatment, n is the day in drylot from 1 to 58, and WG_{in} is the least-square means of weight gain on day n for treatment i. WG_{ik} is the least-square means of average daily gain on day k for treatment i measured in kg, k is the day on pasture from 1 to 119, $Cattle\ Price_i$ is the hundredweight price per animal in treatment i, and 45.35924 is the scalar used to convert dollars per hundredweight to dollars per kilogram. The value of additional gain is calculated as the difference in value between treatments and divided by the difference in weight gained. Cattle prices were collected from the Livestock Marketing Information Center (LMIC) for medium and large frame feeder heifers with yield grade 1 in April from 2010-2019. The average price for heifers in the 800-850lb weight category is \$131.57/cwt and the average price for heifers in the 850-900 lb weight category is \$127.70/cwt. The base weight of each category is assumed to be its midpoint, i.e. 825 for the 800-850lb category and 875 for the 850-900lb category. The price slide represents how the price changes between these two midpoints as heifer weight increases. The price slide is calculated as the difference in price divided by the difference in weight, measured in hundredweight, and so the price slide is -$7.75/cwt.

The price received per animal in each treatment was calculated using a price slide:

$$Cattle\ Price_i = CWT_m + [(H_i - WT_m) * S_m], \tag{B.19}$$

where $Cattle\ Price_i$ is the price received per individual animal in each treatment i, CWT_m is the price of the m^{th} weight class to which the heifer belongs, H_i is the weight of the representative heifer of treatment i, WT_m is the lower bound weight associated with the m^{th} weight class, and S_m is the price slide for the m^{th} weight class. For example, the price slide of the LP heifer (389.84 kg or 859.45 lbs) is: (859.45-825)/100*(-7.75) = -2.67/cwt. Therefore, the price received is: 131.57-2.67 = $128.90/cwt ($2.84/kg). In metric units, the price slide is: (389.84-374.21)/45.36*(-7.75)=-2.67/45.36 kg. The price received is: 131.57-2.67=$128.90/45.36 kg ($2.84/kg).

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