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Hannah F. Speer

Robert A. Cushman

Harvey Freetly

Jay Parsons

Jessica Windh

See next page for additional authors

Authors

Hannah F. Speer, Robert A. Cushman, Harvey Freetly, Jay Parsons, Jessica Windh, and M. E. Drewnoski

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Forage Based Livestock Systems

Effect of beef heifer development systems utilizing corn residue and late summer planted cover crops on growth, reproductive performance, and economics

Hannah F. Speer,[†] Robert A. Cushman,[‡] Harvey C. Freetly,[‡] Jay Parsons,[‖] Jessica Windh,[‖] Mary E. Drewnoski[†,1]

[†]Department of Animal Science, University of Nebraska-Lincoln, Lincoln, NE 68583, USA
[‡]USDA, ARS, U.S. Meat Animal Research Center, Clay Center, NE 68933, USA
[‖]Department of Agricultural Economics, University of Nebraska-Lincoln, Lincoln, NE 68583, USA
[1]Corresponding author: mdrewnoski2@unl.edu

Abstract

The objective of this study was to evaluate growth and reproductive performance of heifers developed using 3 different winter systems in the midwestern U.S. Spring-born heifers (n = 1,156; 214 d of age; SD ± 17 d) were used in a 3-yr study to evaluate performance in winter development systems, which utilized cover crop (CC) and corn residue grazing. Heifers were assigned to 1 of 3 treatments: grazing corn residue with 0.77 kg/d dried distillers grains (CD) or 1.69 kg/d wheat midds (CW) supplementation followed by a grower ration in the drylot, or grazing late summer planted oat-brassica CC followed by corn residue grazing with 0.35 kg/d dried distillers grains supplementation (CC). Supplementation during the corn residue phase was targeted to result in a common body weight (BW) (276 kg; ~45% of mature BW) by the end of the winter development period. Grazing of corn residue (CD and CW) and CC began in early November. After 63 d, heifers assigned to CC were moved to corn residue; on day 77 heifers assigned to CD and CW began receiving a grower ration in the drylot. In mid-February (day 98), heifers were comingled and managed in a single group. Breeding season began in June and lasted for 29 d. The ADG of heifers assigned to CC when grazing CC (days 1 to 63) was greater (0.76 kg/d; $P < 0.01$) than those assigned to CD or CW (0.58 kg/d and 0.49 kg/d, respectively). Gain during the last 35 d of the winter period for heifers assigned to CC (0.36 kg/d) was less ($P < 0.01$) than those assigned to CW (0.49 kg/d) but not different from CD heifers (0.41 kg/d). Overall (days 1 to 98), winter ADG was greater ($P < 0.05$) for heifers assigned to CC (0.62 kg/d) than CD (0.53 kg/d) or CW (0.50 kg/d), which did not differ ($P = 0.42$). Percent of mature BW in May (27 d pre-breeding) was greater ($P < 0.01$) for heifers assigned to CC (52%) than for those on CD and CW (50%), which did not differ ($P = 0.64$). Pregnancy rates were affected by treatment ($P < 0.03$), with heifers assigned to CC (76%) being greater than CW (64%) and CD heifers being intermediate (70%). When accounting for the differences in cost and the value of open and bred heifers, the economic return tended to differ ($P = 0.07$) among treatments, with CC and CW not differing ($P \geq 0.20$) from CD but return for CC being $73 greater than CW ($P = 0.02$). Utilizing oat-brassica CCs early in the winter followed by a slower rate of gain while grazing corn residue with distillers supplementation appears to be as effective for developing beef heifers in the midwestern U.S. as supplementing distillers grains.

Lay Summary

This study examined 3 winter development systems for beef heifers in the midwestern U.S., focusing on their growth and reproductive performance. Over 3 yr, spring-born heifers were assigned to one of 3 treatments: grazing corn residue with either distillers grains (CD) or wheat midds (CW) supplementation, or grazing oat-brassica cover crop (CC) followed by corn residue grazing with distillers grains supplementation (CC). The goal was to achieve a similar target body weight in all 3 treatments by the end of the winter period. Results showed that heifers grazing the oat-brassica CC initially gained weight faster than those on corn residue with supplements. Thus, during the latter part of winter, when CC heifers were grazing corn residue, less distillers were supplemented to achieve a slower rate of gain than heifers in the other 2 treatments. However, the CC heifers had greater winter average daily gains overall compared to the corn residue heifers. Pregnancy rates were not significantly different between the CC and CD heifers, though CC heifers were greater than CW heifers, which did not differ from CD heifers. In conclusion, the study suggests that all 3 systems, yield comparable results in developing beef heifers effectively.

Key words: corn residue, cover crop, heifer development, heifer growth, pregnancy, winter grazing

Introduction

Heifers are a key component of beef cow production systems because they will replace old and/or less productive cows in the herd. Developing replacement heifers can be quite expensive, with the greatest proportion of the expenses associated with the opportunity cost of keeping rather than selling the heifer at weaning, followed by feed costs (Hughes, 2013). To ensure heifers attain puberty by their first breeding season, producers typically target a growth rate to achieve a target percentage of their expected mature body weight (BW). Managing heifers to reach a lower percentage of mature BW (<60%) may help reduce development costs without negatively impacting pregnancy rates (Funston and Deutscher, 2004); however, there are other genetic and environmental

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Table 1. Initial and final forage mass and initial nutrient composition of oat, turnip, and radish mix

	2016	2017	2018
Forage mass		kg DM/ha	
Initial	6,003	4,191	2,755
Final	3,432	1,497	1,465
Nutrient composition		% of DM	
OM	85.0	87.3	88.2
CP	16.4	17.9	15.8
DOM[1]	59.1	70.3	71.6

[1]Digestible organic matter. Calculated by multiplying OM percentage and IVOMD.

factors that influence the onset of puberty and ability to conceive. Plane of nutrition is a major factor that not only affects when a heifer attains puberty (Cardoso et al., 2018), but also impacts fertility, in general. At certain times during the developmental period, plane of nutrition can affect oocyte quality in the sense that a nutritional challenge negatively impacts growing oocytes in pre-antral follicles, resulting in reduced fertility when oocytes are later ovulated (Leroy et al., 2015).

Corn residue is a prominent winter forage resource in the Midwest that, along with dried distiller grains plus solubles (DDGS) supplementation, can serve as a low-cost option for wintering growing cattle (Watson et al., 2015). Studies also demonstrate that corn residue grazing and DDGS-based supplementation can be a cost-effective method for developing beef heifers (Larson et al., 2011; Summers et al., 2014). Dried distillers grains with solubles are commonly supplemented in corn residue grazing systems because DDGS serves as both a protein (30.8% CP; NASEM, 2016) and energy source (108% TDN; Loy et al., 2008), and DDGS can be fed to target different rates of gain (Watson et al., 2015). In other parts of the Midwest, wheat midds could serve as a viable supplement option, as wheat midds are a good source of protein and moderate in energy content (18.6% CP and 72.9% TDN; NASEM, 2016). An important difference between wheat midds and DDGS is that wheat midds provide most of their protein as rumen degradable protein (RDP), whereas DDGS contain predominantly rumen undegradable protein (RUP). A greater proportion of the protein provided in a protein supplement such as RUP rather than RDP has been demonstrated to improve pregnancy rates in heifers developed on low-quality forage (Mulliniks et al., 2013). Both DDGS and wheat midds are potential options to supplement cattle grazing corn residue; however, regional availability, as well as cost, will ultimately drive supplementation decisions made by cattle producers.

Grazing of late summer planted oat-brassica cover crops (CCs) can also be an effective way to winter growing cattle in the Midwest (Cox-O'Neill et al., 2017a; Drewnoski et al., 2018), as their protein content and digestibility remain high during the fall and early winter months (Lenz et al., 2019). However, this winter grazing system has not been evaluated for impacts on heifer development. Our null hypothesis was that growth and reproductive performance would not differ between the different forage and protein source systems. The objective of this study was to evaluate growth, reproductive tract development, and pregnancy rates of heifers developed in 3 different winter systems targeted to result in a common BW at 10.5 mo of age. The systems evaluated were a late summer planted oat-brassica CC grazing followed by corn residue grazing with DDGS supplementation or corn residue grazing while receiving energy and protein supplementation as either DDGS or wheat midds followed by being fed a forage-based growing ration in drylot.

Materials and Methods

All experimental procedures involving animals were approved by the U.S. Meat Animal Research Center (USMARC) Animal Care and Use Committee in accordance with the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 2010).

Treatments

A total of 1,156 spring-born MARC II (4 breed composite: ¼ Gelbvieh, ¼ Simmental, ¼ Hereford, ¼ Angus) heifers were used in a 3-yr study (376 in year 1, 386 in year 2, and 394 in year 3) conducted from 2016 to 2018 at the U.S. Meat Animal Research Center in Clay Center, NE. Each year heifers (213 ± 17 d of age; DOA) were stratified by birth date and weaning weight and randomly assigned within classification to 1 of 12 replicates. About 4 replicates were randomly assigned to 1 of 3 grazing treatments: corn residue with DDGS (CD) or wheat midds (CW) supplementation, or late summer planted oat-brassica CC followed by corn residue supplemented with DDGS (CC).

Three pivot irrigated fields (50 ha each) containing corn residue and 1 pivot irrigated field of CC (50 ha) were used each year. The CC was planted in early to mid-August of each year and consisted of a seed mixture of oats (94 kg/ha), daikon radish (2.2 kg/ha), and purple top turnip (1.7 kg/ha). Initial forage yield before turning CC heifers out to graze was 6,003 DM/ha in year 1, 4,191 DM/ha in year 2, 2,755 kg DM/ha in year 3 (Table 1). For both the CC and corn residue, fields were divided into 12.5-ha quarters and 4 replicates (30 to 33 heifers/replicate; 2.40 to 2.64 heifers/ha) were assigned to graze. The corn was relatively high yielding with an average 12,500 kg corn grain/ha. The corn residue quarters that were assigned to the CC heifers were not grazed until after they were removed from CC.

Supplement was provided 3 times weekly while heifers were on corn residue to achieve 45% of mature BW (276 kg) by the end of the winter-feeding period in mid-February (214 ± 17 DOA). All heifers were targeted to reach 55% of mature BW (388 kg) by breeding in June (417 ± 17 DOA). Average daily supplement offered for each treatment is listed in Table 2. All heifers received a free-choice vitamin and mineral supplement while on their respective grazing treatments.

A complete timeline of the study is provided in Fig. 1. Grazing treatments were initiated in mid-November (214 ± 17 DOA) of each year. After 63 d (end of phase 1/start of phase 2), heifers on CC treatment were moved in mid-January (276 ± 17 DOA) to corn residue and supplemented with DDGS for the remaining 35 d of the winter treatment period. Heifers on CD and CW treatments remained on corn residue until day 78 and were subsequently moved to the drylot in early February where they received a grower ration for the last 20 d of the treatment period (Table 3). Relocation of CD and CW heifers to the drylot at this time occurred because significant ice cover on the fields in year 1 resulted in low corn residue availability; CD and CW heifers were managed as such in years 2 and 3 to be consistent across years. Heifers in the drylot consumed 5.1 kg DM/d on average and were targeted to gain 0.50 kg/d. The treatment period ended after 98 d in late-February (end of phase 2) at which point all heifers were comingled (311 ± 17 DOA). The breeding season began in June and lasted 29 d, where heifers were bred at 14 mo (417 to 446 ± 17 DOA) of age by natural service. The bull-to-heifer ratio used during breeding was 1 to 24.

Animal Data Collection

Individual BWs were collected on all heifers at study initiation in mid-November (day 0), end of phase 1 (day 63), end of phase 2 (day 98), the first week of May (pre-breeding), and in August (pregnancy diagnosis). In March (about a month after the end of phase 2), heifers were submitted for a transrectal ultrasonographic examination to determine reproductive tract score (RTS) and determine heifer pubertal status. Reproductive tract scoring is based on a range of 1 to 5, with 1 being an infantile tract, toneless uterine horns, and no palpable follicles, and 5 being a tract with large follicles (>10 mm) and a functioning corpus luteum present (i.e., heifer is cycling) (Andersen et al., 1991). Moving from a RTS of 1 to 5, uterine horn and ovary size increase; scores of 2 or 3 indicate small follicles are present, while heifers assigned a

Table 2. Average daily supplement offered to heifers during mid-November to mid-January (phase 1) and mid-January to late-February (phase 2) of the winter grazing period

	Treatment[1]		
	CC	CD	CW
Supplement DM intake, kg/hd/d			
Phase 1[2]	—	0.73	1.62
Phase 2[3]	0.35	0.92	1.96

[1]Grazing treatments: corn residue with DDGS supplementation (CD); corn residue with wheat midds supplementation (CW); late summer planted CC followed by corn residue with DDGS supplementation (CC).
[2]Heifers 9 mo of age at the end of phase.
[3]Heifers 10.5 mo of age at the end of phase.

Table 3. Dietary composition by year of grower ration fed during drylot period for heifers grazing corn residue with DDGS (CD) or wheat midds (CW) supplementation

Ingredient, % of DM	Year		
	2016	2017	2018
Alfalfa haylage	46.7	17.5	—
Earlage	38.9	40.0	—
Corn silage	—	42.5	—
Alfalfa hay	14.4	—	—
Alfalfa/grass hay	—	—	74.3
Corn, dry-rolled	—	—	25.5
Diet nutrient content, % of DM[1]			
CP	15.4	10.3	13.0
TDN	70.2	73.5	64.5

[1]Calculated using NASEM (2016) values for each ingredient.

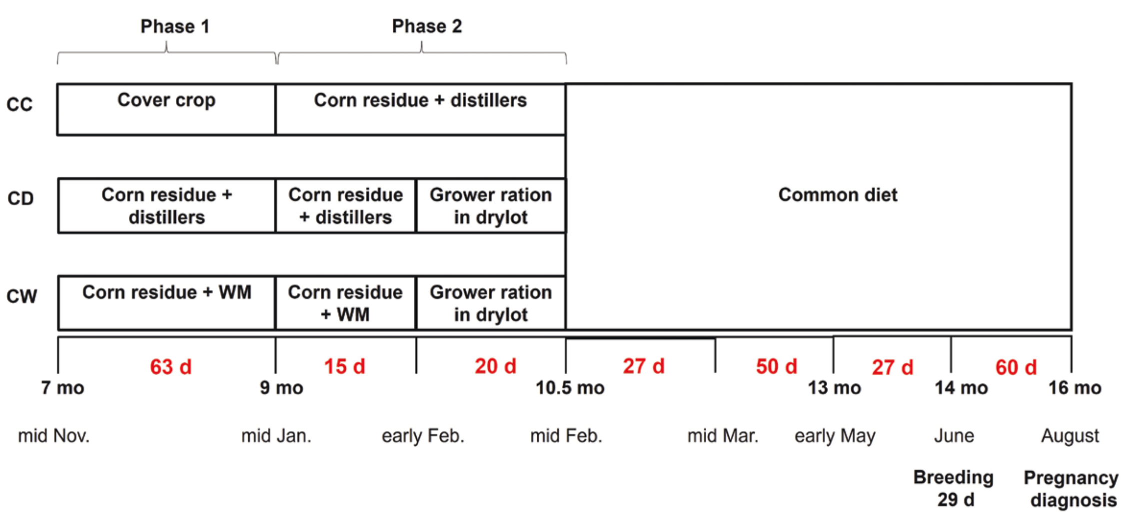

Figure 1. Experimental timeline and illustration of dietary treatments of winter heifer development systems. Heifers were assigned to either graze CC followed by corn residue grazing (CC) or graze corn residue while receiving protein supplementation as either dried distillers grains (CD) or wheat midds (CW). At the end of phase 1, CC heifers were placed on corn residue and received a dried distillers grains supplement for the remainder of the experimental feeding period (phase 2). In phase 2, CD and CW heifers remained on corn residue 14 to 16 d before being placed in the drylot. Following phase 2, all heifers were comingled and managed as a single group and fed a common diet.

RTS of 4 have large follicles but no detectable corpus luteum (Andersen et al., 1991). In early May (pre-breeding) at 13 mo (390; SD ± 17 d) of age, RTS was again ultrasonographically evaluated, and antral follicle count, ovarian length and height, and uterine horn diameter were determined (McNeel and Cushman, 2015). Hip heights and body condition scores (BCS) were also collected at this time. Pregnancy was determined in August via ultrasonography.

Forage Laboratory Analysis

Biomass and quality samples were collected from the CC treatment prior to the start of grazing. For biomass determination, 4 random 0.37-m^2 areas were sampled in each replicate. The turnips and radishes within each area were pulled up so grazeable root biomass could be included, and oats were clipped at ground level. Samples were separated by species, with the brassica leaves being separated from the root, and dried in a 60°C forced-air oven (model LBB2-21-1; Despatch, Minneapolis, MN) until a constant weight was obtained (AOAC, 1965; method 935.29). Forage quality samples were taken on the same date as the biomass samples. Each species (oats, radish, and turnip) was collected at random within each replicate and separated according to species type. Samples were placed in a portable cooler with ice for transport to the laboratory. Once at the lab, brassicas were separated into leaf and root, and stored at −20 °C until time of analysis. Samples were then dried at 60 °C in a forced-air oven until a constant weight was obtained and ground through a 1-mm screen using a Wiley mill (Thomas Scientific, Swedesboro, NJ). Quality samples were composited by replicate within year as a constant percentage of total biomass and were analyzed for DM (100 °C), OM, CP, and in vitro OM digestibility (IVOMD).

Organic matter was determined by placing samples in a muffle furnace for 6 h at 600 °C (AOAC, 1999; method 4.1.10). Samples were analyzed for nitrogen using a combustion chamber (TruSpec N Determinator; LECO Corporation, St. Joseph, MO; AOAC, 1999; method 990.03), and CP was calculated by multiplying nitrogen content × 6.25. In vitro OM disappearance was determined after a 48-h incubation period using the method described by Tilley and Terry (1963), modified by adding urea to the McDougall's buffer (McDougall, 1948) at a rate of 1 g urea/L buffer solution, to ensure adequate nitrogen was available for microbes in the rumen fluid (Weiss, 1994). Blanks were included in both incubation runs to adjust for any feed particles that might have come from the inoculum. Four grass hay standards with known in vivo digestibility were used to adjust IVOMD values for run-to-run variation (Stalker et al., 2013). The percent of digestible organic matter on a DM basis was calculated by multiplying IVOMD, % of OM by OM, % of DM, and is an estimate of energy availability in the forage.

Economic Analysis

The 3 winter development systems were evaluated under an economic lens, using 5-yr average prices for each input to reduce the effect of markets and increase the objectivity of the study. Monthly prices from 2016 to 2020 for DDGS, wheat midds, hay, and corn were obtained from Livestock Market Information Center, the USDA Minneapolis weekly feedstuffs report, and USDA NASS for Nebraska, respectively. All prices were normalized to 2019 prices using the producer price index (USBLS, 2022) to eliminate any effects of inflation. No patterns were observed in the data requiring econometric estimations of prices, so a simple average of price was used for each feed input. The average price per U.S. ton on an as-fed basis used for DDGS, wheat midds, alfalfa hay, and corn was $158.31, $90.22, $98.79, and $121.07, respectively. For corn residue grazing a $37/ha cost was used as reported by Cox-O'Neill et al. (2017b) and a CC grazing cost of $190/ha which included the cost of seed ($72/ha), N fertilizer cost and application ($69/ha), and custom seed drilling expenses ($49/ha).

Feed costs were calculated for each replicate (n = 12/yr) on a per heifer basis. Cost of supplementing DDGS or wheat midds in each phase (Fig. 1) was calculated by using average daily supplement offered per heifer within a herd. Because the drylot diet varied from year to year, feed costs during the drylot phase for CD and CW heifers were calculated using a common diet of 5.7 kg alfalfa and 2.1 kg dry-rolled corn designed to simulate the ADG observed in the drylot for these treatments (NASEM, 2016). Value of the heifers was determined by using a long-term (distribution of August and September prices from 2000 to 2021) expected average price/45.5 kg (cwt). A Monte Carlo simulation (10,000 iterations) method was used to determine the long-term average bred and open heifer prices for each weight class. The Monte Carlo simulation is a mathematical technique that uses the range and underlying distribution of the data to simulate a more robust data set. Our available data encompassed 22 yr, or approximately 2 cattle market cycles, however, the Monte Carlo simulation used that data to simulate 10,000 additional datasets. This method is more informative than using either the current year's prices or a simple average of several years because it averages across multiple simulated cattle cycles using probability distributions of prices. Due to the price slide in the beef industry, the lighter heifers sell for a slightly higher price/cwt (45.5 kg) than heavier heifers. Using an estimate from the University of Florida extension, bred heifers will sell for 1.5 times the cost of a steer in years that the U.S. national cowherd is decreasing or constant, and up to 1.65 times the cost of a steer in years that national cowherd is expanding (Prevatt, 2020).

A weighted average value per heifer was calculated for each herd by multiplying the percentage of bred and open heifers by their respective prices. The sum of these values was then multiplied by the mean herd BW at time of pregnancy diagnosis (August). Feed and grazing costs were subtracted from the weighted average revenue to calculate average economic return per heifer. All other costs were assumed to be the same across treatments. The return for the CD treatment was subtracted from the return in the CC and CW treatments to calculate difference in return. The CD treatment was set equal to 'zero' and considered the baseline for comparison as it is the most common, and the numbers reported are the difference in economic return.

Statistical Analysis

Three replicates in the second year (2 from CD, 1 from CW) were removed from the study 1 wk after grazing corn residue due to acidosis issues; these replicates were all located on the same pivot field. One replicate of CC that was assigned to graze this pivot in the second year was also removed from the study following the end of phase 1. For all statistical analyses, herd nested within treatment and year was considered the experimental unit. All data except for pregnancy data were

Table 4. Effect of winter heifer development system on bodyweight and average daily gain of heifers

Item	Treatment[1]			SEM[2]	*P* value
	CC	CD	CW		
Mid-November (initial) BW, kg	219	218	217	1.06	0.34
Mid-January (mid) BW, kg[3]	267[a]	255[b]	248[b]	2.47	<0.01
Late-February (final) BW, kg[4]	281[a]	270[b]	265[b]	2.92	<0.01
May (pre-breeding) BW, kg[5]	318[a]	308[b]	307[b]	2.67	<0.01
August (pregnancy diagnosis) BW, kg	374[a]	366[b]	362[b]	2.27	<0.01
May BW, % of mature BW[6]	52[a]	50[b]	50[b]	0.44	<0.01
ADG, kg/d					
Mid-November to mid-January (phase 1)	0.76[a]	0.58[b]	0.49[b]	0.04	<0.01
Mid-January to late-February (phase 2)	0.36[b]	0.41[ab]	0.49[a]	0.03	<0.01
Early February to late-February (Drylot)[7]	—	0.66	0.68	0.07	0.77
Mid-November to late-February (Overall)	0.63[a]	0.53[b]	0.50[b]	0.03	<0.01
Late-February to May (Pre-breeding)	0.46	0.52	0.53	0.03	0.10

[1]Grazing CC followed by grazing corn residue with DDGS supplementation (CC); grazing corn residue with DDGS (CD) or wheat midds (CW) supplementation followed by grower ration in the drylot.
[2]Average SEM across all treatments.
[3]CC to corn residue and receiving DDGS supplementation; CD and CW on corn residue receiving DDGS and wheat midds supplementation, respectively, for 15 d.
[4]CC removed from corn residue; CD and CW removed from drylot.
[5]Measured 27 d before breeding on June 1.
[6]Based on herd average mature cow BW of 612 kg.
[7]20 d.
[a,b]Means within a row lacking a common superscript differ ($P < 0.05$).

analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC). Pregnancy data were analyzed using the GLIMMIX procedure of SAS with binomial distribution of the data. Fixed effects were treatment and year, and group nested within treatment and year was a random effect. Kenward–Roger approximation was utilized for degrees of freedom. Significance was declared at $P \leq 0.05$. Tendencies at $P > 0.05$ but ≤0.10.

Results

Heifer BW and Average Daily Gain

Initial (mid-November) BW did not differ among treatments ($P = 0.34$; Table 4). At the end of phase 1 (mid-January), heifers assigned to CC had a greater ($P < 0.01$) BW (267 ± 2.34 kg) than those assigned to CD and CW (255 ± 2.61 and 248 ± 2.46 kg; respectively); heifers assigned to CD tended ($P = 0.06$) to have greater BW than those on CW. Final winter (late-February) BW was greater ($P < 0.01$) for CC heifers (281 ± 2.86 kg) than for CD (270 ± 3.04 kg) and CW heifers (265 ± 2.86 kg;) which did not differ ($P = 0.30$). In May (pre-breeding), BW was greater for CC heifers (318 ± 2.62 kg) compared to CD (308 ± 2.78 kg) or CW heifers (307 ± 2.62 kg; $P \leq 0.01$) which did not differ ($P = 0.63$). Consequently, CC heifers achieved a greater ($P < 0.01$) percentage (52%) of mature BW, 27 d prior to the breeding season, than CD and CW heifers, which did not differ ($P = 0.64$). Likewise, August (pregnancy diagnosis) BW was greater for CC (374 ± 2.22 kg) heifers in comparison to CD (366 ± 2.37 kg) and CW (362 ± 2.23 kg; $P \leq 0.02$) heifers, while CD and CW heifers did not differ ($P = 0.22$) from one another.

Average daily gain during phase 1 was greater ($P < 0.01$) for heifers assigned to CC than for those assigned to CD and CW (0.76 ± 0.033 vs. 0.58 ± 0.037 and 0.49 ± 0.035 kg/d, respectively), while heifers assigned to CD tended ($P = 0.08$) to have greater gain than those on CW (Table 4). In phase 2, when heifers assigned to CD and CW grazed corn residue for 15 d followed by 20 d in the drylot, heifers assigned to CW had a greater ($P < 0.01$) ADG than those on CC (0.49 ± 0.028 vs. 0.36 ± 0.028 kg/d, respectively) and tended to have greater ADG ($P = 0.07$) than those on CD (0.41 ± 0.029 kg/d). The ADG of heifers on CC and CD did not differ ($P = 0.18$). During the 20-d period in the drylot, ADG was not different between heifers assigned to CD and CW ($P = 0.77$) as both gained approximately 0.67 kg/d. Average daily gain over the entire winter treatment period for heifers on CC (0.63 ± 0.027 kg/d) was greater than CD (0.53 ± 0.029 kg/d; $P = 0.02$) and CW (0.50 ± 0.027 kg/d; $P < 0.01$), whereas CD and CW heifers did not differ from each other ($P = 0.42$). There was tendency ($P = 0.10$) for ADG from late-February to May (pre-breeding) to differ across treatments. The heifers previously on CC had less ($P = 0.04$) ADG during the pre-breeding period than the heifers that had been on CW and tended ($P = 0.08$) to be less than those previously on CD. The ADG of heifers previously on CW and CD did not differ ($P = 0.77$) from late-February to May.

Reproductive Measures

Results of heifer reproductive traits measured are listed in Table 5. In March, CC heifers had a greater RTS than CD and CW heifers ($P = 0.04$), which did not differ ($P = 0.64$). There was a tendency ($P = 0.08$) for a difference RTS due to treatment in May. The May RTS of CC heifers was greater ($P = 0.03$) than CD heifers but did not differ ($P = 0.26$) from CW heifers. The May RTS of CD and CW heifers did not differ ($P = 0.22$). Within CC, CD, and CW treatments, the percentage of heifers with an RTS of 5 (i.e., cycling) by

Table 5. Effect of winter heifer development systems utilizing corn residue and CC on reproductive measures and pregnancy rate

Item	Treatment[1]			SEM[2]	*P* value
	CC	CD	CW		
March					
Reproductive tract score[3]	4.18[a]	4.07[b]	4.09[b]	0.03	0.04
May					
Reproductive tract score[3]	4.61	4.50	4.56	0.033	0.08
Uterine horn diameter, mm	10.7	10.8	10.7	0.10	0.58
Total follicle count[4]	20.7	21.3	20.6	0.49	0.55
Average ovary length, mm	24.4	24.4	24.2	0.21	0.82
Average ovary height, mm	14.0	13.9	14.1	0.11	0.43
Hip height, cm	124	123	123	0.60	0.09
BCS[5]	5.39	5.29	5.31	0.032	0.10
August					
Pregnancy rate, %	75.4[a]	69.5[ab]	64.3[b]	2.55	0.01

[1]Grazing CC followed by grazing corn residue with DDGS supplementation (CC); grazing corn residue with DDGS (CD) or wheat midds (CW) supplementation followed by growing ration in the drylot.
[2]Average SEM across all treatments.
[3]Reproductive tract score (1 = prepubertal to 5 = pubertal; Andersen et al., 1991).
[4]Sum of follicles present in left and right ovaries.
[5]Body condition score (1 = emaciated to 9 = obese).
[a,b]Means within a row lacking a common superscript differ ($P < 0.05$).

May (13 mo of age) were 65, 57, and 59%, respectively ($P = 0.24$). No differences were observed across treatments for uterine horn diameter, total antral follicle count, ovary length, or ovary height ($P \geq 0.43$). The BCS of heifers in May tended ($P = 0.10$) to differ among treatments, with BCS of CC heifers being greater (P = 0.05) than CD heifers but not differing ($P = 0.12$) from CW heifers. The BCS of CD and CW heifers in May did not differ ($P = 0.56$). Hip height in May tended to differ ($P = 0.09$) across treatments, with height of CC heifer not differing ($P = 0.13$) from CS heifers but being greater ($P = 0.04$) than CW heifers. Hip height of CS and CW heifers did not differ ($P = 0.55$). The tendencies for differences in BCS and hip height were biologically minor as all heifers were in good condition (BCS of 5 or greater) and similar in frame size. Pregnancy rates in August were greater ($P < 0.01$) in CC heifers (75.4 ± 0.025%) compared to CW heifers (64.3 ± 0.028%) but were not different ($P = 0.15$) from CD heifers (69.5 ± 0.031%).

Economic Analysis

Values, feed costs, and differences in return above baseline (CD) are listed in Table 6. The mean heifer value, which was a weighted average value calculated based on percentage of bred and open heifers, was greater for CC ($1,726) compared to CD ($1,653) and CW ($1,610; $P < 0.05$), with CD and CW not differing from each other ($P = 0.22$). Feed cost was also greater for the CC treatment compared to both CD and CW treatments at $94.13/heifer ($P < 0.01$), but CD ($46.17/heifer) was lower ($P < 0.01$) in comparison to CW ($47.65/heifer). Return above baseline tended ($P = 0.07$) to differ among treatment groups, with CC and CW not differing ($P \geq 0.20$) from CD but return for CC being $73 greater than CW ($P = 0.02$).

Discussion

In beef heifer development programs, altering rate of gain by limit-feeding (Freetly et al., 2001; Roberts et al., 2009) or feeding lower-quality feedstuffs along with protein supplementation (Funston and Larson, 2011; Larson et al., 2011; Summers et al., 2014) can reduce feed costs while optimizing the use of feed resources. Previous work conducted with altering rate and timing of gain in beef replacement heifers has used either stair-step regimens cycling through periods with high rates of gain followed by low rates of gain and then high again (Park et al., 1998; Grings et al., 1999; Cardoso et al., 2014), or a period of low gain followed by one of high gain (Freetly et al., 2001) in the postweaning development period. The current study was targeting a greater rate of gain earlier in the winter treatment period followed by a slower rate of gain of the heifers in the CC treatment, with a consistent rate of gain targeted for heifers in CD and CW treatment groups throughout the winter treatment period.

Corn residue is limiting in metabolizable protein (Fernandez-Rivera et al., 1989). Dried distillers grains plus solubles are high in CP (31%) and RUP (68% of CP), making them an excellent source of metabolizable protein. They are also high energy. In corn residue grazing systems, DDGS can be fed to growing calves at different amounts to target a desired rate of gain (Watson et al., 2015). Heifers on the CD treatment were supplemented with DDGS to target a gain of 0.50 kg/d over the fall and winter (Welchons and MacDonald, 2017). Wheat midds have less energy (73% TDN) and protein (18.6% CP) than DDGS with the majority of the protein being ruminally degradable (NASEM, 2016) and thus more wheat midds (1.69 kg/d) have to be provided to achieve similar gains to the heifers in the CD (0.77 kg/d). We were able to achieve growth rates of heifers on CW that were similar to heifers on CD.

As expected, CC grazing during early winter resulted in greater ADG than the other treatment groups grazing corn residue. The late winter ADG (phase 2) was intentionally reduced for the heifers in the CC groups by offering a lesser amount of DDGS (0.35 kg/d) so they would be similar in BW to the CD and CW heifers by the end of the treatment period. Although we did not completely achieve the goal as the CC

Table 6. Mean value, feed cost, and difference in economic return in 3 heifer winter development systems

Item	Treatment[1]			SEM[2]	*P*-value[3]
	CC	CD	CW		
Open value[4], \$/cwt[6]	138.95	139.98	140.30		
Bred value[4,5], \$/cwt[6]	233.32	235.82	236.47		
Mean value, \$/heifer[7]	1,726[a]	1,653[b]	1,610[b]	23	<0.01
Feed cost, \$/heifer[8]	94.13[a]	46.17[b]	47.65[c]	0.084	<0.01
Return above CD, \$/heifer[9]	31.68	0.00	−41.69	22	0.07

[1]Grazing CC followed by grazing corn residue with DDGS supplementation (CC); grazing corn residue with DDGS (CD) or wheat midds (CW) supplementation followed by growing ration in the drylot.
[2]Average SEM across all treatments.
[3]Main effect of treatment.
[4]Average value across treatment. A Monte Carlo simulation method was used to determine the long-term average bred and open heifer prices for weight classes represented by mean palpation (August) herd BW.
[5]Assumes bred heifers are 1.5 times the price of a steer in years that the U.S. national cowherd is decreasing or constant, and up to 1.65 times the price of a steer in years that national cowherd is expanding (Prevatt, 2020).
[6]\$ per 100 lbs (45.5 kg) of BW.
[7]Weighted average value per heifer calculated by multiplying the percentage of bred and open heifers to their respective prices. Sum of these values was then multiplied to the mean herd BW at time of pregnancy diagnosis (August).
[8]Includes supplement, drylot feed, corn residue grazing, and CC costs.
[9]Difference in return calculated by subtracting mean economic return of CD treatment from CC and CW treatments.
[a,b]Means within a row lacking a common superscript differ ($P < 0.05$).

heifers were 11 to 16 kg heavier at the end of the winter development period than heifers in the other treatments.

Digestibility of late summer planted oats, turnip tops, and radish tops will decline slightly from December to January due to loss of total ethanol soluble carbohydrates, but digestibility remains high with a minimum IVOMD of 67%, 84%, and 82% for oats, turnip tops, and radish tops, respectively (Lenz et al., 2019). Furthermore, protein content changes little from November to January, with oats, turnip tops, and radish tops containing 16%, 24%, and 27% CP, respectively (Lenz et al., 2019). The rate of gain for CC heifers during phase 1 was expected to be around 0.70 kg/d as steers grazing a CC mix (21% CP, 86% IVOMD) identical to the one in the current study were reported to have gained 0.72 kg/d over a period of 65 d during the winter (Cox-O'Neill et al., 2017a).

After the winter treatment period, heifers on CD and CW treatments tended to have a greater ADG than CC heifers; this is likely compensatory BW gain. Nevertheless, in May, the BW of heifers in the CD and CW groups remained slightly less than that of CC heifers, although all groups had reached at least 50% of their mature BW, approximately 1 mo prior to the onset of breeding. BW influences the age at which heifers become pubertal (Patterson et al., 1992). Thus, BW may have had some effect on final pregnancy rates.

Pregnancy rates in the CW were less than the CC. This suggests that wheat midds supplementation 3 times weekly to achieve 0.50 kg/d in corn residue grazing systems may not be as effective as CC grazing followed by DDGS supplementation on corn residue. Some corn grain is present in the field after harvest, and it is usually consumed within the first 30 d of grazing residue (Watson et al., 2015). Both corn grain and wheat midds are sources of readily fermentable carbohydrates, and, therefore, have good energy value. Carbohydrates in corn are primarily in the form of starch, while wheat midds contain highly digestible fiber plus some rapidly fermentable starch. Wheat midds fed to heifers in the CW treatment in the current study were not analyzed for starch content but the reported mean starch content is 25.6 ± 5.7% (NASEM, 2016). The heifers were fed a considerable amount of wheat midds at once as they were supplemented 3 times a week resulting in heifers being offered 3.8 to 4.6 kg/heifer per feeding. This could have resulted in heifers consuming enough starch to affect growing follicles. In a review, Leroy et al. (2008) discussed that providing high-energy diets in the form of starch is beneficial for growth of follicles but not necessarily for the growing oocyte. Armstrong et al. (2001) observed that increasing energy content of the diet increased plasma insulin and insulin-like growth factor-I in dairy heifers, which stimulated pre-ovulatory growth but compromised oocyte quality when it was later ovulated. Therefore, the ability of CW heifers to become pregnant could have been compromised due to wheat midds supplementation on corn residue from 7 to 9 mo of age when pre-antral follicle development was occurring.

The form of protein provided by wheat midds may have also contributed to differences observed. Both CC and CD received DDGS as a supplement when on corn residue. The majority of the protein in wheat midds is RDP whereas the majority of protein in DDGS is RUP. Providing a protein source with more RUP has been shown to improve pregnancy rates in heifers developed on low-quality forage (Mulliniks et al., 2013).

Mean value per heifer in the CC treatment was greater than either the CD or CW treatments because a greater percentage of CC heifers were pregnant. Feed costs were also greater for CC heifers primarily due to the added cost of establishing the CC. Ultimately, the added value and added cost observed in the CC treatment resulted in an economic return per heifer that was greater than CW but not different from CD.

Conclusion

In conclusion, the assessment of 3 distinct systems for heifer development in the midwestern U.S. reveals viable options contingent upon resource availability. While utilizing corn residue alongside distillers supplementation presents a low-cost approach, substituting distillers with wheat midds yields similar overall feed costs and heifer value. Alternatively, incorporating a late summer oat-brassica mix followed by corn residue grazing with reduced distillers supplementation incurs higher costs but results in greater heifer value. Each system offers its own set of advantages and trade-offs, highlighting the importance of considering available resources and specific management goals in selecting the most suitable approach for heifer development.

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Conflict of interest statement

The authors declare no conflicts of interest.

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