Winter grazing of stockpiled native forages during heifer development delays body weight gain without influencing final pregnancy rates[1]

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ABSTRACT: The objective of this study was to test the effects of protein supplementation strategy and different stockpiled forage species on growth, nutritional status, and reproductive performance of yearling beef heifers. In a 5-yr study, yearling beef heifers (n = 266) were stratified by body weight (BW) at weaning to 1 of 3 stockpiled forages: 1) endophyte-infected tall fescue (**TF**, *Schedonorus arundinaceus* (Schreb.) Dumort; 7.21% crude protein [CP] and 67.13% neutral detergent fiber [NDF], dry matter [DM] basis), 2) big bluestem (*Andropogon gerardi* Vitman) and indiangrass (*Sorghastrum nutans* L.) combination (**BI**; 4.32% CP and 71.06% NDF, DM basis), or 3) switchgrass (**SG,** *Panicum virgatum* L.; 3.87% CP and 76.79% NDF, DM basis). Forage treatments were then randomly assigned to receive 1 of 2 supplement types: 1) 0.68 kg heifer^{-1} d^{-1} of dried distillers grains with solubles (**DDGS**: 28% CP and 108% total digestible nutrients [TDN]) or 2) 0.22 kg heifer^{-1} d^{-1} of blood meal and fish meal (**BF**: 72.5% CP and 77.5% TDN), resulting in a 3 × 2 factorial arrangement of treatments. Each year, twenty-one 1.2-ha pastures (7 pastures per forage type) were utilized with 2 to 3 heifers per pastures. Treatments were initiated in January and terminated in April at the initiation of breeding. Initial BW was not different ($P \geq 0.22$) by forage or supplement type. During the rest of the grazing period, BW was greater ($P < 0.01$) for TF heifers. However, average daily gain (ADG) was greater ($P < 0.01$) for BI and SG heifers from breeding to final pregnancy diagnosis. Heifers grazing TF pastures had greater ($P < 0.01$) overall ADG than their counterparts. The percentage of mature BW (MBW) at breeding was greater ($P < 0.01$) for TF heifers. Heifer BW and ADG was not influenced ($P \geq 0.06$) by supplementation strategy. Serum glucose concentrations were not different ($P \geq 0.44$) among forage type or supplement strategy. Pregnancy rates at fixed timed-artificial insemination and overall pregnancy rates did not differ ($P \geq 0.38$) by forage or supplement treatment. Owing to forage nutritive value differences, heifers grazing low-quality, warm season grasses lost BW prior to the initiation of the breeding season. However, a negative BW gain prior to breeding did not negatively impact overall pregnancy rates.

Key words: beef heifers, heifer development, protein supplementation, reproductive performance

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INTRODUCTION

In the southeastern United States, stockpiling endophyte-infected tall fescue is utilized as an economical forage option for heifer development

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(Poore et al., 2006; Drewnoski et al., 2009). Many livestock producers have incorporated native-warm-season forage into their forage production systems due to reduced summer forage production of endophyte-infected tall fescue (Lowe et al., 2015). However, native-warm season forages, such as switchgrass (*Panicum virgatum* L), big bluestem (*Andropogon gerardi* Vitman), and indiangrass (*Sorghastrum nutans* L.), are often not utilized for winter grazing in these systems due to a decline in forage nutritive value when dormant. If utilized strategically, stockpiled warm-season forages may be an alternative forage source for heifer development during the winter due to superior herbage accumulation. A concern of developing heifers on stockpiled endophyte-infected tall fescue is that heifer growth may be limited prior to breeding (Poore et al., 2006). In addition, heifers grazing stockpiled warm-season forages may lose BW during the winter grazing period in response to lower nutritive value of warm-season forages, in the form of reduced CP content and increased NDF content, comparatively to stockpiled endophyte-infected tall fescue (McFarlane et al., 2017). Thus, supplementation may be required in order to more effectively utilize stockpiled forage. Lalman et al. (1993) reported increased ADG in heifers provided high-ruminal undegradable protein (RUP) likely in response to improved energy utilization of low-quality forages. Heifers supplemented high RUP required less energy to gain 0.5 kg/d when compared with heifers supplemented propionic acid or monensin, thus increasing efficiency of energy utilization (Lalman et al., 1993). In support, heifers grazing low-quality native range exhibited a compensatory gain period during breeding and increased pregnancy rates and herd retention rate when supplemented high RUP when compared with a low-RUP supplement (Mulliniks et al., 2013). Therefore, we hypothesized that heifers grazing low-quality, native warm-season forages would have similar reproductive performance as heifers grazing higher quality endophyte-infected tall fescue. Our objectives were to determine the effect of stockpiled winter forage and protein supplementation strategy on BW gain, body condition score (BCS), serum metabolites, reproductive performance, and first calf performance of yearling beef heifers.

MATERIAL AND METHODS

All animal handling and experimental procedures were conducted according to the guidelines of the Institutional Animal Care and Use Committee (**IACUC**) of the University of Tennessee (IACUC approval number 2146-0116).

Animal Measurements and Treatments

In a 5-yr study, 266 spring-born, predominately Angus-influenced yearling heifers (initial BW = 331.98 ± 1.99 kg), were utilized to determine the effect of winter grazing stockpiled forage types and protein supplementation strategy on growth, reproductive performance, and serum metabolite concentrations. This research was conducted at the Middle Tennessee Research & Education Center, Spring Hill, TN (35°42′27″N, 86°56′31″W). Heifers were stratified by BW to 1 of 3 stockpiled forage types and received either 1 of 2 protein supplements at study initiation in a 3 × 2 factorial arrangement. Stockpiled forages were: 1) endophyte-infected tall fescue (**TF**; *Schedonorus arundinaceus* (Schreb.) Dumort), 2) big bluestem (*Andropogon gerardi* Vitman) and indiangrass (*Sorghastrum nutans* L.) combination (**BI**), or 3) switchgrass (**SG**; *Panicum virgatum* L.). Pastures (n = 21/year) were 1.2 ha each with 7 pastures forage type^{-1} year^{-1}. Each forage pasture type was then randomly assigned to receive either 1 of 2 supplement types (n = 10 to 11 replicates supplement type^{-1} year^{-1}): 1) 0.68 kg heifer^{-1} d^{-1} of dried distillers grains with solubles (**DDGS**: 28% CP, 74% RUP, 88% TDN) and 2) 0.22 kg heifer^{-1} d^{-1} of blood meal and fish meal (**BF**: 72.5% CP, 67.5% RUP, 69.5% TDN). Heifers were randomly assigned to each treatment combination with either two or three heifers per 1.2 ha pasture. Supplements were provided to the pasture groups at approximately 0800 hours on Mondays and Fridays. Heifers in each pasture were supplemented as a group. Protein supplementation strategies were chosen to assess the influence of high-RUP supplements differing in energy value. Supplements were designed to be isonitrogenous and provided similar amounts of CP at the level of 0.18 kg heifer^{-1} d^{-1}. Prior to the initiation of the supplemental period, heifers were adapted to the supplements for a 2-wk period due to potential intake issues for the BF treatment. After the adaptation period, all fed supplement was consumed and therefore no feed refusals were measured.

All grazing of pastures was terminated in mid- to late-August prior to stockpiling initiation. Stockpiling began on the first day of September prior to each year of the study. Pastures were managed on an annual basis using the following methods: stockpiling began in September, pastures were grazed from January to April during the study grazing period, heifers were removed from

pastures 10 d before the breeding season in April and forage regrowth occurred from April to June, pastures were either grazed or hayed from June to July at the discretion of research station technicians, and mowed (20-cm residual height for BI and SG, 10-cm residual height for TF) in August to initiate regrowth prior to stockpiling. Pastures that were utilized for hay production were fertilized with 67 kg/ha of N in June every year. All pastures were under continuous grazing methods during the winter grazing period. Establishment of warm-season grass pastures (BI and SG) was conducted in May 2008 according to the procedures described by Keyser et al. (2016). Cultivars of warm-season forages were Alamo SG and a mixture (1:1 based on seed mass) of big bluestem and indiangrass ecotypes (Roundstone Native Seed, LLC, Upton, KY) for SG and BI pastures, respectively (Keyser et al., 2016). The grazing period began in January and was terminated in April at fixed-timed AI (TAI). Termination of the different developmental treatments occurred approximately 10 d prior to the onset of the breeding season in April when heifers were managed together grazing an ungrazed endophyte-infected tall fescue pasture. Heifers were removed from experimental pastures on the following dates: 31 March 2013, 30 March 2014, 29 March 2015, 29 March 2016, and 4 April 2017.

All sample collection was conducted at 0900 hours for every sampling period. Heifer BW and BCS (1 = emaciated, 9 = obese; Wagner et al., 1988) were recorded at the initiation of the study and approximately every 28 d until the end of the breeding season in May and again in September at final pregnancy diagnosis. Body condition scores were determined by 2 trained technicians. For each development treatment, the percentage of mature BW at breeding was estimated from the average cow BW at 5 yr of age of the herd of origin. At the initiation of the breeding season in April of each year, all heifers were synchronized utilizing a controlled internal drug-releasing (CIDR) device (Eazi-Breed CIDR, Zoetis Inc., Kalamazoo, MI) with a 7-d CO-Synch + CIDR protocol. Heifers received a single 2-mL intramuscular injection of GnRH (Cystorelin, Merial) and a CIDR on –7 d. Following CIDR removal on day 0, heifers were administered a 5-mL intramuscular injection of PGF (Lutelyse, Zoetis Inc., Kalamazoo, MI). All heifers were given an injection of 2 mL of GnRH (Cystorelin, Merial) intramuscularly approximately 66 h after CIDR removal, and were artificially inseminated with semen from 1 of 3 bulls each year. Timed-artificial insemination was performed on the following dates: 10 April 2013, 9 April 2014, 8 April 2015, 8 April 2016, and 14 April 2017. Cleanup bulls were turned out 14 d after TAI and were utilized to provide natural service to the heifers for a 60-d breeding season with a heifer-to-bull ratio of 1:30. TAI pregnancy diagnosis occurred 30 d after insemination via transrectal ultrasonography based on the presence or absence of an embryonic heartbeat. A final pregnancy diagnosis was administered by transrectal ultrasonography in September of every year. Pregnancy diagnosis for TAI or natural service was verified by back-calculating from calving date. Calving distribution in 21-d intervals was calculated with the start of the calving season coinciding with the first day that 2 or more heifers calved (Lansford et al., 2018). Calf BW was measured at birth from the first calf of heifers in the study.

Nutritional status was assessed by collecting a blood sample (~9 mL; Corvac, Sherwood Medical, St. Louis, MO) via coccygeal venipuncture prior to the start of breeding. Blood samples were cooled and centrifuged at 2,000 × *g* at 4 °C for 20 min. Serum was separated and stored in plastic vials at –20 °C until further analysis. Serum samples were analyzed for glucose, insulin, NEFA, urea N (SUN), and β-hydroxybutyrate (BHB) concentrations. Commercial kits were utilized to perform the analyses for NEFA (Wako Chemicals, Richmond, VA), SUN (Thermo Scientific, Middletown, VA), and glucose (enzymatic endpoint, Thermo Scientific, Middletown, VA) as previously reported (Mulliniks et al., 2013). Serum samples were analyzed for BHB concentrations as previously described (McCarthy et al., 2015) using DL-β-hydroxybutyric acid sodium salt and a Tris buffer (10 mL of Tris hydrochloric acid + 40 mL of deionized water, pH 9) with 30 mg of β-nicotinamide adenine dinucleotide (β-NAD) and an enzyme of 3-hydroxybutyrate dehydrogenase (Sigma-Aldrich, St. Louis, MO). Concentrations of serum insulin were determined by radioimmunoassay (EMD Millipore's Porcine Insulin RIA) using a Wizard2 Gamma Counter (Perkin Elmer, Waltham, MA) as previously reported (Kaufman et al., 2018). The intra- and interassay CV were, respectively, 3.22% and 4.01% for serum NEFA, 4.51% and 5.11% for serum BHB, 4.27% and 4.64% for serum glucose, 4.22% and 4.99% for serum insulin, and 0.79% and 0.76% for SUN.

Forage Measurements

Forage samples (10 samples per pasture) were collected each year at the initiation and at the end of the grazing period using a 0.1-m^2 frame at 8-cm

stubble height to assess forage mass. Sampling was conducted randomly in each 1.2 hectare pasture. Forage sampling at the initiation of grazing occurred on the following dates: 5 January 2013, 13 January 2014, 9 January 2015, 4 January 2016, and 4 January 2017. Samples were collected at the termination of grazing approximately 10 d before the breeding season when heifers were removed from experimental treatments. An additional forage sample was hand-plucked from each pasture for nutritive value analysis from the mid-point of grazing on the following dates: 17 February 2014, 13 February 2015, 9 February 2015, and 25 February 2017. Samples were analyzed for DM, CP, and NDF concentrations. The DM content of the samples was determined by drying at 55 °C in a forced-air oven for 48 h. Samples were ground through a 2-mm screen using a Wiley mill (Thomas Scientific, Swedesboro, NJ). Dry matter and ash were determined according to procedures from Association of Official Analytical Chemists (1990; methods 934.01 and 942.05, respectively). Total N combustion analysis was performed to determine CP (Leco-NS2000 [LECO Corp., St. Joseph, MI]; method 976.06 [Horwitz, 2000]). Neutral detergent fiber content was assessed utilizing the ANKOM 200 fiber analysis system (ANKOM Technology Corp., Fairport, NY).

Statistical Analysis

Normality of data distribution and equality of variances of measurements were evaluated using PROC UNIVARIATE (SAS Institute Inc., Cary, NC, USA). All data were analyzed with pasture as the EU. Heifer performance, calf performance, and serum metabolite measurements were analyzed as a completely randomized design using the MIXED procedure and Kenward-Roger degrees of freedom. The model included the fixed effects of forage type, supplement type, year, and the interaction of forage type × supplement type. Calving performance was analyzed with a model including the fixed effects of sire, calf sex, forage type, supplement type, and the interaction of forage type × supplement type. Julian calving date data were not normally distributed; thus, data were transformed logarithmically. Repeated measures was utilized for variables collected over time with sampling period as the repeated factor and compound symmetry as the covariance structure as determined by Akaike's information criterion. Forage mass and chemical composition analyses were performed using the MIXED procedure with a model, including fixed effects of grazing month, forage type, year, and the interaction of grazing month × forage type and pasture as the experimental unit. Least squares means were compared using Fisher's LSD at a significance level of $P \leq 0.05$. The LSMEANS option was used to calculate treatment means and the PDIFF statement was utilized for the separation of main effects and any interactions. Binomial data (AI pregnancy rate, overall pregnancy rate, calving period) were analyzed with PROC GLIMMIX using a model that included the fixed effects of forage type, supplement type, year, sire, and their interactions. Sire was removed from the pregnancy rate analysis due to lack of significant effects on heifer fertility. Incidence of pregnancy status was analyzed using a binomial logistic regression analysis because this variable was a designation of one of the two possible outcomes (binary response), pregnant or not pregnant. This analysis resulted in the generation of odds and odds ratio. Odds (o) are the probability (p) of being pregnant over not being pregnant ($1 - p$) under a specific treatment. An odds ratio is a ratio of the odds under one treatment over the odds under another treatment. Although probabilities range from 0 to 1, odds range from 0 to positive infinity. Significant differences among treatments were determined using least squares means. Binomial data were analyzed using an odds ratio, and least squares means and SE of the mean were obtained using ILINK function. A power test was conducted for sample size of the binomial data. Tendencies were determined at $0.10 \geq P > 0.05$. The main effect of year was not discussed because year effects do not meet study objectives. Data were presented as main effects if interactions were not determined to be statistically significant.

RESULTS AND DISCUSSION

Forage Characteristics

Warm-season grasses can complement grazing of endophyte-infected tall fescue systems during their summer senescence (Keyser et al., 2016) due to forage mass accumulation even under drought conditions (Sage and Kubien, 2003). Forage mass accumulation potential of warm-season forages may offer another opportunity to extend the grazing season. In the current study, forage accumulation was lower ($P < 0.01$, Table 1) for TF pastures than SG and BI pastures with no differences ($P = 0.93$) between BI and SG pastures. Thus, forage accumulation differences are likely attributed to differences in plant physiology that resulted in increased forage

Table 1. Forage type effects on forage mass accumulation and forage type and grazing period effects (forage type × grazing period) on forage characteristics of stockpiled winter forages from beginning to end of the grazing period

	Treatment[1]			
Measurement	TF	BI	SG	SEM
Forage mass, kg DM/ha	3,124[a]	4,569[b]	4,540[b]	243
CP, %				
January	6.86[ax]	4.09[bx]	3.57[cx]	0.35
February	6.65[ax]	3.80[bx]	3.62[bx]	0.35
April	9.59[ay]	5.72[by]	3.42[cx]	0.40
NDF, %				
January	65.94[ax]	71.51[bx]	76.97[cx]	0.78
February	69.34[ay]	72.73[bx]	77.15[cx]	0.78
April	65.06[ax]	68.24[by]	77.87[cx]	0.87

[a,b,c]Within a forage type, means with different superscripts differ ($P < 0.05$).

[x,y,z]Within a grazing period, means with different superscripts differ ($P < 0.05$).

[1]Forage: tall fescue (TF), big bluestem and indiangrass combination (BI), and switchgrass (SG).

mass accumulation in warm-season forage species (Sage and Kubien, 2003; Lowe et al., 2015).

Forage CP content exhibited ($P < 0.01$; Table 1) a forage type × grazing period interaction. Throughout the grazing study, TF pastures had greater ($P < 0.01$) CP levels than BI or SG pastures. Warm-season grasses (SG and BI) did not differ ($P = 0.70$) in CP content in February at the midpoint of grazing. However, SG pastures had lower ($P < 0.01$) CP content compared with BI pastures in January and April at study initiation and termination. In addition, a forage type × grazing period interaction was detected ($P < 0.01$) for NDF content. Pastures of TF had lower ($P < 0.01$) NDF content the entire grazing period when compared with warm-season pastures. From January to February and February to April, NDF content increased ($P < 0.01$) for TF and BI pastures, respectively. In contrast, during the entire study, SG pastures did not differ ($P \geq 0.41$) in NDF content. Forage nutritive value of stockpiled warm-season forages was lower than stockpiled TF pastures probably due to differences in growing season and decreased nutritive value during dormancy (Vona et al., 1984; Reid et al., 1988). Poore et al. (2006) reported that stockpiled TF increased CP content in late February once forage growth began. Warm-season forages generally senesce in October and start growing in late March in Tennessee (Keyser et al., 2012). Winter dormancy of native warm-season forage reduces CP content while NDF content increases (Reid et al., 1988; Brandyberry et al., 1991). Stockpiled TF pastures maintain nutritive value consistently during winter (Burns and Chamblee, 2000; Poore et al., 2006). As expected, TF pastures had greater nutritive value than warm-season forages throughout the present study.

Animal Performance

Initial BW was not different ($P = 0.80$; Table 2) for heifers by forage type. Body weight was greater ($P < 0.01$) for TF heifers in April at breeding, in May at AI pregnancy diagnosis, and in September at final pregnancy diagnosis when compared with BI and SG heifers. From study initiation in January to breeding in April, heifer ADG was greater ($P < 0.01$) for TF heifers compared to heifers grazing warm-season forages. Differences in ADG during the pre-breeding period may be attributed to forage nutritive value differences among grass species presented above. However, heifers grazing BI and SG pastures compensated from the pre-breeding BW loss and had greater ($P < 0.01$) ADG from breeding to final pregnancy diagnosis than heifers grazing TF. At the initiation of grazing, BCS did not differ ($P = 0.57$) among forage types. However, due to differences in ADG, TF heifers had greater ($P < 0.01$) BCS at breeding and at final pregnancy diagnosis in September. As expected, heifers grazing TF had greater BCS than their warm-season forage counterparts during the study period likely in response to differences in ADG before breeding. Heifers grazing native warm-season grasses in the present study may have reduced their maintenance requirements resulting in greater ADG during the breeding season. In support, heifers grazing low-quality forage increased compensatory gain, likely in response to lower maintenance requirements and capacity to respond to improved forage quality (Ciccioli et al., 2005). Freetly et al. (2008)

Table 2. Forage type effects on heifer growth and reproductive performance during the winter grazing period

	Forage type[1]				
Measurement	TF	BI	SG	SEM	*P*-value
BW, kg					
Initial[2]	331	332	333	2	0.80
Breeding[3]	355[a]	328[b]	306[c]	3	<0.01
AI pregnancy diagnosis[4]	388[a]	369[b]	353[c]	3	<0.01
Final pregnancy diagnosis[5]	438[a]	422[b]	410[c]	3	<0.01
ADG, kg					
Initial to breeding[6]	0.26[a]	-0.05[b]	-0.30[c]	0.03	<0.01
Breeding to final pregnancy diagnosis[7]	0.71[c]	0.81[b]	0.89[a]	0.02	<0.01
Initial to final pregnancy diagnosis[8]	0.54[a]	0.44[b]	0.37[c]	0.01	<0.01
BCS					
Initial[2]	5.70	5.65	5.66	0.04	0.57
Breeding[3]	5.69[a]	5.44[b]	5.25[c]	0.05	< 0.01
Final pregnancy diagnosis[5]	6.03[a]	5.79[b]	5.77[b]	0.05	< 0.01
Percentage of mature BW at breeding, %	55[a]	51[b]	48[c]	0.45	< 0.01
Reproductive performance					
AI pregnancy rate, %	59	54	55	5.8	0.81
Final pregnancy rate, %	93	90	93	3.6	0.72

[a,b,c]Within a forage type, means with different superscripts differ ($P < 0.05$).

[1]Forage: tall fescue (TF), big bluestem and indiangrass combination (BI), and switchgrass (SG).

[2]Initial = January BW.

[3]Breeding = April BW.

[4]AI pregnancy diagnosis = May BW.

[5]Final pregnancy diagnosis = September BW.

[6]January to May ADG.

[7]May to September ADG.

[8]January to September ADG.

indicated that management strategies using periods of BW loss followed by realimentation can improve energy utilization efficiency. The differences in ADG in the present study may be in response to compensatory gain and an increase nutrient utilization. Even with the increase ADG from breeding to final pregnancy diagnosis of the BI and SG heifers, TF heifers had greater ($P < 0.01$) overall ADG from study initiation to final pregnancy diagnosis in September.

Supplementation strategy had no influence ($P \geq 0.13$; Table 3) on BW at the initiation of grazing in January or at breeding in April. Heifers supplemented BF tended ($P = 0.06$) to have greater BW in May at AI pregnancy diagnosis when compared with their counterparts fed DDGS. Heifer BW was similar ($P = 0.20$) between protein supplement types at final pregnancy diagnosis in September. Likewise, protein supplement type had no impact ($P \geq 0.47$) on ADG or heifer BCS ($P \geq 0.43$) during the entire study. Heifers supplemented RUP, monensin, or propionic acid did not differ in BW or ADG during the course of the study (Lalman et al., 1993). In agreement, feeding isonitrogenous supplements to provide 36% CP differing in RUP value (36% or 50% RUP) had no influence on heifer BW or ADG (Mulliniks et al., 2013). Ultimately, different isonitrogenous protein sources providing high RUP had little impact on heifer growth during the winter grazing trial.

Heifers grazing SG had the lowest ($P < 0.01$; Table 2) percentage of mature BW (MBW) at breeding compared to their forage counterparts. In addition, BF-supplemented heifers had greater ($P = 0.05$; Table 3) MBW at breeding than DDGS heifers. Patterson et al. (1992) established that heifers should reach 60% to 65% of MBW prior to breeding to optimize reproductive success. However, heifers developed to a lower (53%) mature BW had similar reproductive performance to heifers raised to greater (58%) mature BW (Funston and Deutscher, 2004). Additionally, heifers grazing dormant native range and fed a high RUP supplement reached 51% MBW while achieving a 94% pregnancy rate (Mulliniks et al., 2013). Mature BW at breeding ranged from 48% to 55% in the present study. Pregnancy rates at timed AI (TAI) were not influenced by forage type ($P = 0.81$)

Table 3. Supplement type effects on heifer growth and reproductive performance during the winter grazing period

	Supplement type[1]			
Measurement	BF	DDGS	SEM	*P*-value
BW, kg				
Initial[2]	333	331	2	0.22
Breeding[3]	332	327	2	0.13
AI pregnancy diagnosis[4]	373	367	3	0.06
Final pregnancy diagnosis[5]	425	421	2	0.20
ADG, kg				
Initial to breeding[6]	–0.02	–0.04	0.02	0.47
Breeding to final pregnancy diagnosis[7]	0.8	0.81	0.01	0.50
Initial to final pregnancy diagnosis[8]	0.45	0.45	0.01	0.72
BCS				
Initial[2]	5.69	5.65	0.03	0.43
Breeding[3]	5.46	5.46	0.03	0.98
Final pregnancy diagnosis[5]	5.86	5.88	0.04	0.71
Percentage of mature BW at breeding, %	52	51	0.4	0.05
Reproductive performance				
AI pregnancy rate, %	54	58	4.6	0.49
Final pregnancy rate, %	90	93	2.7	0.38

[1]Supplement: blood meal and fish meal (BF), and dried distillers grains and solubles (DDGS).
[2]Initial = January BW.
[3]Breeding = April BW.
[4]AI Pregnancy Diagnosis = May BW.
[5]Final Pregnancy Diagnosis = September BW.
[6]January to May ADG.
[7]May to September ADG.
[8]January to September ADG.

and did not differ by supplement type (P = 0.49; Table 3). Likewise, final pregnancy rates were not impacted (P = 0.72) by forage type and were not influenced (P = 0.38) by supplement strategy. Odds for being pregnant at final pregnancy check were 13.3, 9, and 13.3 for TF, BI, and SG, respectively. In addition, odds for being pregnant at final pregnancy for supplemental treatments were 13.3 and 9 for DDGS and BF, respectively. Heifers grazing warm-season grasses lost BW and came into breeding at a negative ADG; however, increased ADG post-breeding that may have influenced reproductive performance in this study. In support, heifers that had an improved plane of nutrition during the first 21-d post-AI had greater pregnancy rates when compared with heifers that maintained or lost BW (Arias et al., 2012). Therefore, conception rates may be improved if direction and magnitude of BW gain coincides with the breeding season (Lynch et al., 1997; Mulliniks et al., 2013; Summers et al., 2014). Production practices have rapidly changed over time, and selection pressure for increase reproductive performance has likely influenced puberty attainment (Funston et al., 2012; Endecott et al., 2013). No differences in age at puberty were reported in heifers developed on low or high planes of nutrition (Freetly and Cundiff, 1997). Summers et al. (2014) determined that puberty attainment prior to the breeding season was not different between heifers developed in a drylot and their counterparts developed on low-quality corn residue. These data suggest that puberty attainment and subsequent reproductive performance may be independent of BW or BW change over time. Overall, reproductive performance was not impacted by grazing low-quality native warm-season forages, which may be partially explained by the compensatory gain at the time of breeding in the current study. Developing heifers to as low as 48% of MBW at the time of breeding did not have a negative impact on reproductive performance, which indicates that reproductive performance of developing heifers may be uncoupled from BW and influenced by direction of BW change at the time of breeding.

Earlier calving heifers have shown to have increased longevity when compared to their contemporaries that calve later (Cushman et al., 2013). Calving date was not influenced by forage type (P = 0.66; Table 4) or by supplement type (P = 0.92; Table 5) in the current study. In agreement,

Table 4. Forage type effects on calving performance and first calf growth of heifers developed during the winter grazing period

	Forage type[1]				
Measurement	TF	BI	SG	SEM	*P*-value
Calving date, Julian date	29	26	31	4	0.66
Calved in first 21 d, %	67	77	76	6	0.27
Calf BW, kg					
Birth	31.1[a]	30.8[a]	29.0[b]	0.6	0.03

[a,b]Means with different superscripts differ ($P < 0.05$).

[1]Forage: tall fescue (TF), big bluestem and indiangrass combination (BI), and switchgrass (SG).

Table 5. Supplement type effects on calving performance and first calf growth of heifers developed during the winter grazing period

	Supplement[1]			
Measurement	BF	DDGS	SEM	*P*-value
Calving date, Julian date	27	30	3	0.92
Calving in first 21 d, %	70	76	5	0.44
Calf BW, kg				
Birth	30.6	30.0	0.6	0.62

[1]Supplement: blood meal and fish meal (BF), and dried distillers grains and solubles (DDGS).

calving date was similar among heifers developed on low-quality native range and supplemented RUP when compared with their cohorts developed in a drylot (Mulliniks et al., 2013). The percentage of heifers calving in the first 21 d of the calving season also was not different by forage type ($P = 0.27$; Table 4) or by supplement type ($P = 0.44$; Table 5). Likewise, heifers grazing low-quality corn residue and winter range during development calved at a similar rate in the first 21-d interval of the calving season as their counterparts developed grazing winter range followed by drylot confinement (Summers et al., 2014). Heifers calving early generally maintain their respective calving groups throughout their productive lifetime and wean heifer calves during their first calving season (Burris and Priode, 1958; Lesmeister et al., 1973; Cushman et al., 2013). In the present study, experimental treatments had no influence on calving date or calving distribution during the calving season.

Calf BW at birth was lower ($P = 0.03$; Table 4) for calves born from heifers grazing SG than their other forage counterparts. Supplementation strategy did not influence ($P = 0.62$; Table 5) calf birth BW. Calf BW at birth was not affected when heifers were developed to 66% or 60% of mature BW at breeding (Funston and Deutscher, 2004). Similarly, calf birth BW did not differ between heifers grazing dormant winter forage and heifers developed in a drylot (Funston and Larson, 2011). Overall, grazing low-quality forages had little impact on calving performance in the present study. Heifers were co-managed with the same nutritional regimen during the breeding season and gestation in our study. The compensatory growth period experienced by heifers grazing warm-season forages occurred during the breeding season, and nutrient restriction was likely not an influence during gestation. Thus, calf performance was not impacted by BW change prior to the breeding season, which is consistent with a report that previous breeding season supplementation and management had no influence on calf birth BW (Lansford et al., 2018).

Table 6. Forage type effects on serum metabolites of heifers during the winter grazing period

	Forage type[1]				
Measurement	TF	BI	SG	SEM	*P*-value
Glucose, mg/dL	80.12	78.44	80.78	1.39	0.44
Insulin, ng/mL	0.33	0.30	0.30	0.07	0.90
NEFA, mmol/L	279.90[c]	366.73[b]	436.35[a]	15.40	<0.01
BHB[2], µmol/L	315.89	307.92	311.76	10.79	0.86
SUN[3], mg/dL	13.86[a]	10.15[c]	11.20[b]	0.30	<0.01

[a–c]Within a forage type, means with different superscripts differ ($P < 0.05$).

[1]Forage: tall fescue (TF), big bluestem and indiangrass combination (BI), and switchgrass (SG).

[3]BHB = β-hydroxybutyrate.

[4]SUN = serum urea N.

Serum Metabolite and Hormone Concentrations

Circulating glucose concentrations did not differ ($P = 0.44$; Table 6) among forage types. Serum insulin concentrations also were not affected ($P = 0.90$) by forage treatment. A lack of glucose concentrations differences among treatments is not surprising since glucose is highly regulated by ruminants (Kaneko, 1989). Heifers grazing TF had lower ($P < 0.01$) circulating NEFA concentrations than their forage counterparts. Elevated circulating NEFA were expected in heifers grazing the warm-seasons forage treatment groups due to a loss in BW pre-breeding. Circulating NEFA concentrations have been shown to increase in heifers that were fed to maintain BW for 95 d (Yambayamba et al., 1996). Concentrations of BHB were not different ($P = 0.86$) among forage types. Heifers grazing TF had greater ($P < 0.01$) SUN concentrations than their respective counterparts. Roseler et al. (1993) suggested that SUN concentrations can provide an indication of N availability as a

result of deamination of endogenous and dietary protein supply. In the current study, TF pastures had greater CP content than warm-season forages during the entire grazing period, which may be the reason for the increased circulating SUN concentrations.

Supplementation strategy did not influence (P = 0.87; Table 7) glucose concentrations. Insulin concentrations also were not impacted (P = 0.34) by supplement type. As expected, circulating NEFA did not differ (P = 0.16) by supplement type due to minimal BW differences associated with supplementation strategy. Heifers supplemented with BF had greater (P = 0.03) BHB concentrations. Heifers supplemented BF had increased ruminal butyrate concentrations relative to their counterparts supplemented DDGS (McFarlane et al., 2017). An increase in ruminal butyrate may have increased BHB concentrations in the current study. In support, increased ruminal butyrate resulted in elevated peripheral BHB concentrations (Krehbiel et al., 1992). In addition, BF-supplemented heifers had greater (P < 0.01) circulating SUN than heifers supplemented DDGS. Heifers were supplemented with isonitrogenous RUP sources, but SUN concentrations were elevated with BF supplementation in the current study. The liver catabolizes excess amino acids to urea (Drackley et al., 2001) resulting in increased circulating urea N. Wickersham et al. (2009) indicated that RUP supplementation increased MP supply and may increase urea synthesis and recycling. Likewise, RUP supplementation may increase utilization of urea for anabolic purposes (Batista et al., 2016). Thus, source of dietary CP, either plant- or animal-based sources, may result in differences in protein catabolism and subsequent nitrogen utilization.

Table 7. Supplement type effects on serum metabolites of heifers during the winter grazing period

	Supplement type[1]			
Measurement	BF	DDGS	SEM	P-value
Glucose, mg/dL	79.91	79.65	1.11	0.87
Insulin, ng/mL	0.35	0.28	0.06	0.34
NEFA, mmol/L	349.32	372.66	12.27	0.16
BHB[2], µmol/L	324.87	298.84	8.50	0.03
SUN[3], mg/dL	12.80	10.68	0.23	<0.01

[1]Supplement: blood meal and fish meal (BF), and dried distillers grains and solubles (DDGS).

[2]BHB = β-hydroxybutyrate

[3]SUN = serum urea N.

Heifers grazing warm-season forages lost or maintained BW from January to April at the start of breeding, but compensated for the restricted gain post-breeding. This delay in heifer BW gain resulted in MBW ranging from 48% to 55% at the start of breeding, which is lower than current recommendations. However, the developmental strategy utilized in this study prior to the breeding season did not negatively influence heifer reproductive performance. In addition, the direction of BW gain at the start of the breeding season may be a more important function of heifer development and subsequent reproductive performance than the direction prior to breeding. This study illustrates that heifers can be developed at a slow or negative rate of gain until breeding, if a compensatory gain period is utilized, while maintaining adequate reproductive performance.

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