# Effects of dry or wet conditions during the preweaning phase on subsequent feedlot performance and carcass composition of beef cattle

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**ABSTRACT:** Our objective was to determine the effects of dry and wet conditions during the preweaning on subsequent feedlot performance and carcass characteristics of beef cattle. Steers ($n$ = 7,432) and heifers ($n$ = 2,361) finished in 16 feedlots in southwestern Iowa through the Tri-County Steer Carcass Futurity Cooperative were used for a retrospective analysis. Cattle originated in the Midwest (Iowa, Missouri, Indiana, Illinois, and Minnesota) and were born in February, March, or April of 2002 through 2013. Feedlot performance and carcass composition data were obtained for each animal. Palmer Drought Severity Index (**PDSI**) values were obtained for each animal's preweaning environment on a monthly basis. Mean PDSI values were used to classify conditions as dry (≤−2.0), normal (>−2.0 and <2.0), or wet (≥2.0) for the cool (April and May), warm (June through August), and combined (April through August) forage growing seasons preweaning. Mixed models were used to evaluate the effects of PDSI class on subsequent performance. Calf sex, date of birth (as day of year), year, and feedlot were also included as fixed effects. When considering PDSI class during the cool season, cattle from normal and wet classes had a greater feedlot delivery BW ($P$ < 0.0001) than dry. Dry and normal classes had greater ($P$ ≤ 0.02) delivery BW than wet during the warm and combined seasons, however. For the cool season, average daily gain was greater ($P$ < 0.0001) for the dry class than normal and wet. Cattle from the normal class for the cool season had greater ($P$ = 0.001) final BW than wet, but the wet class had the greatest ($P$ < 0.04) and dry class had the lowest ($P$ < 0.01) final BW during the warm season. During the cool season, HCW was greater ($P$ < 0.007) for the normal than wet class, although HCW was greater ($P$ ≤ 0.02) for wet compared with dry and normal during the warm season. Calculated yield grade was lower ($P$ ≤ 0.006) for the normal class during the cool season compared with dry and wet. For both the warm and combined seasons, the dry class had lower ($P$ ≤ 0.004) calculated yield grade compared with normal and wet. Carcasses from cattle that experienced normal or wet warm seasons had greater ($P$ ≤ 0.0005) marbling scores than dry, and normal had greater ($P$ = 0.0009) marbling score than dry for the combined seasons. In conclusion, these data indicate that both dry and wet conditions during the preweaning phase may impact ultimate feedlot performance and carcass composition.

**Key words:** beef cattle, carcass composition, drought, feedlot performance, precipitation



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## INTRODUCTION

In spite of the many advances made in management practices, global beef production remains heavily dependent on adequate rainfall to provide for forage growth. Because beef producers are unable to directly change precipitation, it is important to understand its effects on production and to seek to minimize them through best management practices.

To interpret the effects of precipitation on beef cattle production, an appropriate measure must be used. The Palmer Drought Severity Index (**PDSI**) is calculated monthly based on precipitation, evapotranspiration, soil water holding capacity, and runoff (Palmer, 1965). The PDSI is an intermediate range drought measure that not only factors the effects of abnormally dry or wet preceding months on current moisture availability, but is also responsive to new moisture changes. This makes PDSI appropriate for describing moisture surplus or deficit as it is likely to influence forage growth and forage-dependent livestock production. Furthermore, PDSI takes normal precipitation and temperature for each region into account, and was developed to be comparable across both location and time (Heim, 2002).

Dry or wet conditions during the preweaning phase can impact growing animals through both direct and maternal dietary effects (Neville, 1962, Neville et al. 1962). These effects are most commonly quantified as a change in calf weaning BW, but likely persist postweaning. Preweaning growth rate and tissue development can affect postweaning BW gains and ultimately shift carcass composition (reviewed by Berge (1991) and Greenwood and Café (2007)). Although the specific impacts of preweaning nutrient restriction have been investigated in experimental settings, more comprehensive longitudinal studies of preweaning precipitation effects in commercial production settings are limited at best. Anecdotal reports often indicate poor feedlot performance for drought-stressed calves, but this has not been quantified to our knowledge. The objective of this study was to determine the effects of dry and wet conditions during the preweaning phase on subsequent feedlot performance and carcass composition of beef cattle. We hypothesized that dry and wet conditions would alter preweaning calf development, ultimately resulting in feedlot performance and carcass composition differences.

## MATERIALS AND METHODS

A retrospective analysis was performed using feedlot and carcass data for 7,432 steers and 2,361 heifers born in February, March, or April of 2002 through 2013 (Table 1). These cattle originated from 283 cow-calf producers in Midwestern states (Iowa, Missouri, Indiana, Illinois, and Minnesota), and were fed through slaughter in 16 feedlots in southwestern Iowa as part of the Tri-County Steer Carcass Futurity Cooperative (**TCSCF**; Lewis, IA) between 2002 and 2014. All calves were weaned according to individual cow-calf producer practices before being transported to a TCSCF feedlot (mean and variation statistics shown in Table 2). Animals >500 d of age at feedlot arrival were removed from this data set. Cattle were fed and data were collected as described by Reinhardt and Busby (2014).

Pens of cattle were slaughtered in two groups, 28 d apart within each contemporary group from each cow-calf producer, with the goal of slaughtering cattle with an average 12th rib fat thickness of 1.14 cm. BW measurements of cattle were taken individually by TCSCF personnel on feedlot arrival and immediately before the shipment of cattle to the slaughter facility. HCW was recorded at the slaughter facility, and quality grade was assigned by USDA personnel. Trained employees of the TCSCF measured and recorded individual marbling score, 12th rib fat thickness, LM (ribeye) area, and calculated yield grade (Table 2).

The data set obtained from TCSCF included cow-calf producer location and zip code for each animal, which was used to assign each animal to the proper climate reporting division within its respective state. Historical PDSI data were obtained from the National Oceanic and Atmospheric Administration (**NOAA**; Washington, DC), including a numerical PDSI value for each climate region by month. PDSI values typically fall in the range of −4 to 4 (with

**Table 1.** Origin characteristics for cattle finished in 16 Tri-County Steer Carcass Futurity Cooperative feedlots

| Birth month | *n* | Birth year | *n* |
|---|---|---|---|
| February | 1,964 | 2002 | 820 |
| March | 5,133 | 2003 | 356 |
| April | 2,696 | 2004 | 587 |
| | | 2005 | 410 |
| | | 2006 | 674 |
| | | 2007 | 571 |
| | | 2008 | 525 |
| | | 2009 | 1,110 |
| | | 2010 | 652 |
| | | 2011 | 1,668 |
| | | 2012 | 1,613 |
| | | 2013 | 807 |

**Table 2.** Feedlot and carcass summary statistics of cattle finished through the Tri-County Steer Carcass Futurity

| Item | *n* | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|---|
| Age on feedlot arrival,* d | 9,764 | 243 | 44.0 | 126 | 436 |
| Feedlot delivery BW,* kg | 9,793 | 280 | 50.8 | 118 | 487 |
| Average daily gain, kg/d | 9,548 | 1.48 | 0.242 | 0.35 | 2.49 |
| Final BW, kg | 9,548 | 538 | 52.2 | 368 | 738 |
| Days on feed, d | 9,548 | 176 | 28.9 | 85 | 249 |
| Age at slaughter, d | 9,451 | 418 | 35.4 | 320 | 569 |
| HCW, kg | 9,548 | 331 | 33.2 | 218 | 450 |
| Dressing percent, % | 9,548 | 61.5 | 1.69 | 47.6 | 71.8 |
| 12th rib fat thickness, cm | 9,548 | 1.18 | 0.343 | 0.05 | 3.30 |
| LM area, $cm^2$ | 9,548 | 79.7 | 7.46 | 52.9 | 125.8 |
| Calculated yield grade | 9,548 | 2.93 | 0.570 | 0.11 | 5.39 |
| Marbling score† | 9,548 | 1,033 | 75.2 | 800 | 1,480 |

*All animals, including mortalities in the feedlot before slaughter.

†$Trace^0$ = 800, $Slight^0$ = 900, $Small^0$ = 1,000, $Modest^0$ = 1,100, $Moderate^0$ = 1,200, Slightly $Abundant^0$ = 1,300, Moderately $Abundant^0$ = 1,400.

a theoretical range of −10 to 10), with −4 indicating extreme drought and 4 indicating extreme moisture surplus. Monthly PDSI values were assigned to individual animals for each month of the preweaning forage growing season (April through August) for their year of birth based on birth date and zip code of origin.

A random sample of PDSI values was individually checked to validate accuracy, giving a 95% confidence that there are fewer than 1% errors. Further, each zip code was individually verified to have been assigned to the correct climate division. Following verification, mean PDSI values were calculated for individual animal environments for three time periods during the preweaning forage growing phases: cool season (April and May), warm season (June, July, and August), and combined seasons (April through August). For each time period, mean PDSI value was used to assign individual animals to one of three PDSI classes: dry (mean PDSI value ≤−2.0), normal (mean PDSI value >−2.0 and <2.0), or wet (mean PDSI value ≥2.0). These classes were based on PDSI descriptions used to communicate conditions by NOAA and others, and these were used for the analysis in this study. PDSI values from −2.0 to −2.99 are considered indicative of moderate drought, −3.0 to −3.99 of severe drought, and ≤−4.0 of extreme drought. Values from 2.0 to 2.99 are considered indicative of moderately wet conditions, 3.0 to 3.99 of very wet conditions, and ≥4.0 of extremely wet conditions (Heim, 2002). Although different moisture categories have been assigned between PDSI of 1.99 to −1.99 (Heim, 2002), NOAA describes these as mid-range or near-normal, as was used in this study.

### *Statistical Analysis*

All animals, including mortalities in the feedlot before slaughter, were included in the data set for age on feedlot arrival and feedlot delivery BW analysis. For all other performance and carcass parameters, only animals that went to slaughter were included. Some discrepancy exists within final *n* for parameters based on missing or errant data points in the original data set.

Data were analyzed in PROC MIXED of SAS 9.4 (SAS Institute Inc., Cary, NC) with PDSI class (dry, normal, or wet) as a fixed effect in the model, with separate analyses for each forage growing season (cool, warm, and combined). Calf sex, date of birth (as day of year, e.g., February 1 = d 32), birth year, and feedlot were also included as fixed effects in the model to account for variation from these factors. Individual animal was considered the experimental unit. Least square means were separated by least significant difference when $P \leq 0.05$.

## RESULTS

Summary statistics for cattle used in this analysis are presented in Table 2, *n* for each PDSI class during forage growing seasons are presented in Table 3, and mean PDSI values for each PDSI class during forage growing seasons are given in Table 4. The dry class had fewer observations than both normal and wet for all growing seasons considered.

Calf sex affected ($P \leq 0.006$) all parameters reported except for age on arrival ($P \geq 0.32$), days on feed ($P \geq 0.53$), and age at slaughter ($P \geq 0.14$). Feedlot and calf year of birth affected ($P \leq 0.0001$) all parameters except for dressing

**Table 3.** Number of cattle in each PDSI class for each growing season period*

| | PDSI class† | | |
|---|---|---|---|
| Growing season period | Dry | Normal | Wet |
| Cool season (April and May) | 822 | 4,363 | 4,608 |
| Warm season (June to August) | 1,711 | 4,037 | 4,045 |
| Combined seasons (April to August) | 1,542 | 3,858 | 4,393 |

*All animals, including mortalities in the feedlot before slaughter.

†Dry = mean PDSI ≤ −2.00, normal = mean PDSI > −2.00 and < 2.00, wet = mean PDSI ≥ 2.00.

**Table 4.** Mean ± SD PDSI in each PDSI class for each growing season period*

| | PDSI class† | | |
|---|---|---|---|
| Growing season period | Dry | Normal | Wet |
| Cool season (April and May) | −2.33 ± 0.36 | −0.01 ± 1.11 | 3.38 ± 0.64 |
| Warm season (June to August) | −2.75 ± 0.46 | −0.25 ± 1.16 | 3.58 ± 1.25 |
| Combined seasons (April to August) | −2.28 ± 0.38 | −0.18 ± 1.06 | 3.39 ± 0.96 |

*All animals, including mortalities in the feedlot before slaughter.

†Dry = mean PDSI ≤ −2.00, normal = mean PDSI > −2.00 and < 2.00, wet = mean PDSI ≥ 2.00.

percent ($P \geq 0.36$). Calf date of birth (as day of year) affected ($P \leq 0.05$) all parameters except 12th rib fat thickness in the combined seasons ($P = 0.06$). Because these effects were only included in the model to account for expected sources of variation not attributed to PDSI class, these are not presented or discussed.

### *Feedlot Performance*

Effects of PDSI class on feedlot performance are summarized in Table 5. During the cool, warm, and combined seasons, PDSI class affected age on feedlot arrival ($P < 0.0001$), feedlot delivery BW ($P \leq 0.03$), days on feed ($P \leq 0.0001$), and age at slaughter ($P \leq 0.0007$). In addition, PDSI class during the cool season affected ($P < 0.0001$) ADG, and PDSI class during the cool and warm seasons affected ($P \leq 0.006$) final BW. PDSI class did not affect ($P \geq 0.09$) ADG in the warm season or combined seasons or final BW in the combined seasons ($P = 0.83$).

When classified by PDSI during the cool season, age on feedlot arrival was least ($P \leq 0.0001$) for cattle in the dry class and greatest ($P \leq 0.04$) for cattle from the normal class. Age on arrival was greater ($P < 0.0001$) for cattle from dry class in the warm season than those from the normal and wet classes. For the combined seasons, age on arrival was greatest ($P < 0.0001$) for cattle from the dry class and least ($P < 0.001$) for cattle from the wet class. For the cool season, cattle from the dry class weighed less ($P < 0.0001$) on feedlot arrival than the normal or wet class. Conversely, for both the warm and the combined seasons, cattle from the dry and normal classes weighed more ($P \leq 0.02$) than those from the wet class.

ADG was greater ($P < 0.0001$) for cattle from the dry class during the cool season than those from normal or wet class. Cattle from the normal class for the cool season had greater ($P = 0.001$) final BW before slaughter than the wet class. Despite this, cattle from the wet class had the greatest ($P < 0.04$) and dry class had the lowest ($P \leq 0.01$) final BW during the warm season.

Cattle from the dry class during the cool season spent a greater ($P < 0.0001$) number of days on feed than those from the normal and wet classes. For both the warm and the combined seasons, cattle in the dry class spent the fewest ($P < 0.006$) days on feed and those in the wet class spent the most ($P < 0.002$) days on feed. Age at slaughter was greater ($P = 0.0002$) for the normal class compared with the wet class during the cool season. Age at slaughter was greater ($P < 0.05$) for cattle in the dry and wet classes than for the normal class during the warm season. When seasons were combined, age at slaughter was greatest ($P < 0.0001$) for the dry class and least for the wet class ($P \leq 0.02$).

### *Carcass Composition*

Effects of PDSI class on carcass composition are summarized in Table 6. During the cool and warm seasons, PDSI class affected ($P \leq 0.02$) HCW, but when seasons were combined, it did not ($P = 0.87$). Dressing percent was not affected ($P \geq 0.50$) by PDSI class. During the cool, warm,

**Table 5.** Effects of PDSI class* for each growing season period† on feedlot performance

| Item | PDSI class‡ Dry | Normal | Wet | *P* value |
|---|---|---|---|---|
| Age on feedlot arrival,‖ d | | | | |
| Cool season | 232 ± 1.8[c] | 244 ± 0.9[a] | 241 ± 1.0[b] | <0.0001 |
| Warm season | 247 ± 1.5[a] | 241 ± 0.9[b] | 239 ± 1.0[b] | <0.0001 |
| Combined seasons | 251 ± 1.5[a] | 244 ± 0.9[b] | 236 ± 1.1[c] | <0.0001 |
| Feedlot delivery BW,‖ kg | | | | |
| Cool season | 250 ± 2.5[b] | 275 ± 1.3[a] | 274 ± 1.4[a] | <0.0001 |
| Warm season | 275 ± 2.0[a] | 273 ± 1.2[a] | 269 ± 1.4[b] | 0.03 |
| Combined seasons | 276 ± 2.0[a] | 274 ± 1.3[a] | 268 ± 1.5[b] | 0.007 |
| Average daily gain, kg | | | | |
| Cool season | 1.46 ± 0.012[a] | 1.41 ± 0.006[b] | 1.40 ± 0.007[b] | <0.0001 |
| Warm season | 1.40 ± 0.009 | 1.41 ± 0.006 | 1.41 ± 0.007 | 0.68 |
| Combined seasons | 1.43 ± 0.009 | 1.42 ± 0.006 | 1.40 ± 0.007 | 0.09 |
| Final BW, kg | | | | |
| Cool season | 520 ± 2.5[ab] | 521 ± 1.3[a] | 515 ± 1.4[b] | 0.006 |
| Warm season | 512 ± 2.0[c] | 517 ± 1.2[b] | 521 ± 1.4[a] | 0.004 |
| Combined seasons | 518 ± 2.0 | 518 ± 1.2 | 517 ± 1.4 | 0.83 |
| Days on feed, d | | | | |
| Cool season | 186 ± 1.5[a] | 175 ± 0.8[b] | 173 ± 0.8[b] | <0.0001 |
| Warm season | 171 ± 1.2[c] | 174 ± 0.7[b] | 179 ± 0.8[a] | <0.0001 |
| Combined seasons | 171 ± 1.2[c] | 174 ± 0.7[b] | 178 ± 0.9[a] | <0.0001 |
| Age at slaughter, d | | | | |
| Cool season | 416 ± 1.6[ab] | 418 ± 0.8[a] | 414 ± 0.9[b] | 0.0002 |
| Warm season | 418 ± 1.2[a] | 414 ± 0.7[b] | 417 ± 0.9[a] | 0.0007 |
| Combined seasons | 422 ± 1.3[a] | 417 ± 0.8[b] | 414 ± 0.9[c] | <0.0001 |

[a, b, c]Means within a row without common superscripts differ ($P < 0.05$).

*Dry = mean PDSI ≤ −2.00, normal = mean PDSI > −2.00 and < 2.00, wet = mean PDSI ≥ 2.00.

†Cool season = April and May, warm season = June to August, combined seasons = April to August.

‡Least square mean ± SE.

‖All animals, including mortalities in the feedlot before slaughter.

and combined seasons, PDSI class impacted ($P \leq 0.006$) 12th rib fat thickness and calculated yield grade. LM area was affected ($P = 0.002$) by PDSI class in the cool season, but not warm season or combined seasons ($P \geq 0.07$). Marbling score was affected ($P \leq 0.001$) by PDSI class during warm and combined seasons, but not during the cool season ($P = 0.13$).

Cattle in the normal class for the cool season had greater ($P < 0.007$) HCW than those in the wet class. Cattle in the wet class for the warm season had greater ($P \leq 0.02$) HCW than the normal and dry classes. For the cool season, cattle from the wet class had greater ($P < 0.0001$) 12th rib fat thickness than those from the normal class. Fat thickness was greater ($P \leq 0.008$) for cattle from the normal and wet classes compared with the dry class for both the warm and combined seasons. Cattle from the normal class had greater ($P < 0.02$) LM area than dry and wet during the cool season. During the cool season, calculated yield grade was less ($P \leq 0.006$) for the normal class compared with the dry and wet classes. During the warm and combined seasons, the dry class had lower ($P \leq 0.004$) calculated yield grades compared with normal and wet classes.

For the warm season, the normal and wet classes had greater ($P \leq 0.0005$) marbling scores than the dry class. Marbling score was greater ($P = 0.0009$) for the normal class than the dry class during the combined seasons, but the wet class did not differ ($P \geq 0.12$) from either the normal class or the dry class.

## DISCUSSION

Many of the effects of dry or wet conditions during the preweaning phase assessed in this study, while significant, are relatively small in magnitude. Nevertheless, they illustrate that overall plane of nutrition before weaning, as affected by precipitation, may induce physiological responses that remain measurable in the feedlot and postslaughter in large commercially produced populations. In addition, these responses do not appear to always be negative in nature, as postweaning production

**Table 6.** Effects of PDSI class* for each growing season period[†] on carcass composition

| | PDSI class[‡] | | | |
|---|---|---|---|---|
| Item | Dry | Normal | Wet | $P$ value |
| HCW, kg | | | | |
| Cool season | 319 ± 1.6[ab] | 320 ± 0.8[a] | 317 ± 0.9[b] | 0.02 |
| Warm season | 316 ± 1.3[b] | 318 ± 0.8[b] | 321 ± 0.9[a] | 0.01 |
| Combined seasons | 319 ± 1.3 | 319 ± 0.8 | 318 ± 0.9 | 0.87 |
| Dressing percent, % | | | | |
| Cool season | 61.4 ± 0.10 | 61.5 ± 0.05 | 61.6 ± 0.05 | 0.58 |
| Warm season | 61.6 ± 0.08 | 61.5 ± 0.05 | 61.5 ± 0.05 | 0.50 |
| Combined seasons | 61.5 ± 0.08 | 61.5 ± 0.05 | 61.5 ± 0.06 | 0.99 |
| 12th rib fat thickness, cm | | | | |
| Cool season | 1.16 ± 0.018[ab] | 1.13 ± 0.010[b] | 1.21 ± 0.010[a] | <0.0001 |
| Warm season | 1.11 ± 0.015[b] | 1.18 ± 0.009[a] | 1.19 ± 0.010[a] | <0.0001 |
| Combined seasons | 1.13 ± 0.015[b] | 1.16 ± 0.009[a] | 1.19 ± 0.011[a] | 0.006 |
| LM area, $cm^2$ | | | | |
| Cool season | 77.9 ± 0.39[b] | 78.9 ± 0.20[a] | 78.1 ± 0.22[b] | 0.002 |
| Warm season | 78.9 ± 0.31 | 78.2 ± 0.18 | 78.4 ± 0.22 | 0.07 |
| Combined seasons | 79.0 ± 0.31 | 78.4 ± 0.19 | 78.3 ± 0.23 | 0.10 |
| Calculated yield grade | | | | |
| Cool season | 2.92 ± 0.031[a] | 2.83 ± 0.016[b] | 2.93 ± 0.018[a] | <0.0001 |
| Warm season | 2.76 ± 0.025[b] | 2.90 ± 0.015[a] | 2.93 ± 0.018[a] | <0.0001 |
| Combined seasons | 2.81 ± 0.025[b] | 2.88 ± 0.016[a] | 2.91 ± 0.018[a] | 0.006 |
| Marbling score[‖] | | | | |
| Cool season | 1,046 ± 4.0 | 1,040 ± 2.1 | 1,036 ± 2.3 | 0.13 |
| Warm season | 1,028 ± 3.2[b] | 1,040 ± 1.9[a] | 1,042 ± 2.3[a] | 0.0003 |
| Combined seasons | 1,033 ± 3.2[b] | 1,042 ± 2.0[a] | 1,038 ± 2.3[ab] | 0.001 |

[a, b]Means within a row without common superscripts differ ($P < 0.05$).

*Dry = mean PDSI ≤ −2.00, normal = mean PDSI > −2.00 and < 2.00, wet = mean PDSI ≥ 2.00.

[†]Cool season = April and May, Warm season = June through August, Combined seasons = April through August.

[‡]Least square mean ± SE.

[‖]Trace[0] = 800, Slight[0] = 900, Small[0] = 1,000, Modest[0] = 1,100, Moderate[0] = 1,200, Slightly Abundant[0] = 1,300, Moderately Abundant[0] = 1,400.

improved for calves from dry preweaning conditions in several cases.

Forage yield is broadly accepted to be decreased by drought, but forage and diet quality responses to drought are more complex. Although Peterson et al. (1992) and Craine et al. (2009) showed improved forage quality during drought conditions, this may not be representative of negative changes in diet quality related to reduced plant growth and yield (Laude, 1953). A reduction in overall diet quality or availability can reduce maternal milk yield and calf weaning BW (Neville, 1962; Jenkins et al., 2000; Hennessy et al., 2001). The impacts of preweaning nutrient restriction (reviewed by Greenwood and Café (2007)) or any nutritional management that affects growth and development before the finishing phase, such as early weaning (reviewed by Schmidt and Olson (2007)) or grazing low-quality forage postweaning (reviewed by Drouillard and Kuhl (1999)), can affect physiological processes much later in an animal's life resulting in altered feedlot growth and carcass composition.

Dry or wet conditions during the cool season appear to affect calves differently than the same conditions during the warm season. This likely reflects both calf stage of development and diet composition. During the cool season, most of the spring-born calf's diet is milk. Although dry or wet conditions can certainly impact maternal milk yield, the differences in forage quality and availability likely have a less direct impact on calves at this stage based on size, consumption limits of milk, and maternal drive for lactogenesis during early lactation. Conversely, calves may be limited by milk production as they age and consume increasing amounts of forage, which occurs during the warm season for spring-born calves. Any moisture-induced changes in forage quality or availability during the warm season can therefore have a direct impact on the calf's plane of nutrition through grazing and an indirect effect by altering milk production of cows. Boggs et al. (1980) reported that forage intake was negatively related with preweaning ADG during the first 2 mo of life, but that increased forage intake improved ADG during the next 3 mo preweaning. These researchers speculated that forage intake by young calves occurred when milk production of the dam did not meet calf requirements, but that the forage intake was unable to offset poor milk availability.

Calves in the dry class during the cool season were younger and weighed less at feedlot arrival, but appeared to experience compensatory gain (as increased ADG) in the feedlot, resulting in a similar final BW and HCW to calves from the normal PDSI class. These calves were in the feedlot longer than other classes, but were intermediate in age at slaughter, suggesting that time on feed was due primarily to differences before feedlot arrival rather than feedlot performance. Carcasses from the dry class during the cool season had similar marbling to the normal class; thus additional time on feed may have been necessary to reach their genetic potential for intramuscular fat accrual. These calves also had decreased muscle mass (LM area), thus had poorer (increased) yield grade despite similar 12th rib fat thickness, indicating that muscle growth may have been hindered during the preweaning phase and unable to rebound postweaning.

Broadly speaking, calves from the dry class during the warm and the combined forage growing seasons were older, but of similar BW, to calves from the normal class at feedlot arrival. Although it is not immediately apparent why these calves were slower to enter the feedlot, this later entry was likely a major contributor to other differences observed, such as having decreased days on feed and leaner carcasses. These calves had similar feedlot ADG to calves from the normal class, indicating that either calf growth rate was not dramatically limited by dry conditions during the warm season, or that any compensatory growth that occurred while moving from a low nutritional plane caused by dry conditions to the high nutritional plane of the feedlot was completed during backgrounding before feedlot arrival.

Although feedlot ADG was similar, carcasses from the dry class during the warm season or combined seasons had less 12th rib fat thickness and similar LM area, resulting in lower calculated yield grade. In addition, marbling score was reduced for carcasses from these animals. Taken collectively, based on age at slaughter, these results indicate that cattle that experience drought conditions during the warm season or combined seasons may be slower to reach physiological maturity. It seems that nutrient restrictions brought on by drought may limit preweaning growth, which may lead calves to continue to gain muscle and delay the deposition of fat and physiological maturity. At a common BW, these older calves seem to have a higher muscle to fat ratio than their younger counterparts from the normal and wet classes. Alternatively, this could be expressed as the same level of fatness at a heavier HCW. In feeding cattle from the dry class during the preweaning warm season, it may prove possible to continue to feed them to heavier carcass weights without experiencing high yield grade discounts. This is in agreement to what is typically observed with cattle backgrounded on low-quality forage compared with those placed directly on a high-concentrate diet (Owens et al., 1993; Drouillard and Kuhl, 1999).

Cattle from the wet class during the cool season appear to be reaching physiological maturity at a younger age and a lower BW than their counterparts from the normal PDSI class. This may be because they entered the feedlot at a younger age but similar BW to those from the normal class, as the feedlot ADG and number of days on feed of the two groups are not different. These data indicate that they are not being harvested prematurely, as those from the wet class have greater 12th rib fat thickness, despite lighter HCW and smaller LM area, than those from the normal class. This shift in body composition is detrimental to carcass value as the greater external fat was not accompanied by an increase in marbling.

Wet conditions during the warm season decreased feedlot delivery BW, but increased HCW. In general, excess precipitation in the warm season or combined seasons had less effect on feedlot performance or carcass characteristics than in the cool season, suggesting that preweaning calves are more sensitive to the ramifications of wet conditions during the cool season or early preweaning phase.

Although poor preweaning nutritional planes are generally attributed more to dry than wet conditions, our data indicate that wet conditions preweaning may also impact subsequent calf performance. It is difficult to identify a single cause that may be responsible for these effects, as there are many ways in which wet conditions during the cool season could negatively impact diet quality. Increased moisture availability at this stage could decrease nutrient density as plant dry matter content is decreased and overall yield is increased. In some cases, it may not be possible for lactating cows to consume enough of this low dry matter forage to maximize milk production, which may have resulted in effects observed during the cool season. These weather conditions may also alter other factors such as plant secondary metabolite production and animal parasite load that can have an impact on maternal milk production and calf growth rate.

Although unclear how wet conditions preweaning decreased both growth and marbling potential, data from this study suggest that precipitation, and therefore forage quality, early in the preweaning phase may alter later body composition. Less is known about impacts of nutrient intake during the neonatal and early preweaning period on subsequent feedlot performance and carcass characteristics than on fetal or late preweaning stages in ruminants. Recent work in dairy calves demonstrates that metabolic pathways of muscle can be altered by nutrient intake during this period (Wang et al., 2014).

Management responses to dry or wet conditions are also likely to alter calf physiological responses and ultimate feedlot performance and carcass composition. Early weaning is a common management response to drought conditions. Early-weaned calves do not appear to have been placed in the feedlot after dry warm season or combined seasons in this study based on increased cattle ages at arrival for dry classes in those growing seasons. In addition, producers may be more likely to creep feed calves during periods of drought than at other times, which has the potential to improve the overall plane of nutrition enough to increase rate of gain preweaning and mitigate or even reverse the effects of drought on calf performance (reviewed by Lardy and Maddock (2007)). Specific producer management decisions such as creep-feeding are not available for this data set, however. The epidemiological approach used in this study allowed for determination of overall impacts of dry and wet conditions in commercial production settings, including all resulting management changes due to these conditions.

Classes based on mean PDSI were not evenly distributed, with less cattle experiencing dry than normal or wet conditions as defined in this study. This may be due to the drought indicator used (PDSI), years considered, or locations of cow-calf operations included and could have impacted the results of this study.

It should be noted that this analysis focused on a precipitation index rather than temperature (average, high, and/or low) variables or other individual components that contribute to the precipitation index. Temperature can certainly exacerbate effects of dry and wet conditions on soil conditions, and is therefore included in the PDSI model (Heim, 2002). In addition to these effects on forage growth, temperature fluctuation can also alter DMI and cause animals to expend energy to remain within their thermoneutral zone. Thus, it likely plays an additional role outside of precipitation effects explored here and has potential for further study.

## CONCLUSION

Further research is warranted to determine the effects of preweaning dry or wet conditions on calf health, profitability, and other parameters. These data highlight that both dry and wet conditions observed during the preweaning period in spring-calving, Midwestern beef herds may have economically relevant impacts on feedlot performance and carcass composition. A significant portion of these effects is likely attributable to calf plane of nutrition before weaning. As such, producers may want to consider management strategies that will allow them to maintain adequate preweaning nutrition to optimize feedlot performance and carcass composition. Further, feedlot managers may want to consider the impact that dry and wet conditions preweaning have on cattle that they purchase for finishing and work to develop standard operating procedures based on preweaning precipitation that optimizes calf performance, carcass traits, and feedlot inputs.

*Conflict of interest statement.* None declared.

## LITERATURE CITED

Berge, P. 1991. Long-term effects of feeding during calfhood on subsequent performance in beef cattle (a review). Livest. Prod. Sci. 28:179–201. doi:10.1016/0301-6226(91)90142-D.

Boggs, D.L., E.F. Smith, R.R. Schalles, B.E. Brent, L.R. Corah, and R.J. Pruitt. 1980. Effects of milk and forage intake on calf performance. J. Anim. Sci. 51:550–553. doi:10.2527/jas1980.513550x.

Cafe, L.M., D.W. Hennessy, H. Hearnshaw, S.G. Morris, and P.L. Greenwood. 2009. Consequences of prenatal and preweaning growth for feedlot growth, intake and efficiency of Piedmontese-and Wagyu-sired cattle. Anim. Prod. Sci. 49:461–467. doi:10.1071/EA08089.

Craine, J.M., E. Towne, A. Joern, and R.G. Hamilton. 2009. Consequences of climate variability for the performance of bison in tallgrass prairie. Global Change Biol. 15:772–779. doi:10.1111/j.1365-2486.2008.01769.x.

Drouillard, J.S., and G.L. Kuhl. 1999. Effects of previous grazing nutrition and management on feedlot performance of cattle. J. Anim. Sci. 77(Suppl 2):136–146. doi:10.2527/1999.77suppl_2136x.

Greenwood, P.L., and L.M. Cafe. 2007. Prenatal and pre-weaning growth and nutrition of cattle: long-term consequences for beef production. Animal 1:1283–1296. doi:10.1017/S175173110700050X.

Heim, R.R. Jr. 2002. A review of twentieth-century drought indices used in the United States. Bull. Amer. Meteor.

Soc. 83:1149–1165. doi:10.1175/1520-477(2002)083<1149:arotdi>2.3.co;2.

Hennessy, D.W., S.G. Morris, and P.G. Allingham. 2001. Improving the pre-weaning nutrition of calves by supplementation of the cow and/or the calf while grazing low quality pastures 2. Calf growth, carcass yield and eating quality. Aust. J. Exp. Agric. 41:715–724. doi:10.1071/EA00153.

Jenkins, T.G., C.L. Ferrell, and A.J. Roberts. 2000. Lactation and calf weight traits of mature crossbred cows fed varying daily levels of metabolizable energy. J. Anim. Sci. 78:7–14. doi:10.2527/2000.7817.

Lardy, G.P., and T.D. Maddock. 2007. Creep feeding nursing beef calves. Vet. Clin. North Am. Food Anim. Pract. 23:21–28. doi:10.1016/j.cvfa.2006.11.002.

Laude, C. 1953. The nature of summer dormancy in perennial grasses. Bot. Gaz. 3:284. doi:10.1086/335770.

Neville, W.E. 1962. Influence of dam's milk production and other factors on 120-and 240-day weight of Hereford calves. J. Anim. Sci. 21:315–320. doi:10.2527/jas1962.212315x.

Neville, W.E., D.M. Baird, H.C. McCampbell, and O.E. Sell. 1962. Influence of dam's milk production and other factors on post-weaning performance and carcass characteristics of Hereford cattle. J. Anim. Sci. 21:943–949. doi:10.2527/jas1962.214943x.

Owens, F.N., P. Dubeski, and C.F. Hanson. 1993. Factors that alter the growth and development of ruminants. J. Anim. Sci. 71:3138–3150. doi:10.2527/1993.71113138x.

Palmer, W.C. 1965. Meteorological drought. Research Paper no. 45 Department of Commerce Weather Bureau, Washington, D.C.

Peterson, P.R., C.C. Sheaffer, and M.H. Hall. 1992. Drought effects on perennial forage legume yield and quality. Agron. J. 84:774–779. doi:10.2134/agronj1992.00021962008400050003x.

Reinhardt, C.D., and W.D. Busby. 2014. An audit of the current U.S. Department of Agriculture frame size scoring system. J. Anim. Sci. 92:2654–2265. doi:10.2527/jas.2013–7425.

Schmidt, T.B., and K.C. Olson. 2007. The effects of nutritional management on carcass merit of beef cattle and on sensory properties of beef. Vet. Clin. North Am. Food Anim. Pract. 23:151–163. doi:10.1016/j.cvfa.2006.11.004.

Wang, P., J.K. Drackley, J.A. Stamey-Lanier, D. Keisler, and J.J. Loor. 2014. Effects of level of nutrient intake and age on mammalian target of rapamycin, insulin, and insulin-like growth factor-1 gene network expression in skeletal muscle of young holstein calves. J. Dairy Sci. 97:383–391. doi:10.3168/jds.2013-7042.