# Effects of creep feeding and its interactions with other factors on the performance of meat goat kids and dams when managed on pasture

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**ABSTRACT:** Creep feeding and its possible interactions with other influential factors (genetics, litter type, and sex) for weaning traits were studied in meat goat kids and their dams. Kids across 3 yr were creep fed (254 kids; 5 pens) or not creep fed (255 kids; 5 pens) from 30 to 90 d of age. Creep-fed kids had higher ($P \leq 0.05$) preweaning average daily weight gain and weaning weights (113.1 ± 13.0 g/d; 15.0 ± 0.8 kg) than kids not creep fed (99.8 ± 13.1 g/d; 14.0 ± 0.8 kg). However, financial returns were not higher ($P > 0.05$) for creep-fed kids compared with kids not creep fed. There was no difference ($P > 0.05$) in kid conformation score or survival rates between the treatment groups. The only important interaction among kid traits was treatment × litter type ($P < 0.05$) for FAMACHA scores. Within noncreep pens, single kids had lower (better; $P < 0.05$) FAMACHA scores (2.9 ± 0.3) than twin kids (3.9 ± 0.3). There was no litter-type effect on FAMACHA scores for kids within the creep feed pens. Dams of the creep-fed ($n$ = 175) and noncreep ($n$ = 178) kids were also evaluated. Treatment did not affect ($P > 0.05$) litter weights, dam weight change, gross revenue for weaned litters, or fecal egg counts. Treatment interacted with litter type ($P < 0.05$) to effect packed cell volume (PCV). In the noncreep group, dams raising singles had higher (better; $P < 0.05$) PCV (18.7 ± 1.3%) than dams rearing twin kids (15.7 ± 1.3%). The litter-type effect on dam PCV was not evident ($P > 0.05$) in the creep-fed group. Creep feeding improved some kid growth traits but did not improve dam traits or financial returns. Interactions of creep treatment with other factors were minimal for doe-kid traits.

**Key words:** creep feed, dam performance, kid performance, meat goat, weaning

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## INTRODUCTION

As a nontraditional livestock class in the United States, meat goats have been studied at a much lower level than other livestock classes such as cattle and sheep. Long-standing traditional livestock management practices such as creep feeding (Reid, 2018) have received little experimentation in the context of meat goat production. Creep feeding is a nutrient supplementation strategy used during the preweaning stage of livestock management to improve offspring performance. The practice involves providing offspring with supplemental feed in an area that excludes the dams. Effects on creep feeding on preweaning weight gain in lambs have been variable (Glimp, 1971; Wilson et al., 1971; de Villiers et al., 2002; Brand and Brundyn, 2015). Two studies published on goats (Goetsch et al., 2002; Htoo et al., 2015) have also produced mixed results. Despite limited data, numerous outreach publications exist guiding meat goat producers in creep feeding and there are various commercial creep feeds and creep feeders designed for meat goats available for producers to purchase. Various

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other factors such as breed, litter type, and sex have consistently affected preweaning kid performance as reviewed by Browning and Leite-Browning (2011). It is important to determine if creep feeding interacts with any of these other factors to affect kid performance.

Doe fitness is the primary determinant of meat goat profitability (Browning et al., 2011). If creep feeding enhances some aspect of doe fitness or performance via postpartum weight maintenance or internal parasite reduction, then overall enterprise economics may be improved. Postpartum dam weight changes in response to creep feeding have been evaluated in ewes (da Silva et al., 2012; Brand and Brundyn. 2015). However, creep feeding comes at a cost. It is not clear if potential benefits of creep feeding on kid or dam performance offset the added costs in goats. The current study was designed to examine the effects of creep feeding and its possible interactions with other factors on growth, health, and financial characteristics of meat goat kids and their dams at weaning.

## MATERIALS AND METHODS

### *Herd Management*

Protocols used within this study were in accordance with the Tennessee State University Animal Care and Use Committee using the FASS Guide for Care and Use of Agricultural Animals in Research and Teaching (3rd edition). This study was conducted at the Tennessee State University Research Station located along the Cumberland River in Nashville, TN (36.1754$^{0}$, −86.8300$^{0}$). The area has a humid, subtropical climate. All animals in this study were semi-intensively managed on cool-season tall fescue (*Festuca arundinacea*) and warm-season bermudagrass (*Cynodon dactylon*) pastures supplemented with orchardgrass hay (*Dactylis glomerata*) for ad libitum consumption along with free access to water and mineral supplement. Other grasses, clovers, broadleaf weeds, and woody browse species were also available in the grazing areas.

Straightbred and crossbred kids were sired by straightbred Kiko (bred to Boer- and Kiko-sired does), Myotonic (bred to Myotonic does), Spanish (bred to Boer- and Spanish-sired does), and Savanna bucks (bred to Boer-, Kiko-, and Spanish-sired does) and born across three production years (Table 1). Does were bred to kid once annually. Kidding occurred in March and May of the first 2 yr and only in March for the third year to make a total of five contemporary groups of kids on study. Kids in each contemporary group were born in 4 to 6 wk kidding seasons. Offspring were assigned to one of two treatments, creep feeding or no creep feeding at 30 d of age. The two treatments were equally balanced by dam breed, sire breed of kids, sex, and litter type. Each treatment contained half of the offspring born (Table 1). Each contemporary group included one creep feed pen and one noncreep pen, so each treatment was replicated in five pens across the three study years. Kids suckled dams unrestricted on pasture. The kids in each contemporary group were weaned at the median age of 90 d. Kids were not vaccinated before weaning. All dams were dewormed at kidding per general herd management protocol. In the second year, dams were mass dewormed in both contemporary groups when kids reached 60 d of age because a large number of the dams presented clinical signs of internal parasitism (i.e., anemia, scours, mandibular edema, and lethargy). Otherwise, dams and kids were treated individually if symptoms of internal parasitism were evident.

### *Creep Feeding*

At the median age of 30 d, creep-fed kids were provided a commercial, nonmedicated goat grower pellet for ad libitum consumption (16% crude protein (CP), 2.51 Mcal/kg of digestible energy as fed; Tennessee Farmers Cooperative Item #93317). Each creep pen included one feeder (Sydell© 8’ bunk feeder) sheltered in a hut and surrounded by paneling wide enough for kids to enter while excluding dams. Creep feeders were placed in areas that kids walked by daily. A measured amount of feed was placed in the creep feeders daily until kids

**Table 1.** Number of study dams, sires, and kids used per year

| | Production year | | | |
|---|---|---|---|---|
| Class | 2014 | 2015 | 2016 | Total |
| Sire breed of dams | | | | |
| Boer | 27 | 24 | 16 | 67 |
| Kiko | 42 | 38 | 30 | 110 |
| Myotonic | 17 | 13 | 13 | 43 |
| Spanish | 47 | 39 | 34 | 120 |
| Savanna | 7 | 4 | 2 | 13 |
| Sire breed of kids | | | | |
| Kiko | 6 | 6 | 3 | 15 |
| Myotonic | 3 | 2 | 1 | 6 |
| Spanish | 4 | 5 | 3 | 12 |
| Savanna | 4 | 9 | 6 | 19 |
| Kids by treatment | | | | |
| Creep | 97 | 83 | 74 | 254 |
| No creep | 98 | 85 | 72 | 255 |

were weaned. Kids had 24 h access to creep feed. Consumption was determined by weighing orts after a 24 h period. When the amount of feed remaining measured less than 30 g, the amount of daily feed provided was increased. The feeders were checked intermittently throughout each study day. If a feeder was found empty before 24 h, more feed was provided, and that amount was included when determining the amount consumed within the 24 h period. Does were not fed supplemental concentrate during the study period.

### *Data Collection*

Weights for kids and dams were taken at approximately 30, 60, and 90 d of age. An additional weight for kids was recorded 24 h after weaning to measure shrink weight. The actual age of individual kids at weaning were used in average daily weight gain (ADG) calculations. Litter weights for dams were calculated at 30 and 60 d and at weaning. Body conformation scores for kids were recorded by official US Department of Agriculture (USDA) market specialists 24 h after weaning. Kids were graded subjectively as fitting within superior (selection 1), average (selection 2), and poor (selection 3) muscle classifications (McMillin and Pinkerton, 2014). Market value of meat goat kids generally increases as conformation score improves from 3 to 1. The USDA Agricultural Marketing Service market reports published around the time of weaning from the regional goat auction (Tennessee Livestock Producers, Columbia, TN) were used to help assign the market value of each kid. The average of the low and high price reported for each weight and selection class was used in this study. The gross revenue generated of each study kid was defined as its market value estimated by using the conformation score assigned by the USDA graders, shrink weight, and the average price of the selection score-weight class obtained from the USDA market report most recently published relative to the weaning date. Net income for kids was determined within each contemporary group after subtracting the average per kid cost of creep feed from creep-fed kid market value. Pen orts data were used to estimate average feed intake per kid and the actual purchased creep feed costs were applied to intake estimates. The market values of each kid in a litter were combined to create the gross revenue values for dams.

Blood samples were collected by jugular venipuncture from each dam at weaning. The samples were held in vacuum tubes treated with ethylenediaminetetraacetic acid and spun down in duplicate by centrifugation for 10 min at 17,000 × *g* to measure packed cell volume (PCV). If the duplicate readings were separated by more than two percentage units, the sample was rerun. The PCV determined the level of anemia that each dam exhibited. To assess anemia level in kids, a FAMACHA score was recorded for each kid at weaning. FAMACHA is a scoring system used to estimate the anemic level of goats due to the nematode, *Haemonchus contortus*, based on the lower conjunctiva color (Kaplan et al., 2004). Scores ranged from 1 to 5, with 1 being normal and 5 being very anemic.

Fecal samples were collected from the dams at weaning. The samples were analyzed using the McMaster Method (Coles et al., 2006). A 2 g sample was mixed in 28 mL of sodium nitrate flotation solution with a specific gravity of 1.25 to 1.30. The samples were viewed using a McMaster slide that contained two boxed grids per slide. Eggs were counted in each box, added together, and multiplied by 50 to get the eggs per gram of feces (fecal egg count, FEC). This method determined the parasitic load for each dam.

### *Statistical Analysis*

For statistical analysis of kid data, fixed effects used throughout all models were treatment group (creep or no creep), breed of sire, breed of dam, sex of kid (buckling or doeling), litter type (single or twin), treatment × sire breed, treatment × dam breed, treatment × sex, and treatment × litter type. A split-plot design was modeled with treatment in the whole plot and all other fixed effects residing in the subplot. Six sets of triplets entered the study herd and were integrated into the twin group because of the small triplet subclass. Litter type at birth was used as a source of variation for 30 d weight, 60 d weight, and survival until weaning. Litter type at weaning was used as a source of variation for weaning weight, ADG, FAMACHA and conformation scores, shrink weight, and financial returns. Dam breed was defined by the sire breed of the dams (i.e., maternal grandsire breed of the kids) because of the many small subclasses of crossbred dams. Actual kid at the time of data recording was used as a covariate in models for weight-related traits. The covariate was not used for survival at weaning because of the inability of the model to converge when age was included. Random effects used for all models were contemporary group, sire nested within sire breed and pen nested within treatment and contemporary group. Linear mixed models by PROC MIXED (SAS, 2011) was used to analyze 30 d start weight, 60 d weight, 90 d weaning weight, ADG, shrink weight, and financial return values. Kid survival was analyzed utilizing a binomial distribution and logit function, and conformation and FAMACHA scores were analyzed utilizing a Poisson distribution and logit link function using generalized linear mixed model by PROC GLIMMIX in SAS applying the Newton–Raphson optimization technique with ridging and an overdispersion parameter (SAS, 2011). Kids that suckled from 30 d until weaning were coded "1" for survival and those that died were coded "0." The means calculated for kid survival, FAMACHA score, and market score were generated by inverse link transformation to the original scale.

For statistical analysis of dam data, the fixed effects used for all models were sire breed of dam, service sire breed, litter type, and treatment group. Response variables were dam body weight change, FEC, PCV, litter weights at 30, 60, and 90 d (weaning), and litter gross revenue. There were 12 creep and 17 noncreep dams removed from the analysis at weaning because of the loss of their litters. Dam weight at weaning subtracted from dam weight at 30 d was used to determine live weight change. Random effects used for all models were contemporary group, dam sire nested within dam sire breed, service sire nested within service sire breed, and pen nested within treatment. The FEC values were transformed using $\log_{10}$(FEC + 1) for analysis and back transformed using antilog to obtain geometric means. All variables were analyzed using linear mixed models by PROC MIXED in SAS (SAS, 2011).

For both kid and dam models, main effects and interactions were considered significant when probability levels were equal or less than 0.05 for the $F$-statistic. For testing creep treatment, pen was used as the experimental unit per St-Pierre (2007). Nonsignificant terms were removed to reduce models; however, treatment remained in all models regardless of significance. Least square means were analyzed using the Tukey–Kramer means separation test.

## RESULTS AND DISCUSSION

### *Kid Traits*

***Breed effects.*** Sire breed of kids influenced ($P < 0.05$) all kid traits except survival (Table 2). Myotonic-sired kids weighed less ($P < 0.05$) than Kiko- and Savanna-sired kids (Table 3). Wang et al. (2017) reported the smaller size of Myotonic goats compared with Kiko, Spanish, and Boer goats. Myotonic- and Savanna-sired kids had better ($P < 0.05$) conformation scores than Kiko-sired kids (Table 4). Previous work indicated that the Boer influence improved the conformation scores of kids when harvested at 7 mo of age compared with the Kiko and Spanish influence but did not improve objective measures of carcass yield (Browning et al., 2012). Savanna and Boer are similar breeds from South Africa and it seems that they similarly improve subjective kid conformation scores. Kiko-sired kids had better ($P < 0.05$) FAMACHA scores than kids of the other sire breeds (Table 4), suggestive of better health status.

Dam breed affected ($P < 0.05$) 7 of the 10 response variables (Table 2), including all of the weight-related traits. Kids of Myotonic dams tended to be on the lower end of the weight ranges and kids of Kiko dams tended to be on the higher end of the weight ranges (Tables 3 and 4). Breed comparisons should be viewed with some caution because this creep-feeding study was conducted across three separate mating schemes that were part of concurrent breed evaluations (Wang et al., 2017; Stevens, 2018;

**Table 2.** Sources of variation for kid traits

| | Sources of variation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Trait | Treatment (TRT) | Breed of sire (SR) | TRT × SR | Sire breed of dam (DM) | TRT x DM | Litter type (LT) | TRT × LT | Kid sex (SX) | TRT × SX |
| 30-d weight | NS | * | NS | *** | NS | *** | NS | *** | NS |
| 60-d weight | NS | ** | NS | *** | NS | *** | NS | *** | NS |
| Weaning weight | ** | * | NS | *** | NS | *** | NS | *** | NS |
| ADG | ** | * | NS | ** | NS | *** | NS | *** | NS |
| Shrink weight | NS | * | NS | *** | NS | *** | NS | *** | NS |
| Kid survival | NS | NS | NS | NS | NS | ** | NS | NS | NS |
| Conformation | NS | ** | NS | NS | NS | *** | NS | ** | NS |
| Gross revenue | NS | * | NS | *** | NS | *** | NS | *** | NS |
| Net income | NS | * | NS | *** | NS | *** | NS | *** | NS |
| FAMACHA | NS | ** | NS | NS | NS | *** | * | NS | NS |

Level of significance: ***$P < 0.001$; **$P \le 0.01$; *$P \le 0.05$; NS, $P > 0.05$.

**Table 3.** Genetic factors affecting preweaning kid traits

| Class | 30 d weight, kg | 60 d weight, kg | Weaning weight, kg | ADG$^{*}$, g | Survival, % |
|---|---|---|---|---|---|
| Breed of sire | | | | | |
| Kiko | 7.91 ± 0.45$^{a}$ | 12.84 ± 0.46$^{a}$ | 15.35 ± 0.81$^{a}$ | 115.50 ± 13.28$^{a}$ | 95.61 ± 3.26 |
| Myotonic | 7.14 ± 0.50$^{b}$ | 10.80 ± 0.58$^{b}$ | 12.79 ± 0.90$^{b}$ | 92.76 ± 13.95$^{b}$ | 89.47 ± 8.52 |
| Savanna | 8.21 ± 0.44$^{a}$ | 12.85 ± 0.44$^{a}$ | 15.20 ± 0.78$^{a}$ | 109.20 ± 13.14$^{a}$ | 92.89 ± 4.72 |
| Spanish | 7.44 ± 0.46$^{b}$ | 11.99 ± 0.48$^{ab}$ | 14.57 ± 0.83$^{ab}$ | 109.80 ± 13.44$^{a}$ | 95.31 ± 3.61 |
| Sire breed of dam | | | | | |
| Boer | 8.20 ± 0.43$^{a}$ | 12.70 ± 0.42$^{ab}$ | 14.61 ± 0.78$^{b}$ | 101.70 ± 13.16$^{b}$ | 91.91 ± 5.22 |
| Kiko | 8.27 ± 0.43$^{a}$ | 13.17 ± 0.41$^{a}$ | 16.16 ± 0.77$^{a}$ | 124.20 ± 13.09$^{a}$ | 90.97 ± 5.55 |
| Myotonic | 6.48 ± 0.46$^{b}$ | 10.66 ± 0.49$^{c}$ | 12.69 ± 0.85$^{c}$ | 97.56 ± 13.61$^{b}$ | 96.17 ± 3.48 |
| Savanna | 7.57 ± 0.51$^{a}$ | 11.92 ± 0.59$^{abc}$ | 14.17 ± 0.96$^{bc}$ | 102.80 ± 14.51$^{b}$ | 95.10 ± 5.46 |
| Spanish | 7.85 ± 0.42$^{a}$ | 12.16 ± 0.40$^{b}$ | 14.74 ± 0.76$^{b}$ | 107.80 ± 13.00$^{b}$ | 92.90 ± 4.39 |

$^{a,b,c}$Least square means (±SE) within a class and trait not sharing a common superscript differ ($P \le 0.05$).

$^{*}$ADG taken from 30 to 90 d of age.

**Table 4.** Genetic factors affecting kid traits 24 h after weaning

| Class | Shrink weight, kg | Conformation score | Gross revenue, $ | Net income, $ | FAMACHA score |
|---|---|---|---|---|---|
| Breed of sire | | | | | |
| Kiko | 14.53 ± 0.87$^{a}$ | 2.65 ± 0.16$^{a}$ | 56.74 ± 3.26$^{ab}$ | 55.67 ± 3.30$^{ab}$ | 2.60 ± 0.22$^{a}$ |
| Myotonic | 12.29 ± 0.96$^{b}$ | 2.33 ± 0.16$^{b}$ | 49.25 ± 3.93$^{b}$ | 48.19 ± 4.00$^{b}$ | 4.02 ± 0.41$^{b}$ |
| Savanna | 14.59 ± 0.85$^{a}$ | 2.39 ± 0.15$^{b}$ | 60.08 ± 3.13$^{a}$ | 59.09 ± 3.17$^{a}$ | 3.22 ± 0.25$^{b}$ |
| Spanish | 14.01 ± 0.89$^{ab}$ | 2.56 ± 0.16$^{ab}$ | 57.45 ± 3.40$^{ab}$ | 56.17 ± 3.45$^{ab}$ | 3.54 ± 0.29$^{b}$ |
| Sire breed of dam | | | | | |
| Boer | 14.03 ± 0.85$^{b}$ | 2.47 ± 0.15 | 56.55 ± 3.09$^{b}$ | 55.43 ± 3.12$^{b}$ | 3.50 ± 0.32 |
| Kiko | 15.68 ± 0.84$^{a}$ | 2.47 ± 0.15 | 63.77 ± 3.02$^{a}$ | 62.49 ± 3.06$^{a}$ | 3.20 ± 0.29 |
| Myotonic | 12.08 ± 0.90$^{c}$ | 2.46 ± 0.16 | 49.22 ± 3.48$^{b}$ | 48.11 ± 3.52$^{b}$ | 3.22 ± 0.34 |
| Savanna | 13.55 ± 1.00$^{bc}$ | 2.36 ± 0.17 | 55.08 ± 4.11$^{ab}$ | 54.02 ± 4.15$^{ab}$ | 3.56 ± 0.45 |
| Spanish | 14.02 ± 0.83$^{b}$ | 2.52 ± 0.15 | 54.77 ± 2.94$^{b}$ | 53.85 ± 2.98$^{b}$ | 3.35 ± 0.30 |

$^{a,b,c}$Least square means (±SE) within a class and trait not sharing a common superscript differ ($P \le 0.05$).

Khanal et al., 2019). Sire and dam breeds, although managed together, were not fully represented across all three mating schemes. However, each sire and dam breed was represented in all study pens and balanced between the creep-fed and noncreep pens within each contemporary group. It was important to account for breed variation when testing creep-feeding effects and to identify any breed × treatment effects. No breed × treatment interactions were evident for kid traits.

***Sex and litter-type effects.*** Litter type had a significant effect ($P < 0.05$) on all kid traits measured (Table 2). Singles weighed and gained more ($P < 0.01$) than twins at all time points (Table 5). Singles also had a better ($P < 0.01$) mean conformation score and higher ($P < 0.01$) financial return values than twins (Table 6). Singles were also more likely ($P < 0.01$) to survive until weaning compared with twins (Table 5). Sex had a significant effect ($P < 0.05$) on all traits except survival and FAMACHA (Table 2). Bucklings showed weight and weight gain advantages ($P < 0.01$) when compared with doelings for all weight and ADG periods (Table 5). Males also had a better conformation score ($P < 0.01$) and higher financial return values ($P < 0.01$) than females (Table 6). Performance advantages for single kids and male kids generally agree with previous work at this location (Browning and Leite-Browning, 2011).

***Creep-feeding effects.*** Intake of creep feed increased steadily throughout the 60 d study, with individual kids consuming an average of 90 g/d at the 5 wk midpoint and 154 g/d at the 9 wk endpoint of the study. Total per kid intake of creep feed across the study period was 4,482 g (71 g/d). Creep feeding significantly affected ($P < 0.05$) weaning weight and ADG (Table 2). There was no difference for kid weight ($P > 0.05$) among treatment groups at 30 d. This result was expected as the analysis was done to confirm balanced kid weights between the two treatment groups at the start of the project. Kids in creep-fed group weighed more and had a higher ADG ($P < 0.05$) than noncreep kids after 60 d of supplemental feed (Table 5). Over the course of

**Table 5.** Nongenetic factors affecting preweaning kid traits

| Class | 30 d weight, kg | 60 d weight, kg | Weaning weight, kg | ADG$^{*}$, g | Survival, % |
|---|---|---|---|---|---|
| Treatment | | | | | |
| Creep | 7.72 ± 0.42 | 12.37 ± 0.41 | 15.00 ± 0.77$^{a}$ | 113.80 ± 13.04$^{a}$ | 94.51 ± 3.42 |
| No creep | 7.62 ± 0.42 | 11.87 ± 0.42 | 13.95 ± 0.77$^{b}$ | 99.84 ± 13.07$^{b}$ | 92.79 ± 4.41 |
| Litter type | | | | | |
| Single | 8.62 ± 0.42$^{a}$ | 13.67 ± 0.40$^{a}$ | 16.13 ± 0.75$^{a}$ | 120.70 ± 12.94$^{a}$ | 96.55 ± 2.36$^{a}$ |
| Twin | 6.73 ± 0.42$^{b}$ | 10.57 ± 0.38$^{b}$ | 12.82 ± 0.75$^{b}$ | 92.94 ± 12.91$^{b}$ | 88.78 ± 6.29$^{b}$ |
| Sex of kid | | | | | |
| Doeling | 7.16 ± 0.42$^{a}$ | 11.07 ± 0.39$^{a}$ | 13.04 ± 0.75$^{a}$ | 92.07 ± 12.91$^{a}$ | 94.40 ± 3.50 |
| Buckling | 8.19 ± 0.42$^{b}$ | 13.18 ± 0.39$^{b}$ | 15.91 ± 0.75$^{b}$ | 121.60 ± 12.93$^{b}$ | 92.93 ± 4.31 |

$^{a,b}$Least square means (± SE) within a class and trait not sharing a common superscript differ ($P \le 0.05$).

$^{*}$ADG from 30 to 90 d of age.

**Table 6.** Nongenetic factors affecting kid traits 24 h after weaning

| Class | Shrink weight, kg | Conformation score | Gross revenue, $ | Net return,$ | FAMACHA score |
|---|---|---|---|---|---|
| Treatment | | | | | |
| Creep | 14.32 ± 0.85 | 2.49 ± 0.15 | 57.84 ± 3.05 | 55.73 ± 3.08 | 3.20 ± 0.25 |
| No creep | 13.42 ± 0.85 | 2.47 ± 0.15 | 53.92 ± 3.07 | 53.83 ± 3.10 | 3.41 ± 0.26 |
| Litter type | | | | | |
| Single | 15.50 ± 0.82$^{a}$ | 2.36 ± 0.14$^{a}$ | 63.46 ± 2.89$^{a}$ | 62.48 ± 2.92$^{a}$ | 2.98 ± 0.23$^{a}$ |
| Twin | 12.24 ± 0.81$^{b}$ | 2.61 ± 0.15$^{b}$ | 48.30 ± 2.87$^{b}$ | 47.08 ± 2.90$^{b}$ | 3.67 ± 0.28$^{b}$ |
| Sex of kid | | | | | |
| Doeling | 12.43 ± 0.81$^{a}$ | 2.55 ± 0.15$^{a}$ | 49.01 ± 2.86$^{a}$ | 47.81 ± 2.90$^{a}$ | 3.37 ± 0.28 |
| Buckling | 15.32 ± 0.82$^{b}$ | 2.41 ± 0.14$^{b}$ | 62.75 ± 2.88$^{b}$ | 61.75 ± 2.92$^{b}$ | 3.36 ± 0.28 |

$^{a,b}$Least square means (± SE) within a class and trait not sharing a common superscript differ ($P \le 0.05$).

the study, feed efficiency for the creep-fed kids was 7.47 g of creep feed per 1 g of added weight gain.

Kids in the current study showed increased weight gain while consuming creep feed at a lower rate than in previous goat studies. Goetsch et al. (2002) reported no increase in weight gain or kid weights when an 18% CP creep feed was consumed at 152 g/d on pasture from 6 to 19 wk of age. Creep feeding increased kid growth rates in Htoo et al. (2015) with kids consuming 230 g/d of a 14% CP feed in a pen-based, intensive management system from 7 to 84 d of age. Differences in management systems likely explain differences among studies for kid responses to creep feed. Lamb studies have also yielded mixed results. Most studies reported significant improvements in weaning weights of creep-fed lambs (Wilson et al., 1971; Vera and Ortega, 2000; da Silva et al., 2012; Terblanche et al., 2012; Brand and Brundyn (2015). To the contrary, Glimp (1971) and de Villiers et al. (2002) showed that creep feeding did not improve the weaning weight or ADG of lambs. There are a number of factors that could affect the growth response of lambs or kids to creep feed. Creep feed quality and intake levels are probably two of the more obvious influencing factors. Condition of the lactating does and pasture areas may also play a role. There was wide variation between the five contemporary groups for average creep feed intake levels on this study (13 to 136 g/d). This emphasized the importance of evaluating the influence of creep feeding over multiple years.

Creep feed did not alter ($P > 0.05$) shrink weights or kid conformation scores (Table 6). Martin et al. (1981) reported improved feeder calf grades (i.e., conformation scores) when creep feed was provided. There have not been prior reports of creep feeding improving conformation in small ruminants. Creep and noncreep kids did not differ ($P > 0.05$) for gross revenue or net income estimates. There were no other studies found in the literature reporting the effect of creep feed on goat kid financial returns. Additional costs associated with creep feeding equipment and labor were not factored into the analysis, which would further erode any potential financial benefit of creep feeding to a meat goat enterprise. Broadhead et al. (2018) reported that although creep feeding increased calf weaning weights, the added costs of creep feeding (feed, labor, equipment, etc.) resulted in a loss of $71.05/calf marketed for creep-fed calves compared with noncreep-fed calves over 3 yr.

Creep treatment did not interact with kid genetics or kid sex to affect any of the performance or health traits. Treatment interacted ($P < 0.05$) with litter type to influence kid FAMACHA scores (Table 1). In noncreep kids, single kids had better (lower) FAMACHA scores than twin kids (Figure 1). Creep feeding removed the effect of litter type on kid FAMACHA scores. Twin kids compete for milk, while single kids do not. Twins are more inclined to graze for nutrient intake, leading to greater *H. contortus* larvae ingestion from the pasture and elevated FAMACHA scores compared with single kids. Single kids may also have another undefined nutritional advantage that caused their FAMACHA scores to be lower than twin kids. Heightened nutritional challenges of twin kids may have been satisfied to some extent through creep feed supplementation, thus eliminating the litter-type effect on FAMACHA score and causing the significant interaction. The feed was not medicated, eliminating an active drug effect on FAMACHA scores. Creep feeding lowered FEC and anthelmintic treatments in lambs by 60 d of age (de Melo et al., 2017). The lamb observation supports the loss of difference in FAMACHA scores between singles and twins in the creep-fed group.

### Dam Traits

***Breed and litter-type effects.*** Service sire had an effect ($P < 0.05$) on 30, 60, and 90 d litter weights and litter gross revenue value. Sire breed of dam had an effect ($P < 0.05$) on all dam traits except fecal egg count. Myotonic-sired goats (dams or litters) had lower ($P < 0.05$) litter weights than the other breeds, while Kiko- and Spanish-sired dams produced litters with higher gross revenue values ($P < 0.05$) than litters produced by Boer- and Myotonic-sired dams (data not shown). It was previously reported that the Myotonic breed is a smaller-sized meat goat than Kiko and Spanish breeds and that significant variation existed among Boer, Kiko, and Spanish does for traits similar to those recorded here (Browning et al., 2011; Wang et al., 2017; Khanal et al., 2019).

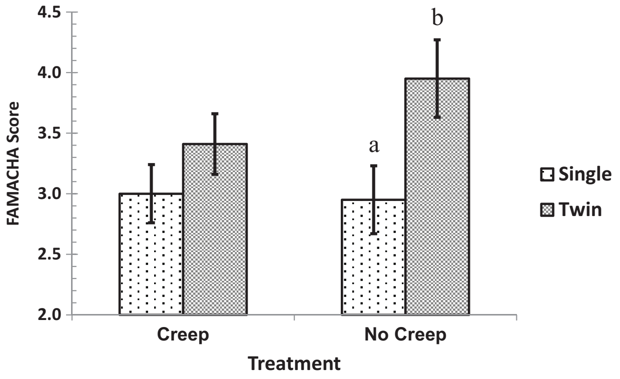

**Figure 1.** Treatment × litter-type effect on FAMACHA score in kids. $^{a,b}$Least square means (± SE) within the noncreep group differed ($P < 0.05$).

Litter type significantly influenced six of the seven dam traits measured (Table 7). There was greater ($P < 0.05$) weight loss in does that reared twins compared with those that reared singles (Table 7). Does and ewes lost more weight when they reared more offspring in previous studies (Constantinou, 1989; Snowder and Glimp, 1991; Browning et al., 2011), although this has not always been evident (Terblanche et al., 2012). As expected, litter weights and associated gross revenue were higher for does raising twins than for does raising singles (Table 7). Litter type is a major factor that determines productivity in small ruminant females.

***Creep-feeding effects.*** Creep feeding as a main effect did not influence any of the dam traits measured (Table 7). The lack of an effect on dam weight change agreed with observations in sheep (de Villiers et al., 2002; da Silva et al., 2012; Terblanche et al., 2012; Brand and Brundyn. 2015). The lack of a creep-feed effect on litter weights was unexpected considering the differences in litter weaning weight. The effect of creep feed on kid weaning weights (Table 5) appeared not large enough to affect litter weight significantly. There are no previous studies found that analyzed creep-feed effect on litter weight in meat goat does. Additionally, treatment did not interact with litter type to influence litter weight traits or most of the other traits recorded.

There was an important ($P < 0.05$) two-way interaction of treatment × litter type on PCV (Table 7). Within the noncreep group, dams rearing twins had lower PCV than dams raising singles. Creep feeding caused a loss of significance for the litter-type effect on dam PCV (Figure 2). Previously, does that bore twins were reported to have lower PCV values than those that bore singles (Baker et al., 1998; Mandonnet et al., 2005). Milk production increases with litter size independent of kid suckling activity (Browning et al., 1995). Lactation decreases immune support within the dam, making them more susceptible to parasites (Mandonnet et al., 2005; Beasley et al., 2010). A primary indicator of internal parasitism in goats is lowered PCV. Creep feed reduced dam sensitivities to litter-type effects on PCV in this study by perhaps lessening the differences in lactation-related stress between single- and twin-bearing dams. However, studies in cows and ewes concluded that milk yield was not affected by creep feed (Wilson et al., 1971; Lopes et al., 2016). It is not clear if the PCV differences between does raising singles or twins in the current study were the result of varied levels of internal

**Table 7.** Treatment and litter-type effects on doe production and health traits

| | Treatment (TRT) | | Litter type (LT) | | *P*-values | | |
|---|---|---|---|---|---|---|---|
| Trait | Creep | No creep | Single | Twin | TRT | LT | TRT × LT |
| Body weight change, kg | −1.75 ± 0.69 | −1.37 ± 0.69 | −1.08 ± 0.67$^{a}$ | −2.04 ± 0.69$^{b}$ | NS | ** | NS |
| 30 d litter weight, kg | 11.13 ± 1.03 | 10.90 ± 1.03 | 8.88 ± 1.02$^{a}$ | 13.15 ± 1.02$^{b}$ | NS | *** | NS |
| 60 d litter weight, kg | 17.65 ± 0.74 | 16.54 ± 0.74 | 13.79 ± 0.67$^{a}$ | 20.40 ± 0.67$^{b}$ | NS | *** | NS |
| Litter weight at weaning, kg | 21.87 ± 0.84 | 20.75 ± 0.84 | 16.02 ± 0.78$^{a}$ | 26.60 ± 0.82$^{b}$ | NS | *** | NS |
| Gross revenue value, $ | 80.36 ± 4.14 | 78.24 ± 4.13 | 62.48 ± 3.90$^{a}$ | 96.12 ± 4.10$^{b}$ | NS | *** | NS |
| Packed cell volume, % | 17.28 ± 1.25 | 17.21 ± 1.26 | 18.31 ± 1.21$^{a}$ | 16.18 ± 1.23$^{b}$ | NS | *** | * |
| Fecal egg count, eggs/g | 1,287 | 1,095 | 1,147 | 1,317 | NS | NS | NS |

$^{a,b}$Least square means (±SE) within a class and trait not sharing a common superscript differ.

Level of significance: ***$P < 0.001$; **$P \le 0.01$; *$P \le 0.05$; NS, $P > 0.05$.

parasitism or some other divergence in nutritional or health status. Dam FEC values discussed earlier did not help explain the PCV results. Elimination of the litter-type effect on dam PCV by creep feed mirrored the loss of a litter-type effect on FAMACHA scores in creep-fed kids.

This study examined the effects of creep feeding on meat goat kid and dam production and health traits. Creep feed increased preweaning weight gain and removed the litter-type effect on FAMACHA scores but did not affect kid survival, conformation, or financial return. Creep feed reduced the disparity in PCV between does raising singles and does raising twins, although FEC and doe weights were not altered. The effects of creep feeding on anemia indicators in kids and their dams were consistent and novel observations that may warrant further investigation. It might be advantageous to provide creep feed to kids for enhanced preweaning growth performance. However, for doe productivity, where enterprise profit or loss is generally determined, creep feeding did not have a substantial impact under the conditions of this study. Creep feeding input was not sufficient to modify the effects of major factors such as genetic composition, sex, or litter type on doe-kid performance outside of the anemia indicators. Different feed formulations or management plans may produce different responses to creep feed in meat goats. The dynamic nature of feed costs or kid market values should also be considered when assessing outcomes. Residual benefits of creep feeding that extend beyond weaning (and beyond the scope of this study) have not been explored. Additional research should be considered to better define the utility of creep feeding in commercial meat goat production systems.

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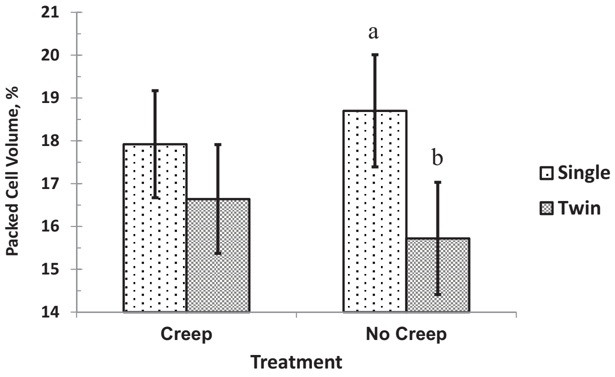

**Figure 2.** Treatment × litter-type effect on PCV in dams. $^{a,b}$Least square means (± SE) within the noncreep group differed ($P < 0.05$).

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