In most pasture-based, meat-goat production systems, a major management challenge is control of gastrointestinal nematodes (GIN). Use of legumes and forbs that contain plant secondary compounds may reduce fecal egg count (FEC) expressed as eggs per g of fresh feces (epg) and/or improve overall protein nutrition to help animals better tolerate effects of GIN parasitism. This research monitored performance, FEC, FAMACHA© scores, and number of doses of dewormer administered to meat-goat kids grazing chicory (Cichorium intybus L.; CHIC), birdsfoot trefoil (Lotus corniculatus L.; BFT), or red clover (Trifolium pretense L.; RCL) pastures. Goat kids grazing RCL (68.9 g/d ± 5 g/d) had greater (P < 0.03) overall average daily gain compared to those grazing CHIC (35 g/d ± 5 g/d); BFT (53.2 g/d ± 5 g/d) was intermediate. When averaged over the season, there was a weak trend (P = 0.19) for goat kids grazing CHIC (2,034 epg) to have greater FEC compared to RCL (1,194 epg); BFT (1,718 epg) was intermediate. Typically goat kids grazing CHIC had greater (P < 0.001) monthly FAMACHA© scores than those grazing RCL with scores for goats grazing BFT similar to RCL. There was a weak trend for number of dewormer doses administered based on FAMACHA© scores to be less (P = 0.13) when goats grazed RCL (5.5 doses) compared to CHIC (6.3 doses); BFT (6.1 doses) was intermediate. Grazing red clover pasture, and to some extent birdsfoot trefoil, appeared to have a beneficial effect on meat-goat kid performance and on GIN-parasite infection (low FEC) in comparison to chicory pastures.

Key Words: Birdsfoot Trefoil, Chicory, Goats, Parasites, Performance, Red Clover

Summary

In most pasture-based, meat-goat production systems, a major management challenge is control of gastrointestinal nematodes (GIN). Use of legumes and forbs that contain plant secondary compounds may reduce fecal egg count (FEC) expressed as eggs per g of fresh feces (epg) and/or improve overall protein nutrition to help animals better tolerate effects of GIN parasitism. This research monitored performance, FEC, FAMACHA© scores, and number of doses of dewormer administered to meat-goat kids grazing chicory (Cichorium intybus L.; CHIC), birdsfoot trefoil (Lotus corniculatus L.; BFT), or red clover (Trifolium pretense L.; RCL) pastures. Goat kids grazing RCL (68.9 g/d ± 5 g/d) had greater (P < 0.03) overall average daily gain compared to those grazing CHIC (35 g/d ± 5 g/d); BFT (53.2 g/d ± 5 g/d) was intermediate. When averaged over the season, there was a weak trend (P = 0.19) for goat kids grazing CHIC (2,034 epg) to have greater FEC compared to RCL (1,194 epg); BFT (1,718 epg) was intermediate. Typically goat kids grazing CHIC had greater (P < 0.001) monthly FAMACHA© scores than those grazing RCL with scores for goats grazing BFT similar to RCL. There was a weak trend for number of dewormer doses administered based on FAMACHA© scores to be less (P = 0.13) when goats grazed RCL (5.5 doses) compared to CHIC (6.3 doses); BFT (6.1 doses) was intermediate. Grazing red clover pasture, and to some extent birdsfoot trefoil, appeared to have a beneficial effect on meat-goat kid performance and on GIN-parasite infection (low FEC) in comparison to chicory pastures.
Introduction

Production of meat goats supplies both live animals and meat for many ethnic and health-product markets in the United States (Liu et al., 2013). In most pasture-based, small-ruminant production systems, a major management challenge is control of gastrointestinal nematodes (GIN). Overloads of GIN, especially the barbepore worm (Haemonchus contortus L.) can severely reduce goat-kid weight gain (Zajac and Moore, 1993). Many currently available anthelmintics are becoming ineffective in controlling GIN due to parasite resistance to these drugs (Terrill et al., 2001; Howell et al., 2008). If not controlled, Haemonchus, a blood feeder, can cause severe anemia resulting in poor weight gain and deteriorating health in goats.

The use of the FAMACHA© system by producers to determine the degree of anemia and need for administering dewormer to individual animals can help to slow the rate of resistance of GIN to anthelmintic drugs (Kaplan et al, 2004). Management options for grazing livestock can also help reduce effects of GIN infection. Use of legumes and forbs can improve overall protein nutrition to boost the immune system and improve animal resilience to Haemonchus. When finishing livestock on pasture, resilience is defined as an animal’s ability to maintain body weight gain in spite of increasing GIN burdens (Albers et al., 1987). In addition, grazing management using rotational stocking (Burke et al., 2009) can break the worm life cycle and help maintain swards with high nutritive value (increased energy and protein) for increased GIN resilience in meat goats (Turner et al., 2014).

Some grasses, legumes, and forbs contain plant secondary compounds that may reduce GIN loads. Forage chicory (Cichorium intybus L.) is a perennial forb, which contains a group of secondary plant compounds (sequiterpene lactones; Foster et al., 2011) that can potentially reduce GIN-parasite infections (Marley et al., 2003). Birdsfoot trefoil (Lotus corniculatus L.) is a perennial legume that contains condensed tannins (CT) and can improve protein utilization in ruminants (Naumann et al., 2013) and reduce fecal egg count (FEC; Min et al., 1999; Terrill et al., 2009).

Red clover (Trifolium pretense L.) is a legume containing the secondary plant compound, polyphenol oxidase, which increases rumen-undegradable protein for improved protein nutrition in ruminants (Broderick and Albrecht, 1997).

The objective of this research was to monitor FEC, FAMACHA© scores, selective blood parameters, and the number of doses of dewormer administered to meat-goat kids when finished on pastures of chicory (CHIC), birdsfoot trefoil (BFT), or red clover (RCL).

Materials and Methods

All experimental procedures were previously reviewed and approved by the Institutional Animal Care and Use Committee, Appalachian Farming Systems Research Center, Beaver, W.Va., United States. The experiment was conducted for two years during the 2009 and 2010 growing seasons in Beaver, W.Va. Details as to the establishment, seeding and agronomic management are reported by Cassida and Turner (2016).

In summary, replicated 0.2-ha pastures of CHIC (cv. Oasis); BFT (cv. Pardee); or RCL (cv. Cinnamon) were established with prairie bromegrass (Bromus catharticus Bahl. cv. Lakota). Each of nine pasture strips was divided into 10 paddocks (14.6 m x 14.6 m). Pastures were managed with rotational stocking using 72 meat-goat kids (beginning mean BW 24.2 kg ± 0.6 kg). Beginning in late May through late September/early October, kids were moved approximately every 4 d resulting in about a 36-d rest period each year. Animal BW were determined in June through mid-September. In 2009, data collection began on 9 June, while in 2010 data collection was initiated on 8 June; then in each year, data were collected every 14 d and ended on 15 September and 14 September, respectively. In 2009, because of health concerns during the same time frame in the study because there was no similar concern during the same time frame in August, data collection became every 2 wk (Zajac and Conboy, 2006), and third-stage larvae were classified to determine percent H. contortus in the larval population.

At the end of each month (every 28 d), 10 ml of blood were collected via jugular venipuncture from each animal and packed cell volume (PCV) was determined via centrifugation to measure degree of anemia. The remainder of blood was allowed to clot, centrifuged to isolate serum, and serum stored at -20°C until analyzed for total protein and albumin using automated procedures on an Express Plus Chemistry Analyzer (PoleStar Labs, Escondido, Calif.). Blood globulin was determined by difference (total protein minus albumin) to assess activity of the immune system.

Statistics.

For this evaluation, a database was used that had the same time frame each year in order to evaluate the number of doses of dewormer administered to the animals during this critical time beginning in June through mid-September. In 2009, data collection began on 9 June, while in 2010 data collection was initiated on 8 June; then in each year, data were collected every 14 d and ended on 15 September and 14 September, respectively. In 2009, because of health concerns for the majority of the grazing animals, an extra FAMACHA© assessment was done the following week after the first-scheduled assessment in August. On that date, all animals grazing CHIC, BFT and RCL pastures were administered the two dewormers; this data was not included in the overall evaluation of the study because there was no similar concern during the same time frame in August 2010.

For the 120-d time frame in this evaluation, biweekly BW was used to calculate an overall average daily gain (ADG).
The BW and ADG during this time frame were analyzed using PROC MIXED of SAS (SAS Inst. Inc., Cary, N.C.). The FEC and biweekly FAMACHA® were analyzed using PROC MIXED in SAS (SAS Inst. Inc., Cary, N.C.). The FEC data were transformed via logarithm as \[ \log_{10} (\text{FEC} + 1) \] to accommodate a count of zero; transformed data statistics were used for statistical inferences, while untransformed least square means were presented. The FEC data and bi-weekly FAMACHA® score data were analyzed using day as a repeated measure with the following linear model: rep (random) tmt (fixed) rep*tmt (random) year (fixed) year*tmt (fixed) rep*year (random, pooled) rep*year*tmt (random, pooled) date*year*tmt (fixed) date*year (fixed), date*year*tmt (fixed), residual (random). Designations were as follows: rep is the replicate; tmt is the pasture (CHIC, BFT, RCL) treatment; year is the year of study; and date is the date when FAMACHA® and FEC was determined for an individual animal. Mean separations were done using t-statistics at \( P<0.05 \) unless otherwise indicated with \( P \leq 0.10 \) considered a trend, \( P \leq 0.15 \) a weak trend, and \( P > 0.15 \) a numerical difference, and separated using PDIFF of SAS (SAS Inst. Inc., Cary, N.C.).

Monthly blood data and associated FAMACHA® scores were analyzed as a multi-year, randomized complete block design based on the field layout of pastures (pastures were not re-randomized each year) using PROC MIXED in SAS (SAS Inst. Inc., Cary, N.C.). Year and tmt were designated as fixed effects, while replication was random. Measurement periods within year were analyzed as a repeated measure. All differences were significant at \( P < 0.05 \), unless otherwise indicated with \( P \leq 0.10 \) considered a trend, \( P \leq 0.15 \) a weak trend, and \( P > 0.15 \) a numerical difference, and separated using PDIFF of SAS (SAS Inst. Inc., Cary, N.C.).

Results

Body Weight and 120-d ADG.

Overall there was a treatment by date interaction (\( P < 0.01 \)) for changes in BW over this 120-d period (Figure 1). Meat goats grazing RCL had greater (\( P < 0.05 \)) BW compared to CHIC on all weigh days (Figure 1); meat goats grazing BFT were typically intermediate, except early in the grazing season. Mid- to late-season (8 June to 15 September) pasture treatment influenced overall BW and followed a trend (\( P < 0.01 \)) of RCL (28.5 kg ± 0.5 kg) > BFT (27 kg ± 0.5 kg) > CHIC (25.6 kg ± 0.5 kg). Goat kids grazing RCL (69 g/d ± 5 g/d) had greater (\( P < 0.03 \)) 120-d ADG compared to those grazing CHIC (35 g/d ± 5 g/d); BFT (53 g/d ± 5 g/d) was intermediate (Table 1). The 120-d mean ADG across all pasture treatments in 2010 (58.3 g/d ± 3.9 g/d) was greater (\( P < 0.05 \)) compared to 2009 (46.4 g/d ± 3.9 g/d).

FEC.

Overall, there was a year by date interaction (\( P < 0.001 \); in 2009, FEC were greater on 22 June, 6 July, 20 July, 1 September, and 15 September, but not different on other sampling dates compared to 2010 (Figure 2). When averaged over the 120-d period using both years, goat kids grazing CHIC (2034 epg...
± 207 epg) tended (P = 0.19) to have numerically greater FEC compared to RCL (1194 epg ± 206 epg); BFT (1718 epg ± 210 epg) was intermediate. The FEC was variable over each 120-d period in 2009 and 2010 (Figure 3); there was no year by date by pasture treatment interaction (P > 0.20).

Monthly Blood PCV and FAMACHA© Score

In June and August, PCV were not different (month by treatment interaction, P < 0.001) among pasture treatments. In July goats grazing RCL had greater PCV than those grazing BFT or CHIC, while in September those grazing RCL had greater PCV than those grazing CHIC; BFT was intermediate (Figure 4). Corresponding monthly FAMACHA© scores showed a similar, but opposite trend to PCVs (month by treatment interaction, P < 0.001; Figure 4). When averaged over the 120-d grazing seasons, no difference among pasture treatments were observed for monthly PCV (mean 28 percent) or FAMACHA© scores (mean 2.9).
Monthly Serum Total Protein, Albumin, and Globulin Concentrations.

All blood-serum concentrations are expressed as mg/dL. There was a trend for a month by treatment interaction ($P = 0.07$) for total protein (Figure 5). Goat kids grazing RCL had greater ($P < 0.05$) total protein in serum compared to those grazing CHIC in July, August, and September; those grazing BFT were similar ($P > 0.10$) to CHIC in July, and similar ($P > 0.10$) to RCL in August and September. Overall, total protein was greater ($P < 0.05$) for kids grazing RCL compared to CHIC, with BFT intermediate.

Serum albumin concentrations followed a similar numerical trend (month by treatment interaction; $P < 0.20$) as total protein for RCL and CHIC in June, and BFT was intermediate in August and September (Figure 5). Overall, goat kids grazing RCL showed a trend for greater ($P = 0.07$) blood albumin compared to those grazing CHIC, with BFT intermediate.

There was little evidence of month by treatment interaction ($P > 0.40$) or treatment ($P > 0.40$) effect for serum globulin concentrations (Figure 5). Overall, concentrations in June, August, and September were similar (mean 2.9 mg/dL ± 0.1 mg/dL); all were greater than concentrations in July (2.7 mg/dL ± 0.1 mg/dL).

Bi-weekly FAMACHA® Score

There was a treatment by date interaction ($P < 0.001$) for bi-weekly FAMACHA® score (Figure 6). Overall, FAMACHA® scores were not different ($P > 0.10$; Figure 6) for 8 June, 22 June, 6 July, and 17 August; however, on 20 July, 3 August, and 1 September goat kids grazing CHIC had greater ($P < 0.05$) scores than those grazing RCL. On 15 September, scores when grazing CHIC were greater ($P < 0.05$) than when grazing BFT with scores from RCL intermediate. Typically, scores for goats grazing BFT were similar to RCL or intermediate. On the 15 September, FAMACHA® scores for goats grazing CHIC were greater ($P < 0.05$) than those grazing BFT with RCL intermediate (Figure 6). There was also a year by date effect ($P < 0.001$) in that scores in June, mid-August and mid-September were greater in 2010 compared to 2009 (data not shown). Bi-weekly FAMACHA® scores among pasture groups averaged 2.9 over the 120-d period (Table 2).

Doses of Dewormer

The number of dewormer doses administered based on FAMACHA® scores showed a weak trend ($P = 0.13$) to be less when goats grazed RCL (5.5 doses) compared to CHIC (6.3 doses); BFT (6.1 doses) was intermediate (Table 2). When comparing actual number of doses administered to a once monthly deworming regimen (COUNTQ ratio), goat kids grazing RCL (1.4 ratio) received less ($P < 0.03$) dewormer doses compared to goat kids grazing either BFT (1.5 ratio) or CHIC (1.6 ratio), but this was impacted by year (Figure 7). Overall
mean-total doses of dewormer given per animal per year was less (P < 0.001) in 2009 (5.3) compared to 2010 (6.6). Overall mean days to first re-dosing was not different (P > 0.82) among the pasture groups (mean 29.8 days; Table 2). However, since more doses were administered in 2010 compared to 2009, the days to first re-dosing were shorter (year-by-treatment interaction, P < 0.001) for CHIC, BFT and RCL in 2010 (22.8, 21.6, and 17.5, respectively) compared to 2009 (38.5, 36.2, and 42, respectively; Figure 8).

**Discussion**

**Weight Gain**

The 120-d weight gain by meat-goat kids grazing CHIC were less compared to those grazing RCL and BFT (Table 1). Comparative weight-gain data for meat goats grazing improved temperate pastures containing chicory, birdsfoot trefoil, or red clover is limited. Across all types of improved pasture, reported season-long weight gains by meat goats in the United States ranged from 27 g d⁻¹ to 100 g d⁻¹ (Goodwin et al., 2004; Animut et al., 2005; Muir, 2006; Lema et al., 2007; Lema et al., 2008; Turner et al., 2013; 2014). Meat-goat kids gained 90 g d⁻¹ grazing pure chicory in Tennessee (Lema et al., 2008), which was better than grazing chicory/brassica mix or bermudagrass (Cynodon dactylis L.). No weight-gain comparisons were located for meat goats grazing birdsfoot. Turner et al. (2013) reported similar change in body weight trends and gains when meat-goat kids grazed red clover plus orchardgrass (Dactylis glomerata L.) pastures. The reason for less weight gain when meat-goat kids grazed CHIC compared to RCL or BFT in the present study is related to variations in forage mass and nutrient composition in CHIC paddocks compared to RCL or BFT in 2009 (Turner et al., 2010; Cassida and Turner, unpublished data), thus potentially reducing DMI and overall performance when compared to RCL or BFT. However, this contrasts with results from New Zealand, where lambs gained more weight when grazing chicory than birdsfoot trefoil (Marley et al., 2003; 2006). Lambs typically gain 50 percent to 150 percent more weight than meat-goat kids on the same pastures (Animut et al., 2005; Turner et al., 2014) and others have reported gains of 150 g d⁻¹ to 300 g d⁻¹ grazing pure stands of chicory (Kidane et al., 2010; Miller et al., 2011).

Performance (change in body weight and gain) by grazing livestock is impacted by a complex interaction of factors including: forage species, plant selectivity by the animal, dry matter intake, and forage digestibility; all of these factors in turn are influenced by livestock species, seasonal changes in proportion of forage species in the sward, forage mass, nutritive value, time on pasture, and secondary plant compounds (Villalba and Provenza, 2009). In a short, 21-d feeding study, Heckendorn et al. (2007) reported that lambs offered fresh chicory did not gain weight (zero g/d) compared to lambs offered fresh birdsfoot trefoil (80 g/d) or ryegrass-alfalfa (70 g/d) forages. In an 80-d graze-
ing study, Miller et al. (2011) reported greater ADG when lambs grazed chicory (280 g/d) compared to bermudagrass (20 g/d) pastures. Overall performance (weight gain) in ruminants is related to DMI and forage digestibility. Heckerdorn et al. (2007) reported that the DMI by lambs offered freshly-harvested chicory was about half compared to lambs offered fresh ryegrass-alfalfa (*Medicago sativa* L.) forage during a short feeding trial and may have been related to initial animal adjustment to the diet. The overall digestibility of chicory alone can be similar to alfalfa (Turner et al., 1999). Although CHIC paddocks in the present study contained little if any bromegrass during the grazing season (K.A. Cassida, personal communication), successful establishment and maintenance of a cool-season grass in chicory pastures may improve rumen breakdown and use of organic matter and fiber for improved digestibility and overall nutritive value of chicory (Li and Kemp, 2005). Chicory is high in pectin (typically 80 g/kg to 90 g/kg DM; Ivarsson et al., 2011). Pectin is rapidly fermented in the rumen and needs a high rumen-degradable protein (RDP) present to insure efficient microbial protein synthesis for optimal nutrient-use efficiency during rumen microbial fermentation. Even though chicory was high in crude protein (CP) in the present study, the protein may not be rapidly degraded in the rumen (high RDP); this aspect was not evaluated in the current study. In a reverse scenario to the present study, addition of 10 percent sugar beet (*Beta vulgaris* L.) pulp (high pectin) to an Italian ryegrass [*Lolium perenne* L. ssp. *multiflorum* (Lam.) Husnot] hay diet (high in CP) resulted in optimal microbial protein synthesis in goats (Masuda et al., 1999).

The energy-to-protein ratio in grazed forages has an overall impact on nutrient utilization in the rumen and weight gain in growing animals. For growing goat kids, the desired total digestible nutrients (TDN) to CP ratio ranges from 5.8 to 6.1 (Turner et al., 2013). McCutcheon et al. (2012) reported that the season-long (9 July to 4 September) mean TDN:CP ratio for chicory grown in Ohio was 3.6. In beef cattle, TDN:CP ratios < 5 suggested the need for supplemental energy for
improved utilization of protein (Moore et al., 1999). In the present study, the ratio was approx. 4.5 for CHIC (high CP) and 3.5 for BFT and RCL (high CP; K.A. Cassida, personal communication); all indicated low available energy in relation to available protein in the rumen. Even with the need for supplemental energy, consideration then must be given to the type of energy supplement [corn grain (high starch) compared to soy hulls (low starch)]. More research is needed to address the type of supplemental energy and protein for different forage swards to aid in understanding improved performance and resilience to GIN infection in grazing meat-goat kids.

Although not evaluated in the present study, secondary plant compounds can also influence performance by ruminants. Phytoestrogens in red clover can improve overall weight gain in lambs (Moorby et al., 2004). Birdsfoot trefoil contains CT which can improve nutrient (protein) use and improve weight gain in lambs (Douglas et al., 1995). Overall impact of sesquiterpene lactones on weight gain of growing goats has not been reported.

**FEC**

Lack of differences among forage treatments in our study contrasts with previous reports. Niezen et al. (1994) reported that lambs grazing chicory had greater FEC compared to those grazing red clover. Marley et al. (2003) reported that lambs grazing chicory had greater FEC than lambs grazing birdsfoot trefoil on day 7 of a grazing study. Miller et al. (2011) reported lower FEC when lambs grazed chicory pastures compared to bermudagrass pastures for 80 d. In contrast, Heckendorn et al. (2007) reported that feeding fresh-harvested chicory or birdsfoot trefoil reduced total daily FEC (specific for *Haemonchus*) by 89 percent and 63 percent, respectively, when compared to a control group of lambs offered fresh-harvested ryegrass-alfalfa. Kidane et al. (2010) observed lower FEC when growing lambs (artificially dosed with the abomasal parasite, *Teladorsagia circumcincta*) grazed chicory compared to perennial ryegrass-white clover pastures. *T. circumcincta* is an internal strongylid parasite, which infects the lining of the abomasum, but unlike *Haemonchus* does not feed on blood to cause anemia (Roebet al.,
During the grazing season in the present study in a temperate environment in the eastern U.S. pastures, the major GIN in cultivated feces was *H. contortus* (data not shown). Even though *Haemonchus* was the dominant larval species in the present study, FEC was not reduced when meat-goat kids grazed chicory compared to RCL or BFT. Marley et al. (2003) reported that lambs grazing chicory had greater FEC compared to those grazing birdfoot trefoil and speculated that CT in birdfoot trefoil reduced egg-laying abomasal adults and not stage-4 larvae, whereas with the secondary compounds in chicory, the reverse was true. Nadarajah et al. (2015) reported a 6-yr summary of meat-goat bucks of various breeds finished on pasture after an initial administration of dewormers representing two or three classes of anthelmintic. Any subsequent administration of dewormer was based on individual FAMACHA® score of 3 or greater. Bucks administered no additional dewormer were classified as resistant to GIN, while those administered subsequent dewormer were classified as susceptible to GIN. Resistant bucks had greater ADG and lower FAMACHA® scores than susceptible bucks; FEC was not different between the groups.

Interpretation of data from grazing studies using selective deworming of individual animals (used in the present study) is difficult (Burke et al., 2009). Wildeus and Zajac (2005) have reported seasonal trends in GIN in pastures grazed by meat goats. In the present study, greater FEC were observed in 2009 compared to 2010. This is, in part, related to a greater number of doses administered per animal and shorter number of days to re-dosing in 2010 compared to 2009. In addition, 2009 was the first year pastures were grazed since establishment of forages in the pastures. Grazing in 2009 probably loaded pastures with parasite eggs which could have survived the winter resulting in greater initial levels in 2010 pastures compared to 2009 and the greater need for control (administer dewormer) in 2010. Also, different groups of goat kids with different genetics were used each year. Young, growing meat-goat kids with high dietary nutrient requirements are typically more sensitive to GIN infections compared to older animals. The aim of selective deworming using FAMACHA® is to reduce FEC in animals shedding the most eggs based on development of anemia measured by the eye-lid score; therefore, a source of variation in FEC throughout the grazing season is a result of selective deworming practices. Our study also used grazing management based on rotational stocking of paddocks. Re-entry time to a previously grazed paddock can affect FEC (Burke et al., 2009). In the present study, reentry time averaged approximately 24 d across the grazing season, which was likely not long enough to reduce infective larval populations on grazed forage. During the summer with adequate moisture and high ambient temperatures, conditions are typically favorable for GIN (especially *Haemonchus*) egg hatch and subsequent larval development (Colvin et al., 2008) and probably influenced trends in FEC. Also, the main goal of grazing management using rotational stocking is to maintain vegetative swards with a high-nutritive value (high energy and protein). Grazing high-protein clovers reduced dependence on anthelmintics to control abomasal GIN in lambs (Marley et al., 2005); a similar result was seen in the present study when goats grazed red clover (high protein). However, goats have a delayed immune development to GIN and typically avoid ingestion of parasitic larvae by grazing the tops of canopies. By using rotational stocking for sward management, a low-profile, leafy sward is maintained, and when grazed by goats, more parasitic larvae are likely ingested (Burke et al., 2009).

**Monthly Blood PCV and FAMACHA® Score**

For goats, all blood PCV values were within normal (22 percent to 38 percent) range (Jain, 1993). The overall mean monthly FAMACHA® score (Table 2) was 2.9 (on a 5-point scale; 1 = no anemia and 5 = severe anemia associated with the burden level of *Haemonchus*; Kaplan et al., 2004). In general, a blood PCV of less than 21 percent or a FAMACHA® score of 3 or greater on the scale indicates anemia and the need to deworm meat goats to control *Haemonchus*. Turner et al. (2013) reported similar PCV values and FAMACHA® scores when goat kids grazed red-clover-grass pastures; however, meat-goat kids in that study were dewormed monthly and FAMACHA® scores were used as a supplemental evaluation in order to help monitor the deworming program.
Monthly Serum Total Protein, Albumin, and Globulin Concentrations

Meat goats grazing RCL in the present study had greater weight gains and serum-total protein and lesser FEC compared to CHIC; serum-globulin concentrations were not different among the animals grazing the three different forages. Goats grazing RCL and BFT probably had improved nutrients (especially CP; K.A. Cassida, personal communication) to support greater performance and any immune response to GIN. Greater serum-total protein and globulin have been suggested to be indicative of greater GIN and an active immune response in lambs grazing alfalfa compared to red clover (Marley et al., 2005). In comparison to sheep, goats have a delayed immune response to GIN, and immune responses are typically not fully expressed until 12 months (Hoste et al., 2008). Immune involvement or regulation in goats has been suggested to reduce larval growth/development once larvae are ingested, thus maturation to adult worms is reduced along with FEC (Hoste et al., 2010). The FEC was reduced in young goats grazing RCL compared to CHIC in the present study, but it is not clear if goats were mounting an immune response as calculated serum-globulin concentrations were not different among goats grazing the three forages, with BFT being intermediate.

Results of the present study represent a complex relationship among forage secondary compounds, forage CP, FEC, and blood parameters. Chicory contains sesquiterpene lactones, which are reported to have anthelmintic activity (Foster et al., 2011). Grazing plants with CT (Min and Hart, 2003), such as BFT, has been reported to reduce FEC possibly by CT damaging the cuticle on adult Haemonchus to reduce total female adults laying eggs, and thus overall FEC (Kommuru et al., 2015). In addition, interpretation of results is further complicated by selective deworming of individual animals in each pasture group, which probably impacted the number of adult female worms, FEC, and blood parameters.

Doses of Dewormer

Miller et al. (2011) reported reduced GIN infection and need for administration of dewormer when lambs grazed chicory compared to bermudagrass pastures. Turner et al. (2016) reported that a GIN-resistant sheep breed, Katahdin, needed less deworming (based on FAMACHA® score) compared to Suffolk lambs and meat-goat kids (Boer breeding) when finished on orchardgrass-red clover-white clover pastures. In the present study, doses of dewormer were based on FAMACHA® scores and varied with year (Figure 7 and Figure 8). The FEC and need to deworm based on FAMACHA® score were probably more influenced by seasonal rainfall patterns (Cassida and Turner, 2016) than by different goat groups used each year.

Conclusion

Grazing red clover, and to some extent birdsfoot trefoil, appeared to have a beneficial effect on meat-goat-kid performance (high ADG) and resilience to GI-parasite infection (low FEC and reduced administration of dewormer) in comparison to forage chicory.

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