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The Use of Chambourcin Grape Extract as a Natural Anthelmintic in Goat Kids

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Summary

Gastrointestinal parasitism is one of the greatest economic threats to goat production in the United States. Further, with increased frequencies of anthelmintic resistance, there is compelling interest in natural dewormers, such as alternatives containing condensed tannins. Therefore, the objective of this study was to evaluate effects of fermented Chambourcin grape extract (CG) on parasite level and performance in meat-type goat kids. On October 14, 2014, mixed-breed male and female meat-type goat kids (n = 45; 17.17 kg ± 0.79 BW) were stratified by fecal egg count, weight, sex, and were allocated randomly to 1 of 3 treatments: 1. an oral dose (10-mL per 4.5 kg of BW) of CG at 7 d (D7) intervals (n = 15), 2. the same dose of CG at 14 d (D14) intervals (n = 15), or 3. control (C; 30-mL oral dose of water at 14 d intervals; n = 15). Condensed tannins were extracted, purified, and standardized from CG and were found to have a concentration of 0.33 mg/mL. Kids were maintained on tall fescue [*Lolium arundinaceaum* (Schreb.) Darbysh] and mixed-browse pasture with 14-percent crude-protein, corn-soybean-meal-based creep feed for the duration of the 63-d study. Data were analyzed using PROC MIXED of SAS. Two contrast statements were used to compare the mean of C compared with D7 and D14 and the mean of D7 compared with D14. Start BW, end BW, ADG, and gain did not differ ($P \geq 0.42$) across treatments. Start, end, and change from start to end body condition scores, fecal egg counts, and packed cell volumes did not differ ($P \geq 0.12$) across treatments. End FAMACHA© scores were higher ($P = 0.02$) from D7 and D14 compared with C. White blood cell (WBC) concentrations at the end of the study were lower ($P = 0.04$) from C compared with D7 and D14; whereas, D14 tended ($P = 0.08$) to be greater compared with D7. Start neutrophil concentrations tended ($P = 0.08$) to be higher from C compared with D7 and D14 and a change ($P = 0.05$) was found in neutrophil concentrations from start to end of study from C compared with D7 and D14. End of study basophil concentrations were greater ($P = 0.04$) from D14 compared with D7. End of study hemoglobin concentration and mean-corpuscular hemoglobin concentration percent tended to be lower ($P = 0.07$ and $P = 0.06$, respectively) from C compared with D7 and D14. End of study mean-corpuscular hemoglobin concentrations were lower ($P = 0.04$) from C compared with D7 and D14 and a change ($P = 0.04$) was found in mean-corpuscular hemoglobin concentrations from start to end of study from C compared with D7 and D14. Change from start to end of study platelet concentrations differed ($P = 0.04$ and $P = 0.02$, respectively) from C compared with D7 and D14. Other blood parameter counts were similar ($P > 0.10$) across treatments. Therefore, fermented Chambourcin grape extract may not be an effective natural anthelmintic for controlling nematodes in creep-fed goat kids.

Key Words: Anthelmintic, Condensed Tannin, Goats, Grape Extract

Introduction

Gastrointestinal nematodes (GIN) are the largest constraint to profitable goat production worldwide (Shaik et al., 2006). Since their introduction in the 1960s, broad-spectrum synthetic anthelmintics have been the primary defense against GIN infection in small ruminants (Hoste, 2011). However, due to widespread prevalence of anthelmintic resistance in goat GIN and in response to increased consumer awareness of chemical use in agricultural production, alternative, natural control methodologies are needed to increase profitability in the small ruminant industry (Shaik et al., 2006; Terrill et al., 2009).

A compilation of research by Muir (2011) suggested that phytotherapy or use of plants containing flavonoids, as a natural anthelmintic, should be evaluated. The most abundant flavonoids are polyphenols (Githiori, 2006). Polyphenols are tannins, which manifest as plant secondary metabolites, and are linked to plant defense mechanisms against insects (Githiori, 2006; Oksana et al., 2012). Tannins are comprised of two groups: condensed tannins (CT) and hydrolysable tannins (Anthanasiadou, 2001). Condensed tannins are compounds that may demonstrate biological activities in ruminants, such as binding to proteins and suppression of GIN infection (Naumann et al., 2013).

Elevated levels of CT have been quantified in dark red, blue, or black pigmented fruits, such as grapes; many dark orange or red-skinned vegetables; some legume cereals and beans; tree nuts, such as almonds, pecans and hazelnuts; cocoa beans; wine; and spices, such as cinnamon (King and Young, 1999; Gu et al., 2004; Mattivi et al., 2008). King and Young (1999) indicated that pH, level of astringency, and bitterness are linked to CT concentration (King and Young, 1999). Condensed tannins are compounds that possess high molecular weights, 500 to 3,000, that demonstrate biological activities causing them to react and precipitate most proteins (Muir, 2011). An increase in concentration of CT is also observed when comparing red grape juice to red wine (King and Young, 1999), indicating that fermentation may positively influence CT levels (Githiori, 2006).

In a companion paper, Cash et al. (2016) reported that organic fermented Pinot Noir grape extract may be an effective strategy for controlling GIN and increasing performance in Katahdin lambs. Therefore, the objective in the current study was to evaluate effects of fermented Chambourcin grape extract on performance and parasite level in goat kids.

Materials and Methods

Animals and experimental design

This project was conducted at the Lincoln University Allen T. Busby Farm in Jefferson City, Mo. and was approved by the Animal Care and Use Committee (14-4). Pastures at the Allen T. Busby Farm have been historically utilized for small ruminant grazing. Mixed-breed, male and female meat-type goat kids (n = 45; 17.17 kg ± 0.79 kg BW) were maintained on endophyte-infected tall fescue [*Lolium arundinaceaum* (Schreb.) Darbysh] and mixed-browse pasture with 14-percent crude-protein (CP), corn-soybean-meal based creep feed for 81 d post-weaning and were allowed to acquire a natural GIN infection. Starting October 14, 2014, kids were stratified by FEC, weight, and sex, and allocated randomly to 1 of 3 treatments: 1. drenched with Chambourcin grape extract (CG) every 7 d (D7) at a rate of 10-mL per 4.5 kg of BW (n = 15); 2. drenched with CG every 14 d (D14) at a rate of 10-mL per 4.5 kg of BW (n = 15); and 3. drenched with 30-mL of water every 14 d (C; n = 15). In accordance with established farm procedures, animals were removed from the study if they met three out of the following four criteria: 1. FEC of > 4,000 eggs/g; 2. FAMACHA© score of > 4; 3. packed cell volume (PCV) of < 21 percent; or 4. a BCS < 2. For the duration of the 63-d trial, kids grazed fescue and mixed-browse pasture and had *ad libitum* access to water, mineral (Redmond Naturals, Redmond, Utah), and creep feed. Throughout the study, kids were maintained in a single group with ear tag numbers as the primary identification method.

Condensed tannin and feedstuff analysis

Condensed tannins were extracted, purified, and the concentration of protein bound CT and the procyanidins:prodelphinidin ratio of CT from CG were determined according to Cash et al. (2016).

Carbon, N, and CP were analyzed for pastures by a C/N analyzer (Elementar Vario Macro Cube; Donaustraße 7, Hanau, Germany). Chambourcin-grape extract and corn-soybean meal creep feed were analyzed for CP utilizing the same method. Additionally, NDF, ADF, and DM were determined on grab samples, harvested at a 2.54 cm stubble height, which were taken from pastures pre-, mid-, and post-grazing of the trial. Samples were freeze dried with a FreezeZone12 (Labconco Corp., Kansas City, Mo.), ground to pass through a 1 mm screen using a Wiley Mill (Arthur H. Thomas, Penn., USA), and analyzed using the Van Soest (1991) method without α-amylase, using an ANKOM200 Fiber Analyzer (ANKOM Technology, Macedon, N.Y.).

Parasitological procedure and measures

During the 63-d trial, individual fecal samples were taken from the rectum of each animal every 7 d. Fecal egg count was determined within 24 h by the modified McMaster procedure (Whitlock, 1948; Mines, 1977) and quantified by using 2-g subsamples of fresh feces from each kid. Every 7 d, individual blood samples were taken by jugular venipuncture into hematocrit tubes and PCV was determined using a HemataSTAT II Centrifuge (Separation Technology, Inc., Sanford, Fla.) within 6 h of blood collection. Additionally, weights, FAMACHA© scores (Hepworth et al., 2006) and BCS (Russell, 1991) were taken every 7 d by the same experienced evaluator throughout the entire study.

Analysis of complete blood cell counts

Blood samples for complete blood cell (CBC) counts were taken by jugular venipuncture every 14 d into BD Vacutaine K3 EDTA 12-mg blood collection tubes (Fisher Scientific, Pittsburgh, Penn). Samples were shipped to University of Arkansas (Fayetteville, Ark.) in cold storage to maintain sample integrity, and CBC counts were analyzed by an Abbott Cell-Dyn 3700SL Automate Hematology Analyzer (GMI Inc., Ramsey, Minn.) within 24 h of collection.

Statistical analyses

Data were analyzed using PROC MIXED of SAS 9.3 (SAS Inst. Inc., Cary, N.C.). Animal was considered the experimental unit. Treatment means are reported as least squares means with the contrast statements of the mean of control compared with D7 and D14 and the mean of D7 compared with D14. For all statistical analyses, differences were considered significant at $P < 0.05$ and were considered tendencies at P values of less than 0.10 but greater than 0.05.

Results

Pasture averages for all sample dates included: CP = 11.9 percent; NDF = 65.6 percent; ADF = 35.3 percent; DM = 95 percent. Corn-soybean-meal-based creep feed analysis was: CP = 14 percent; NDF = 38.4 percent; ADF = 23.4 percent; DM = 98 percent. Chambourcin-grape extract was found to have a concentration of 0.33 mg/mL of CT. Crude protein was 1.7 mg/mL by sample. The concentration of protein bound CT was determined and found to bind 3.5 mg/mL of protein with a 7.01 percent binding capability. The level of combined procyanidins and prodelphinidin was 0.0007 mg/mL with 12.5 percent Galloylated tannin.

As shown in Table 1, start BW, end BW, ADG, and gain did not differ ($P \geq 0.42$) across treatments. Start, end, and change from start to end of the study BCS also did not differ ($P \geq 0.12$) across treatments.

Natural GIN infection was perceptible in all kids with an average FEC of 12.6 eggs ± 6.47 eggs per g of feces. Three kids were removed from D7, three kids were removed from D14, and one kid was removed from C, because they met three of four health threshold criteria. As displayed in Table 2, end FAMACHA© scores were higher ($P = 0.02$) from D7 and D14 compared with C; however, start, end, and change from start to end FEC and PCV did not differ ($P \geq 0.12$) across treatments.

White blood cell (WBC) concentrations at the end of the study were lower ($P = 0.04$) from C compared with D7 and D14; whereas, D14 tended ($P = 0.08$) to be greater compared with D7. Start neutrophil concentrations tended ($P = 0.08$) to be higher from C compared with D7 and D14 and a change ($P = 0.05$) was found in neutrophil concentrations from start to end of study from C compared with D7 and D14. End of study basophil concentrations were greater ($P = 0.04$) from D7 compared with D14. End of study hemoglobin concentration and mean-corpuscular-hemoglobin concentration percent tended to be lower ($P = 0.07$ and $P = 0.06$, respectively) from C compared with D7 and D14. End-of-study mean-corpuscular-hemoglobin concentrations were lower ($P = 0.04$) from C compared with D7 and D14 and a change ($P = 0.04$) was found in mean- corpuscular-hemoglobin concentrations from start to end of study from C compared with D7 and D14. Change from start to end of study platelet concentrations differed ($P = 0.04$ and $P = 0.02$, respectively) from C compared with D7 and D14. Other blood parameter concentrations were similar ($P > 0.10$) across treatments (Table 3).

Discussion

Evidence has suggested that differences in ruminant species and a lack of direct information about goats have led to dramatic errors in efficacy of GIN control (Hoste et al., 2010). It has been shown that goats metabolize anthelmintics faster than other ruminants (Hoste et al., 2010). Consequently, treating goats at the recommended sheep-dosage rate has resulted in anthelmintic under-dosing, thus causing a reduced efficacy (Hoste et al., 2010). This could help explain the prevalence of anthelmintic resistance and increased resistant GIN in goats (Hoste et al., 2010). Subsequently, the purpose of natural anthelmintics involves a different approach towards the control of GIN in ruminants. Natural-control methods do not always have a direct effect on the parasite, but instead use the animal's own ability to recover and assist in maintaining parasite infections below the economic threshold of the physical capabilities of the animal (Ketzis, 2006). This not only relates to the effectiveness of the control method used, but also to the epidemiology of parasites, animal-management program, ease of integration as a sustainable program, and climate in which pro-

Table 1. Effect of Chambourcin grape extract on performance in goat kids.

	Treatment[a]				
Item	C	D7	D14	SEM[b]	Contrast[c]
Start BW, kg	17.3	17.1	17.1	0.79	ns
End BW, kg	23.1	22.4	23.4	1.27	ns
ADG, kg	0.09	0.08	0.10	0.010	ns
Gain, kg	5.4	5.2	5.9	0.66	ns
Start BCS[d]	2.9	3.0	3.0	0.13	ns
End BCS[d]	2.8	2.9	2.8	0.13	ns
BCS[d] change[e]	-0.25	-0.17	-0.21	0.140	ns

[a] C = Control drenched with 30 mL of water every 14 d, D7 = drenched with Chambourcin every 7 d at a rate of 10-mL per 4.5 kg of BW, and D14 = drenched with Chambourcin every 14 d at a rate of 10-mL per 4.5 kg of BW.
[b] SEM = Pooled standard error of means.
[c] Contrast statements: ns = no significant difference ($P > 0.10$).
[d] BCS = Body condition score, based on 5-point scale, 1 being thin and 5 being obese.
[e] BCS change = Change of start BCS compared with end BCS.

Table 2. Effect of Chambourcin grape extract on parasite parameters in goat kids.

Item	Treatment[a] C	D7	D14	SEM[b]	Contrast[c]
Start FEC, eggs/g[d]	8.5	7.1	22.1	6.50	ns
End FEC, eggs/g[d]	21.7	19.7	19.9	5.57	ns
FEC[d] change, eggs/g[e]	12.9	11.9	-1.0	10.82	ns
Start FAMACHA©[f]	3.3	3.5	3.7	0.20	ns
End FAMACHA©[f]	2.4	3.0	2.7	0.13	W
FAMACHA©[f] change[g]	-0.7	-0.5	-0.9	0.24	ns
Start PCV, %[h]	27.4	28.8	28.6	1.42	ns
End PCV, %[h]	33.0	32.8	34.4	1.00	ns
PCV[h] change, %[i]	3.9	2.7	5.0	1.50	ns

[a] C = Control drenched with 30 mL of water every 14 d, D7 = drenched with Chambourcin every 7 d at a rate of 10-mL per 4.5 kg of BW, and D14 = drenched with Chambourcin every 14 d at a rate of 10-mL per 4.5 kg of BW.
[b] SEM = Pooled standard error of means.
[c] Contrast statements: W = mean of C compared with the mean of D7 and D14 ($P \leq 0.05$); ns = no significant difference ($P > 0.10$).
[d] FEC = Fecal egg count.
[e] FEC change = Change of start FEC compared with end FEC.
[f] FAMACHA© score = 1 - not anemic to 5 - severely anemic.
[g] FAMACHA© change = Change of start FAMACHA© compared with end FAMACHA©.
[h] PCV = Packed cell volume.
[i] PCV change = Change of start PCV compared with end PCV.

duction occurs (Ketzis, 2006). In the least, the precise mechanism by which CT acts as a natural anthelmintic needs to be better understood and a concerted effort on isolation, development, and validation of the effects needs to be undertaken before they are more widely accepted (Githiori, 2006).

In the current study, no change in performance in treated kids was apparent, which suggests there were no added benefits of CT in kids creep-fed a 14-percent CP supplement. In contrast, in a companion study, Cash et al. (2016) reported that fermented, organic Pinot Noir-grape extract improved ADG and total weight gain in lambs not provided any additional supplementation. The widely accepted explanation for positive effects of CT on protein digestion and metabolism is that CT-protein complexes escape ruminal degradation resulting in greater protein availability in the abomasum (Reed, 1995). In kids on a higher plane of nutrition, additional protein-bound CT may not result in improved production and parasite control, because protein needs are already being met (Waghorn, 2008). Madibela and Jansen (2003) fed a diet containing Mistletoe, *Viscum verrucosum*, which supplied 8.9 g/d of CT. Similar to the current study, Mistletoe did not affect ADG in control goats compared with treatment goats (Madibela and Jansen, 2003).

High-CT content (Mattivi et al., 2008; Yang et al., 2009) and world-wide availability make red-grape products a potential source of natural anthelmintics (Kammerer et al., 2004). *In vitro* research conducted by LeShure (2014), revealed grape-pomace extract resulted in 100-percent inhibition of egg hatching into third-stage larvae. It was suggested that grape pomace had efficacy in decreasing hatchability of GIN eggs, as well as decreasing parasite viability in an *in vitro* setting (LeShure, 2014). However, CG extract used in this study had a CT concentration of 0.33 mg/mL, but did not demonstrate a natural bioactive anthelmintic effect in pasture-grazed, creep-fed goat kids. Three experiments conducted by Whitley et al. (2009) to determine the influence of high-CT grain sorghum on parasites suggested there was no influence of diet on PCV or FEC. The authors concluded that high-CT grain sorghum did not suppress GIN in goats (Whitley et al., 2009). Research by Paolini et al. (2005) used Quebracho, *Schinopsis* spp., extract and sainfoin, *Onobrychis*, hay, at a rate of 50-percent CT at 5 percent of DM diet and 3.2-percent CT, respectively. When compared with control animals, worm counts decreased, but differences were not significant. Furthermore, no differences were found in physiological measurements between the three groups (Paolini et al., 2005). In agreement with previously mentioned research, results from the current study exhibited similar response in FEC or PCV and end FAMACHA© scores. In contrast, our lab (Cash et al., 2016) demonstrated that fermented Pinot Noir, with a CT concentration of 0.20 mg/mL, dosed at the same amount and interval as the current study, was an effective strategy for controlling GIN in pasture-grazed Katahdin lambs. Further, Shaik et al. (2006) examined effects of sericea lespedeza, *Lespedeza cuneata*, hay on FEC, PCV, morbidity of adult *Haemonchus contortus* (HC) worms, and larvae. On a diet with a total-CT concentration of 22.4 percent on a DM basis, they found that FEC decreased starting at wk one and continued to decrease for the duration of the study. Also, PCV, number of larvae recovered, and HC recovered from fecal cultures were improved (Shaik et al., 2006). In a study by Mueller-Harvey (2006), grazing of sericea lespedeza forage (50 g CT/kg) achieved high reductions

Table 2. Effect of Chambourcin grape extract on parasite parameters in goat kids.

Item[b]	Treatment[a] C	D7	D14	SEM[c]	Contrast[d]
Start WBC, K/µL	13.93	12.97	14.66	1.894	ns
End WBC, K/ µL	13.20	14.00	17.72	1.491	W; x
WBC change, K/ µL[e]	0.70	-0.90	-2.58	1.774	ns
Start NEU, K/µL	5.57	4.11	5.02	0.558	w
End NEU, K/µL	5.88	5.75	8.07	1.018	ns
NEU change, K/µL[e]	0.22	-1.60	-2.96	1.098	W
Start LYM, K/µL	5.09	5.59	5.19	0.772	ns
End LYM, K/µL	3.35	3.97	3.99	0.594	ns
LYM change, K/µL[e]	1.28	1.92	1.51	0.927	ns
Start MONO, K/µL	2.67	2.32	2.82	0.216	ns
End MONO, K/µL	2.20	1.97	2.42	0.242	ns
MONO change, K/µL[e]	0.63	0.48	0.48	0.233	ns
Start EOS, K/µL	0.61	0.89	0.70	0.196	ns
End EOS, K/µL	1.53	1.26	1.76	0.383	ns
EOS change, K/µL[e]	-0.67	-0.32	-1.10	0.408	ns
Start BASO, K/µL	0.84	0.88	0.93	0.111	ns
End BASO, K/µL	1.19	1.06	1.46	0.135	X
BASO change, K/µL[e]	-0.18	-0.24	-0.50	0.182	ns
Start RBC, K/µL	10.40	10.07	10.83	0.587	ns
End RBC, K/µL	11.06	11.85	12.01	0.548	ns
RBC change, K/µL[e]	-0.38	-1.70	-1.02	0.900	ns
Start HGB, g/dL	8.27	7.83	8.64	0.526	ns
End HGB, g/dL	8.65	9.40	9.99	0.510	w
HGB change, g/dL[e]	-0.15	-1.34	-1.10	0.809	ns
Start HCT, %	19.78	19.23	20.27	1.256	ns
End HCT, %	21.40	22.78	22.88	1.187	ns
HCT change, %[e]	-0.70	-3.48	-2.29	1.779	ns
Start MCV, fL	18.87	18.87	18.67	0.459	ns
End MCV, fL	19.25	19.15	19.00	0.522	ns
MCV change, fL[e]	-0.01	-0.43	-0.32	0.329	ns
Start MCH, pg	8.09	7.71	7.95	0.325	ns
End MCH, pg	7.76	7.93	8.31	0.261	W
MCH change, pge	0.39	-0.03	-0.23	0.291	W
Start MCHC%, g/dL	43.17	41.09	42.63	1.534	ns
End MCHC%, g/dL	40.42	41.73	43.94	1.257	w
MCHC% change, g/dL[e]	2.33	0.67	-0.52	1.410	ns
Start RDW, %	31.17	31.10	31.68	1.129	ns
End RDW, %	31.40	30.11	30.32	1.436	ns
RDW change, %[e]	0.52	0.19	0.93	1.383	ns
Start PLT, K/µL	612.36	547.39	579.53	99.662	ns
End PLT, K/µL	785.25	807.75	960.85	128.975	ns
PLT change, K/µL[e]	22.91	-194.91	-334.62	105.225	W

[a] C = Control drenched with 30 mL of water every 14 d, D7 = drenched with Chambourcin every 7 d at a rate of 10-mL per 4.5 kg of BW, and D14 = drenched with Chambourcin every 14 d at a rate of 10-mL per 4.5 kg of BW.

[b] WBC = White blood cells; NEU = Neutrophils; LYM = Lymphocytes; MONO = Monocytes; EOS = Eosinophils; BASO = Basophils; RBC = Red blood cells; HGB = Hemoglobin; HCT % = Hematocrit percentage; MCV = Mean corpuscular volume; MCH = Mean corpuscular hemoglobin; MCHC % = Mean corpuscular hemoglobin concentration percent; RDW = Red cell distribution width; PLT = Platelets.

[c] SEM = Pooled standard error of means.

[d] Contrast statements: W = mean of C compared with the mean of D7 and D14 ($P \leq 0.05$); X = mean of D7 compared with the mean of D14 ($P \leq 0.05$); lowercase letters represent statistical tendencies ($P \leq 0.10$); ns = no significant difference ($P > 0.10$).

[e] Change = Change of start CBC parameters compared with end CBC parameters.

(57 to 100 percent) in FEC, total fecal egg output, and numbers of parasitic nematodes HC, *Teladorsagia* spp., and *Trichostrongylus* in goats. Further exploration is needed to determine anthelmintic properties and biological processes by which CT influences response of host to nematodes.

Most ruminants are grazers; in contrast, goats are browsers, which in theory limits contact with infective stages of GIN (Hoste et al., 2010). Goat feeding behavior has evolved to browse on a high diversity of plants. This behavior might be involved in the regulation of parasite populations by a combination of self-medication with plant secondary metabolites and avoidance of GIN (Hoste et al., 2010). Goats have developed physiological adaptations to, and dependencies on plant CT, which have carved a browse niche that seeks out CT-containing plants (Muir, 2011).

Goats have a higher tolerance than most ruminants to high levels of CT, which are astringent or bitter and reduce palatability (Lamy et al., 2009). This difference could be the result of existence of tannin-binding proteins in goat saliva (Lamy et al., 2009). For the majority of forage plants with moderate levels of CT, palatability to goats appears to be independent of CT presence and concentration, due to excretion of proline-rich proteins in goat saliva (Lamy et al., 2009). Proline-rich proteins have been the most studied salivary proteins with defense functions against the potential harmful effects of tannins. Saliva of species which ingest high levels of tannins in their regular diet have been reported to have higher levels of proline-rich proteins (Lamy et al., 2009). These salivary proteins are very reactive with CT and bind them as goats ingest forage CT. This may improve palatability of plants with moderate concentrations of soluble CT, but may also negatively affect ability of CT to bind with proteins in the ruminant environment (Muir, 2011). Additionally, some forage CT may interfere with intestinal absorption of amino acids, even in a low pH environment, where CT-protein bonds should be broken (Waghorn, 2008). This phenomenon may be specific to goats only and could further explain the absence of a by-pass protein effect in this study.

Another consideration for the lack of an anthelmintic effect in the current study could be in part due to the increased metabolism rates of goats compared to other ruminants. Pharmacological studies (Sprenger et al., 2013; Gokbulut et al., 2014) indicate that goats metabolize drugs much faster than sheep or cattle, resulting in decreased bioavailability of anthelmintics. Although not as practical, perhaps a shorter dosage interval would have impacted results seen in the current study.

Laboratory examination of the ruminant CBC can be an important addition to physical examinations (Jones and Allison, 2007). Consulting a CBC can often show an immune response to infection or virus before symptoms are presented in the animal. Research conducted by Hoste et al. (2008) illustrated that acquisition and expression of immune responses against GIN species are less efficient in goats and a fully expressed immune response appears delayed in goats compared with other ruminants (Hoste et al., 2008). In this research, some changes were found in CBC results, including significantly lower white blood cell concentrations at the end of the study from C compared with D7 and D14; whereas, D14 tended to be greater compared with D7. Increases in NEU can indicate stress-related health responses (Jones and Allison, 2007). In the current study, start NEU tended to be higher, and a significant change was found in NEU from start to end of study from C compared with D7 and D14. Increases were found in end of study BASO concentrations from D14 compared with D7, which could indicate an allergic response or inflammation (Jones and Allison, 2007). A decrease was found for HGB and MCHC percent from C compared with D7 and D14, which could indicate presence of anemia (Jones and Allison, 2007). A decrease was found in end of study MCH and a greater change from start to end of study in C compared with D7 and D14, again demonstrating anemia (Jones and Allison, 2007). Positive changes in blood parameters involving HGB, MCH, and MCHC percent, could be related to increased antioxidant properties of CT constituents (King and Young, 1999). A significant increase from start to end of study was found in PLT from D7 and D14 compared with C. An increase in PLT may indicate infection or anemia (Jones and Allison, 2007).

Conclusion

Fermented Chambourcin-grape extract may not be a beneficial natural anthelmintic for controlling nematodes in creep-fed goat kids at the dosage rate and interval used in the current study. Continued research is needed to understand why grape extract may be an effective natural anthelmintic in some ruminant animals, but not in goat kids in the current study.

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