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Control of *Haemonchus contortus* in goats with a sustained-release multi-trace element/vitamin ruminal bolus containing copper

J.M. Burke [a,*], J.E. Miller [b,c,d]

[a] Dale Bumpers Small Farms Research Center, USDA, ARS, Booneville, AR 72927, USA
[b] Department of Pathobiological Sciences, School of Veterinary Medicine, Louisiana State University, Baton Rouge, LA 70803, USA
[c] Department of Animal Science, Louisiana State University, Baton Rouge, LA 70803, USA
[d] Department of Veterinary Science, Louisiana State University, Baton Rouge, LA 70803, USA

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Abstract

The objective of this study was to determine the effectiveness of a sustained-release multi-trace element/vitamin ruminal bolus (TEB) containing copper administered to mature does for control of gastrointestinal nematodes (GIN) during summer months and during late gestation. *Haemonchus contortus* was the predominant nematode during these trials. In Experiment 1, yearling Spanish does were untreated or administered TEB ($n = 11$/group) on Day 0 (August 2005) prior to breeding. In Experiment 2, Spanish and Boer does were untreated or administered TEB 6 weeks before kidding. Fecal egg counts (FEC) and blood packed cell volume (PCV) were determined weekly between Days 0 and 42. In both experiments, FEC were reduced within 7 days in TEB-treated compared with untreated does. PCV was similar between treatment groups (Experiment 1) or tended to be lower in the TEB group (Experiment 2). GIN control did not persist more than 28 days. These studies suggest that TEB may be an effective means of GIN control in mature goats, but additional control measures may be necessary.
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Keywords: Copper oxide; Goats; *Haemonchus contortus*; Trace element bolus

1. Introduction

Alternatives to chemical control of gastrointestinal nematodes (GIN) for small ruminants have become necessary because of widespread anthelmintic resistance (Miller and Barras, 1994; Miller and Craig, 1996; Zajac and Gipson, 2000; Terrill et al., 2001; Mortensen et al., 2003). Without adequate control of GIN the small ruminant industry in warm, humid climates, such as the southeastern US, could be in peril. Oxidized copper has been used for GIN control in lambs (Bang et al., 1990; Knox, 2002; Burke et al.,

* Corresponding author. Tel.: +1 479 675 3834;
fax: +1 479 675 2940.
E-mail address: jmburke@spa.ars.usda.gov (J.M. Burke).

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2004), but may be less effective in mature small ruminants (Glennon et al., 2004; Burke et al., 2005).

Oxidized copper was developed for sheep for treatment of copper deficiency (Dewey, 1977; Whitelaw et al., 1980, 1982; Suttle, 1981, 1987) and has been used successfully in goats for the same purpose (Winter et al., 2004). Copper oxide wire particles (COWP) pass from the rumen to the abomasum where it is retained, then free copper is released in the abomasum, which increases concentrations of copper in the abomasal digesta and subsequently stores in the liver (Dewey, 1977; Bang et al., 1990). This concentration of soluble copper creates an environment that causes expulsion of the worms, but the exact mechanism has not been documented (Chartier et al., 2000). A sustained-release multi-trace element/vitamin ruminal bolus (TEB) also has been developed to treat copper deficiency and enhance reproductive performance of ewes (Hemingway et al., 2001; All-Trace, Agrimin Ltd., UK). This bolus is administered in the same manner as COWP, but is retained in the reticulum where free copper is released. In addition, other minerals and vitamins (cobalt, selenium, iodine, manganese, zinc, and Vitamins A, D, and E) are available. A similar bolus containing copper, cobalt and selenium was used in goats and led to increased trace minerals in tissues and increased weight gains (He et al., 2000). TEB has not been examined as an aid in the anthelmintic control of *Haemonchus contortus* in small ruminants.

The objective of the current experiment was to determine the effectiveness of a sustained-release multi-trace element/vitamin ruminal bolus administered to goats during summer months and during late pregnancy for control of naturally acquired GIN.

2. Materials and methods

All experimental procedures were reviewed and accepted by the Agricultural Research Service Animal Care and Use Committee in accordance with the NIH guide for the Care and Use of Laboratory Animals. Pain and stress to animals was minimized throughout the experimental period.

In Experiment 1, which began in August, yearling Spanish does that were naturally infected with GIN were assigned randomly to be untreated or administered a sustained-release multi-trace element/vitamin ruminal bolus (TEB; Small-Trace, Agrimin Ltd., DN20 OSP UK; 3.7 g Cu, 80 mg Co, 40 mg Se, 320 mg I, 2.8 g Mn, 4.1 g Zn, 188,000 IU Vitamin A, 38,000 IU Vitamin D_3, 660 IU Vitamin E; $n = 11$/group) on Day 0. In Experiment 2, naturally infected pregnant Spanish and Boer (1/2 to fullblood) does were blocked by breed and previous copper oxide treatment (19 of 38 does were previously treated in August 2005) to be untreated (12 Spanish; 5 Boer; an additional 3 Boer does were assigned to this group but 2 were removed because of necessary deworming and one aborted) or administered TEB (12 Spanish; 9 Boer).

In both experiments does grazed tall fescue (*Festuca arundinacea*) pastures and were supplemented with free choice trace mineralized salt (Experiment 1: Land O'Lakes Sheep and Goat Mineral, Shoreview, MN; Experiment 2: Cargill Cattle Mineral with a minimum of 2500 μg/g copper from copper sulphate). Exposure to copper in Experiment 1 was minimal as there was no copper in the trace mineralized salt and none had been exposed to copper oxide previously; does grazed pasture year round and were not heavily supplemented with grain over previous winter. Does were supplemented with 450 and 900 g corn/soybean meal (16% crude protein) in Experiments 1 and 2, respectively. Fecal egg counts (FEC), as determined by a modified McMaster technique (Whitlock, 1948) and blood packed cell volume (PCV) were determined weekly between Days 0 (day of treatment) and 42. A pooled fecal sample per rectum was collected on Day 0 in both experiments for culture of larval nematodes. Feces were gently mixed, but pellets were not broken, and misted with water every 2–3 days, and loosely covered with aluminum foil. After 14 days the cultures were wrapped in cheese cloth, and the cheese cloth immersed in warm water (approximately 38 °C). The fecal cultures were subjected to the Baermann method overnight in a funnel with an attached culture tube. L3 larvae were collected from the culture tube and identified.

Body weight was determined on Days 0 and 42 in Experiment 1 and when deworming became necessary in Experiment 2. In Experiment 2, when PCV declined below 19% does were dewormed with moxidectin (Cydectin®; 0.4 mg/kg). Birth weight of kids was determined within 24 h postpartum.

Data were analyzed using the mixed models procedure of SAS (1996). The mathematical model used for PCV, FEC, and body weight included treatment, day, treatment by day, and a repeated statement for day of measurement (Littell et al., 1996). Contrasts were determined using the PDIFF option (all probability values for the hypothesis) in SAS when probability was less than 0.05%. FEC data were log transformed: ln(FEC + 1). Statistical inferences were made on transformed data and untransformed least squares means were presented. Least squares means and standard errors of the mean of all response variables were presented. After does were dewormed FEC or PCV values were no longer included in the analysis.

In Experiment 1, there were five does that rejected the small grinder that accompanies the TEB after administration. Statistical analyses revealed no differences between successful administration of TEB and the grinder and those that rejected the grinder. Therefore, this variable was not included in final analysis.

3. Results

H. contortus was the predominant GIN at time of treatment in Experiment 1 (85% *H. contortus*, 13% *Trichostrongylus* spp., 2% *Oesophgostomum* spp). In Experiment 1, speciation of nematodes was not determined after Day 0. FEC were reduced within 7 days in TEB-treated does from 3600 to 820 eggs/g but tended to increase in untreated does (treatment, $P < 0.007$; treatment by day, $P < 0.07$; Fig. 1A). There was a second increase in FEC on Days 28 and 35 in untreated does, while FEC in TEB-treated does remained low. PCV was not significantly different between treatment groups, though means were the same on Day 0 and increased in TEB-treated does and remained numerically higher (Fig. 1B). Body weights were similar among treatment groups and days (31.3 ± 1.0 kg).

In Experiment 2, proportion of nematodes were 75% *H. contortus*, 23% *Trichostrongylus* spp., and 2% *Oesophagostomum* spp. Fourteen days after treatment the proportion of *H. contortus* in TEB-treated does decreased to 45% and *Trichostrongylus* spp. increased to 55% with no changes in untreated does. FEC tended

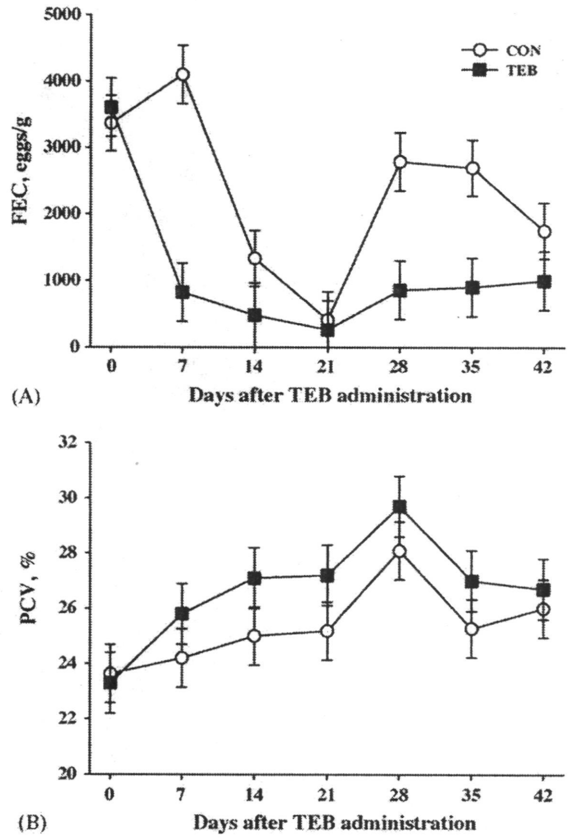

Fig. 1. Least squares means and standard errors of fecal egg counts (FEC; treatment, $P < 0.007$; treatment by day, $P < 0.07$; A) and packed cell volume (PCV; B) of non-pregnant, yearling Spanish does that were untreated (CON; $n = 11$; open circle) or administered a trace element bolus (TEB; $n = 11$; closed square) on Day 0 of Experiment 1.

to be lower between Days 7 and 21 in TEB compared with untreated does and were similar between groups by Day 35 (treatment by day, $P < 0.07$; Fig. 2A). PCV tended to be lower in untreated compared with TEB-treated does, though means of TEB-treated does were greater on Day 0 ($P < 0.08$). Interestingly, FEC were greater (4097 > 2358 eggs/g; $P < 0.02$) and PCV lower (20.1 < 24.1%; $P < 0.001$) in Boer compared with Spanish does. Number of kids born per treatment and breed (1.8 ± 0.1) was similar. Litter (5.7 ± 0.2 kg) and individual (3.2 ± 0.1 kg) birth weight of kids were similar between treatments and greater for Boer than Spanish kids (litter: Boer, 5.9 ± 0.2 kg; Spanish, 5.5 ± 0.2 kg; individual: Boer, 3.4 ± 0.1 kg; Spanish, 3.1 ± 0.1 kg).

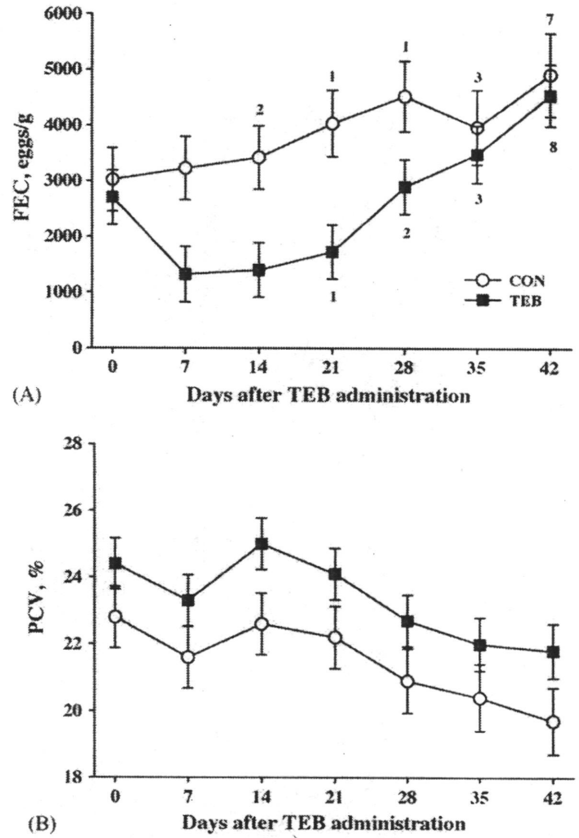

Fig. 2. Least squares means and standard errors of fecal egg counts (FEC; treatment by day, $P < 0.07$; A) and packed cell volume (PCV; $P < 0.08$; B) of pregnant Spanish and Boer crossbred does that were untreated (CON; $n = 17$; open circle) or administered a trace element bolus (TEB; $n = 21$; closed square) on Day 0 of Experiment 2. Number next to symbol indicates number of does that required deworming on those days.

4. Discussion

Administration of TEB to goats led to an 80% and 60% reduction in FEC compared with untreated does in Experiments 1 and 2, respectively. GIN infection was greater at the time of breeding and during late pregnancy in untreated does. Supplemental nutrition of the does on Day 21 in Experiment 1 could have led to an increase in PCV observed in both groups. There was significant rainfall around Day 0 in early August, which could have led to self-cure of untreated does by Day 21 as seen by decreased FEC on Days 14 and 21. An influx of new L3 may lead to expulsion of the adult nematodes (Gordon, 1950) and apparently led to re-infection or a second increase in FEC on Days 28 and 35 in untreated does. FEC in TEB-treated does remained low. As the infection matured FEC increased again in untreated does by Day 28, although FEC of TEB-treated does remained low. These data suggest some efficacy of TEB as a dewormer in goats. Chartier et al. (2000) observed a reduction in FEC in mature does treated with 4 g COWP compared with untreated does. However, Glennon et al. (2004) observed little effect of COWP administration to mature goats. In Experiment 2, the reduction in FEC in TEB compared with untreated animals lasted 3–4 weeks, typical of an anthelmintic and typical to the duration of COWP (Burke and Miller, in press).

Additional minerals and vitamins found in the TEB may boost its effectiveness for GIN control compared with COWP. Worm burdens of *Ostertagia* (*Telodorsagia*) *circumcincta* in cobalt deficient lambs were greater than lambs with normal reserves of cobalt (Ferguson et al., 1989). On the other hand, worm burdens of *H. contortus* were greater in cobalt-supplemented compared with deficient lambs (Threlkeld et al., 1956). In another study, FEC were reduced in cobalt-supplemented compared with non-supplemented Vitamin B_{12}-deficient lambs (Vellema et al., 1996). Insufficient supply of cobalt leads to Vitamin B_{12} deficiency (Ulvund and Pestalozzi, 1990). Presumably, goats in the current study were sufficient in cobalt on Day 0. Heavy metal ions, such as copper and cobalt, bind to sulphydril groups and form complexes leading to toxic effects on living cells (Agranoff and Krishna, 1998; Vargas et al., 1998). This mechanism may also apply to GIN during administration of large quantities of heavy metals to small ruminants. However, smaller quantities may actually meet the trace element requirements of the GIN, which may account for differences among studies in reduction in worm burdens.

There is some evidence of a periparturient rise (PPR) in FEC in association with a relaxation of acquired immunity in goats (Rahman and Collins, 1992; Dorny et al., 1995). This was not examined in the current study. However, a lower mean PCV, but not FEC, in Experiment 2 compared with 1, suggests that the goats were more susceptible to GIN infection in late gestation. More stringent GIN control may be necessary at this time.

There was no improvement in birth weights of kids from TEB-treated dams in the current study. This is not surprising because does were not likely to be mineral deficient. Selenium supplementation to ewes in late pregnancy resulted in increased lambing percentages, though ewes were selenium deficient (Godwin et al., 1970). There is little information on benefits of trace elements to goats to improve kidding rates.

5. Conclusion

TEB offered some control of GIN in mature does for approximately 28 days. FEC were reduced and PCV may be greater in does treated with TEB. TEB should not be administered more than once in 6 months to avoid mineral toxicity. Goats are not as susceptible to copper toxicity as sheep, but excess of copper or other trace minerals supplied by the bolus could lead to toxicity. Other means of GIN control should be practiced in addition to the use of copper oxide. In an integrated control program the trace element bolus should be combined with other non-chemical approaches to reduce the frequency of anthelmintic treatment.

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