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Short communication

Administration of copper oxide wire particles in a capsule or feed for gastrointestinal nematode control in goats

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ABSTRACT

Widespread anthelmintic resistance in small ruminants has necessitated alternative means of gastrointestinal nematode (GIN) control. The objective was to determine the effectiveness of copper oxide wire particles (COWP) administered as a gelatin capsule or in a feed supplement to control GIN in goats. In four separate experiments, peri-parturient does ($n = 36$), yearling does ($n = 25$), weaned kids ($n = 72$), and yearling bucks ($n = 16$) were randomly assigned to remain untreated or administered 2 g COWP in a capsule (in Experiments 1, 2, and 3) or feed supplement (all experiments). Feces and blood were collected every 7 days between Days 0 and 21 (older goats) or Day 42 (kids) for fecal egg counts (FEC) and blood packed cell volume (PCV) analyses. A peri-parturient rise in FEC was evident in the untreated does, but not the COWP-treated does (COWP \times date, $P < 0.02$). In yearling does, FEC of the COWP-treated does tended to be lower than the untreated (COWP, $P < 0.02$). FEC of COWP-treated kids were reduced compared with untreated kids (COWP \times date, $P < 0.001$). FEC of treated and untreated bucks were similar, but *Haemonchus contortus* was not the predominant nematode in these goats. However, total worms were reduced in COWP-fed bucks ($P < 0.03$). In summary, it appeared that COWP in the feed was as effective as COWP in a gelatin capsule to reduce FEC in goats. COWP administration may have a limited effect where *H. contortus* is not the predominant nematode.

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1. Introduction

The challenge of controlling gastrointestinal nematode (GIN) infection in small ruminants throughout the world has greatly increased in recent years because of GIN resistance to chemical anthelmintics. The problem is particularly severe in subtropical areas, such as the

southeastern US, where warm, moist pasture conditions are conducive to growth and survival of the larval stages of *Haemonchus contortus*, a blood-feeding parasite that causes severe anemia in infected animals (Terrill et al., 2001; Mortensen et al., 2003; Kaplan et al., 2005; Howell et al., 2008). As an alternative to chemical anthelmintics, treatment with copper oxide wire particles (COWP) has been used to control *H. contortus* infection in small ruminants (Burke et al., 2004, 2007; Burke and Miller, 2006). These authors reported high efficacy of COWP in young lambs and kids when *H. contortus* was the primary

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infection, but somewhat lower effectiveness when other parasites were predominant. In each of these studies, COWP was administered in a gel capsule per os. Occasionally, capsules would break upon administration, were chewed, and treatment still appeared to be effective in reducing fecal egg counts (FEC; unpublished observations). A convenient mode of administration for a large number of animals would be to include COWP in the feed. The objective of this study was to examine the efficacy of COWP included in the feed or administered as gelatin capsules to goats in reducing GIN infection.

2. Materials and methods

2.1. Experiments 1 and 2: peri-parturient and yearling does

Naturally nematode-infected goats grazed grass pastures at USDA, Agricultural Research Service, Dale Bumpers Small Farms Research Center in Booneville, AR before the experiments began. Animals used were peri-parturient does ($n = 36$) of Spanish, Boer, or Spanish \times Boer breeding, and yearling does ($n = 25$) of Spanish breeding. In early March 2008, does were blocked by breed type (mature does) and randomly assigned to remain untreated ($n = 12$ peri-parturient does; $n = 8$ yearling does), administered 2 g COWP in a gelatin capsule administered per os ($n = 12$ peri-parturient does; $n = 9$ yearling does), or receive COWP in a feed supplement ($n = 12$ peri-parturient does; $n = 8$ yearling does) split into an am and pm feeding. One COWP capsule that had been administered was recovered on the ground. Mature does consumed approximately 75% of the pelleted ration with COWP by the following morning and were offered an additional 2 g/doe in 2.7 kg mixed ration (corn, soybean meal, molasses)/group, but not all does consumed the feed. Yearling does were observed to consume less than half of the COWP pelleted ration within 24 h and were offered another 2 g COWP/goat mixed in 2 kg/group of a mixed ration the following morning. Some does were observed to refuse feed altogether. Thus, does received between 0 and 4 g COWP. Two untreated yearling does required deworming on Day 14 because of low PCV (16%) and were removed from the study thereafter. Mature does were due to start kidding 10 days later and all kidded within 28 days after the study began. In both experiments, goats had access to free choice bermudagrass hay and trace mineralized salt (Land O'Lakes Sheep and Goat Mineral, Shoreview, MN) in semi-confinement. A pooled fecal sample was collected for coproculture (Peña et al., 2002) on Day 0 (day of COWP administration) from the yearling and peri-parturient doe groups. Feces and blood were collected every 7 days between Days 0 (day of COWP administration) and 21 for FEC and blood packed cell volume (PCV) analyses. The FEC analyses for this and subsequent experiments were completed using a modified McMaster technique (Whitlock, 1948), and the PCV analyses were completed using a micro-hematocrit centrifuge and reader.

All husbandry practices and experimental procedures were approved by the Animal Care and Use Committees of the institutions where individual experiments were conducted for this and subsequent experiments.

2.2. Experiment 3: kids

Goats that had naturally acquired GIN at Virginia State University, Petersburg, VA were used for this experiment. In June 2008, 72 April-weaned, mixed-gender (males, $n = 37$; females, $n = 35$) Myotonic ($n = 37$) and Spanish ($n = 35$) kids that were 106 ± 6 days of age were blocked by breed and gender and randomly assigned to treatments. Treatments were an untreated control group, a group dosed with a single gelatin capsule of 2 g of COWP, or a group with COWP mixed into the supplemental feed to provide 2 g/goat in a single feeding ($n = 24$ /group). All feed was consumed. Goat kids rotationally grazed grass pasture as a single group and were supplemented with corn/soybean meal (16% crude protein) at 2% of their body weight. Fecal and blood samples were collected every 7 days between Days 0 (day of COWP administration) and 42 to determine FEC, PCV, and larval population in cultured feces. Body weight was determined at that time.

2.3. Experiment 4: yearling bucks

Naturally infected yearling intact male mixed breed meat goats grazed primarily bermudagrass [*Cynodon dactylon* (L.) Pers.] and bahiagrass [*Paspalum notatum* Flugge] in August 2008 at the Fort Valley State University Agricultural Research Station, Fort Valley, GA. Goats were blocked by FEC and randomly assigned to an untreated group (1.3 kg of non-COWP pellets) or a group fed 2 g COWP in 1.3 kg of a pelleted ration per goat ($n = 8$ /group). Feed was fed only once at the beginning of the grazing study. The feed contained 16% crude protein and was pelleted at a commercial feed mill in Montezuma, GA (Mid-GA Farm Supply, Inc.) with or without COWP (1.5 mg/g of feed). All the feed was consumed within 24 h after which the goats grazed as one group. Goats were slaughtered 28 days later. Fecal and blood samples were collected every 7 days between Days 0 (day of COWP administration) and 28 to determine FEC and PCV, respectively. Adult GIN from abomasum and small intestines of the goats were recovered, counted, and identified to species using a Leica Zoom 2000 phase contrast microscope (Leica Microsystems Inc., Chicago, IL) as described by Shaik et al. (2006).

2.4. Statistical analysis

Data were analyzed as repeated measures (Littell et al., 1996) using mixed models and included COWP treatment, breed type (Experiments 1 and 3), gender (Experiment 3) and interactions in the model (SAS, 1996). An autoregressive covariance structure was used in Experiments 1 and 2, and compound symmetry was used in Experiments 3 and 4. Means were separated using pre-planned pairwise comparisons using the *t*-test when treatment effect was $P < 0.05$. The FEC data were log transformed: $\ln(\text{FEC} + 1)$. Statistical inferences were made on transformed data and untransformed least squares means were presented. Log transformed adult GIN data were analyzed as a completely randomized design using the GLM procedure of SAS. The log transformed FEC of yearling does on Day 0 in Experiment 1 were different among treatments

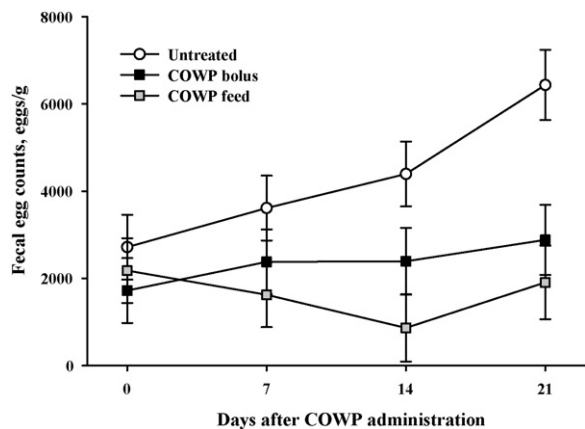


Fig. 1. Effect of administration of copper oxide wire particles (COWP) as a 2 g capsule or incorporated in the feed to deliver 2 g/goat (untreated: open circles, $n = 12$; COWP in capsule: black squares, $n = 11$; COWP in feed: gray squares, $n = 12$) on fecal egg counts (FEC) in peri-parturient does (Experiment 1). Least squares means and standard errors are presented and statistical analysis of FEC was performed on log transformed values.

($P < 0.02$). Therefore, FEC on Day 0 was used as a covariate in this analysis. In Experiment 3, FEC of *H. contortus* was estimated each week by multiplying the FEC least squares mean for each of the three treatment groups by the percentage of *H. contortus* found in the fecal culture.

3. Results

3.1. Experiments 1 and 2: peri-parturient and yearling does

Nematode species present were 72% *H. contortus* for mature does in Experiment 1; the remaining nematodes were mainly *Trichostrongylus* spp. A peri-parturient rise in FEC occurred in untreated does, but not in COWP-treated does (COWP \times date, $P < 0.02$; Fig. 1). FEC were similar between does receiving COWP as a capsule or in the feed. FEC of Spanish does were the lowest of the three breed types, whereas that of Boer does were the highest and the crossbred were intermediate ($1881 \pm 420 < 3024 \pm 441 < 4153 \pm 637$ eggs/g, $P < 0.03$). There was little effect of COWP treatment compared with untreated does during this experiment on PCV (Day 0, 25.6%; Day 21, $23.6 \pm 0.6\%$). PCV of Spanish does was greater than the crossbred ($P < 0.003$) and Boer does ($P < 0.001$), but PCV of the Boer and crossbred was similar ($26.7 \pm 0.71 > 23.3 \pm 0.74$ and $22.0 \pm 1.07\%$).

In Experiment 2, nematode species present were 61% *H. contortus* and remaining nematodes were mainly *Trichostrongylus* spp. In yearling does, FEC of animals receiving COWP as a capsule or in the feed tended to be lower than those of untreated using the covariate analysis (COWP, $P < 0.07$; Fig. 2). PCV declined with time (Day 0, 25.6%; Day 21, $22.5 \pm 0.8\%$; $P < 0.04$), but was similar among treatment groups.

3.2. Experiment 3: kids

In growing goats, FEC declined in response to both COWP treatments between Days 7 and 28 and was lower than untreated kids until Day 35 (COWP \times date, $P < 0.001$;

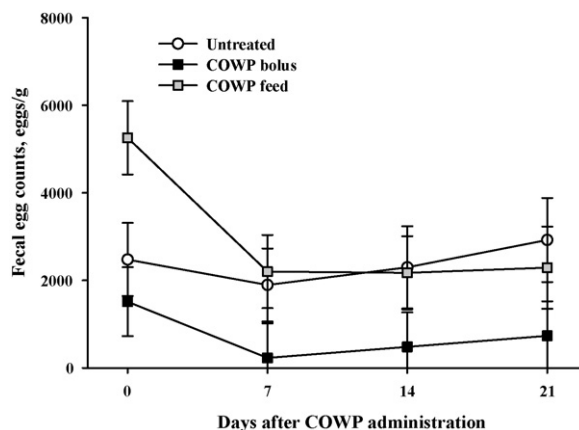


Fig. 2. Effect of administration of copper oxide wire particles (COWP) as a 2 g capsule or incorporated in the feed to deliver 2 g/goat (untreated: open circles, $n = 8$; COWP capsule: black squares, $n = 9$; COWP in feed: gray squares, $n = 8$) on fecal egg counts (FEC) in yearling does (Experiment 2). Least squares means and standard errors are presented and statistical analysis of FEC was performed on log transformed values.

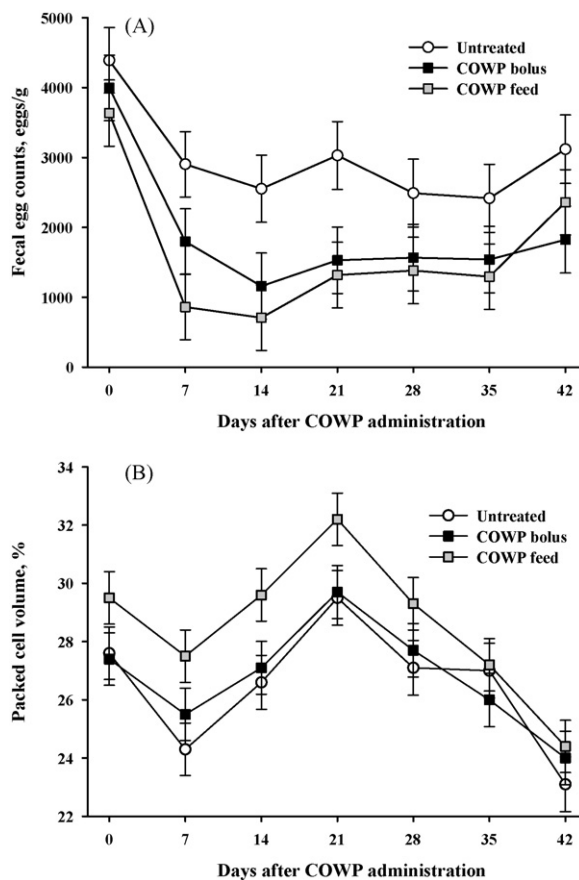


Fig. 3. Effect of administration of copper oxide wire particles (COWP) as a 2 g capsule or incorporated in the feed to deliver 2 g/goat (untreated: open circles, COWP capsule: black squares, COWP in feed: gray squares, $n = 24$ /treatment) on fecal egg counts (FEC; A) and packed cell volume (PCV; B) in weaned kids (Experiment 3). Least squares means and standard errors are presented and statistical analysis of FEC was performed on log transformed values.

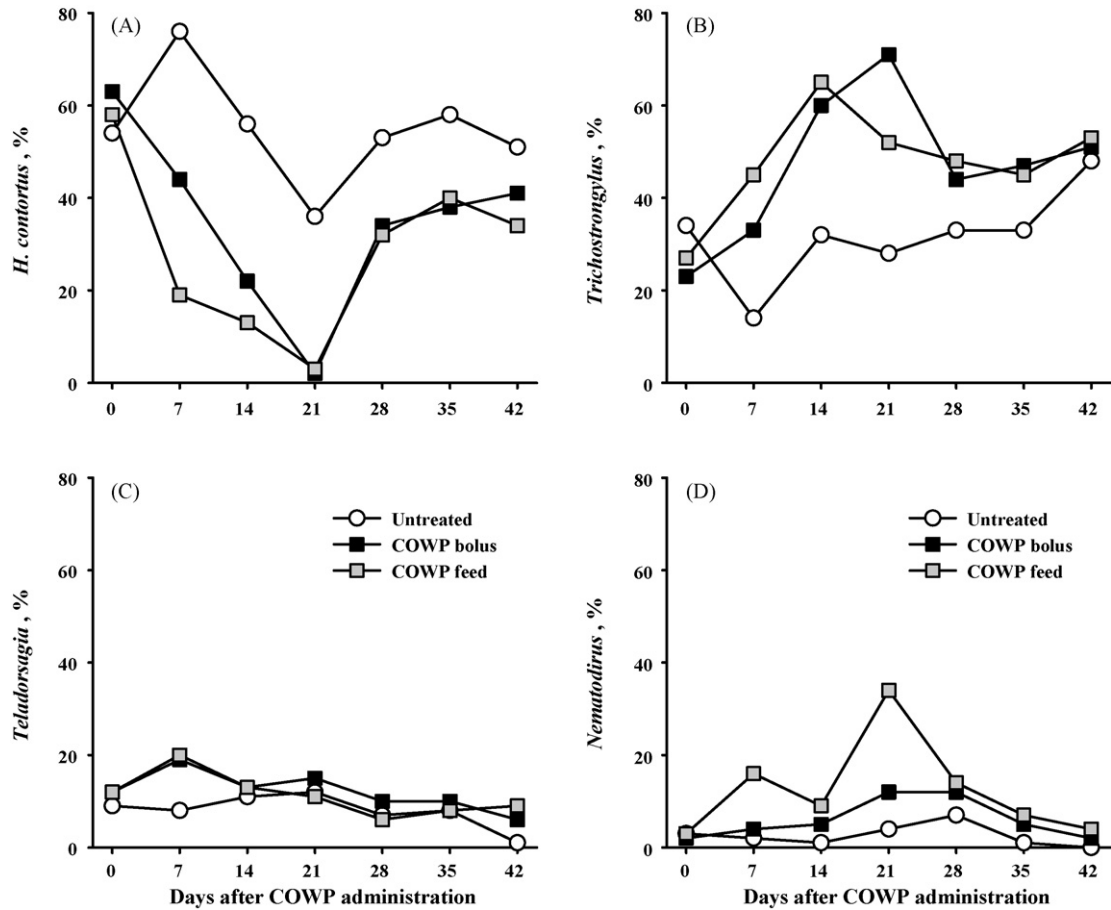


Fig. 4. Effect of administration of copper oxide wire particles (COWP) as a 2 g capsule or incorporated in the feed to deliver 2 g/goat (untreated: open circles, COWP capsule: black squares, COWP in feed: gray squares, $n=24$ /treatment) on percentage of *Haemonchus contortus* (A), *Trichostrongylus* spp. (B), *Teladorsagia* spp. (C), and *Nematodirus* spp. (D) from pooled feces from each treatment group of weaned kids that was cultured for 14 days (Experiment 3).

Fig. 3A). FEC were similar between kids that received COWP as a capsule or in the feed. FEC of Myotonic was lower than that of Spanish kids ($1443 \pm 255 < 2944 \pm 264$ eggs/g; $P < 0.001$), but FEC between male and female kids was similar. PCV tended to be higher in kids that received COWP in the feed, although this difference was apparent on Day 0 ($P < 0.07$; Fig. 3B). Breed or gender had no effect on PCV (data not shown). On Day 0, *H. contortus* was the predominant nematode for all goats and decreased to 2 and 3% of the nematode population by Day 21 in the COWP-treated kids (Fig. 4A). *Trichostrongylus* spp. became the predominant nematode after administration of COWP (Fig. 4B); however, in the untreated group, both *H. contortus* and *Trichostrongylus* spp. were predominant by Day 42. Other minor nematode species present were *Teladorsagia* spp. (Fig. 4C) and *Nematodirus* spp. (Fig. 4D). Estimated FEC of *H. contortus* based on actual FEC and percentage of *H. contortus* in cultured feces is represented by Fig. 5 demonstrating the low impact of *H. contortus* in COWP-treated lambs. Body weight gain was similar ($P = 0.28$) among treatments and increased in all kids from 24.1 ± 0.7 kg on Day 0 to 29.4 ± 0.6 kg on Day 42 of the experiment. Spanish kids were heavier than Myotonic kids ($29.0 > 25.1 \pm 0.7$ kg; $P < 0.001$).

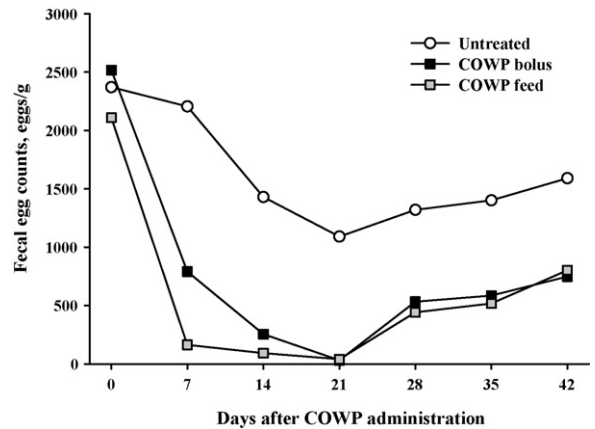


Fig. 5. Effect of administration of copper oxide wire particles (COWP) as a 2 g capsule or incorporated in the feed to deliver 2 g/goat (untreated: open circles, COWP capsule: black squares, COWP in feed: gray squares, $n=24$ /treatment) on fecal egg counts of weaned kids adjusted to percentage of *Haemonchus contortus* cultured in pooled feces between Days 0 and 42 after COWP administration (Experiment 3).

3.3. Experiment 4: yearling bucks

The FEC and PCV were similar between untreated bucks (FEC, 1129 ± 305 eggs/g; PCV, $23.2 \pm 1.3\%$) and those administered COWP (FEC, 947 ± 303 eggs/g; PCV, $24.1 \pm 1.3\%$). PCV increased between Days 14 and 21 (day, $P < 0.004$). Dietary administration of COWP compared with no treatment tended to reduce the number of *H. contortus* ($620 < 1062 \pm 161$; $P < 0.06$) and *Trichostrongylus* spp. ($460 < 1215 \pm 199$; $P < 0.07$) found in the gut, but not *Teladorsagia* spp. (untreated, 317; COWP-treated, 387 ± 72 ; $P > 0.10$). Total worm number was reduced in goats that received COWP ($1467 < 2595 \pm 307$; $P < 0.03$). Percentage of worm numbers of untreated goats was 45.5% *T. colubriformis*, 42.4% *H. contortus*, and 12.1% *T. circumcincta*.

4. Discussion

The COWP administered in the feed to goats was as effective as the gelatin capsule in reducing FEC. There was an increase in FEC between Days 7 and 21, coinciding with the peri-parturient rise in untreated mature does and a slight increase in does treated with the COWP capsule. Goats could have been consuming infective larvae throughout the experiment, leading to this increase. The COWP does not appear to be effective against immature worms in the gut (Burke et al., 2007). An increase in *H. contortus* was evident in kids treated with COWP after 21 days in Experiment 3, which agrees with Burke et al. (2007).

A lack of an effect of COWP on PCV was not unexpected because of the short observational period and the relatively high PCV on Day 0 in all the studies. *H. contortus* was less than 60% for goat kids in Experiment 3, accounting for the lack of anemia in these groups of goats. Similarly, body weight was similar among treatments in goat kids because of the short time frame of the study and low worm burden.

Clinical indicators of GIN infection were similar between untreated and COWP-fed bucks. But, *H. contortus* was not the predominant nematode species for the yearling bucks and FEC were relatively low. Treatment of bucks with COWP in a pelleted diet reduced adult worms in the gastrointestinal tract, although this occurred 28 days after COWP treatment while goats still had access to infected pasture. COWP feeding tended to reduce both *H. contortus* and *Trichostrongylus* spp. by 50 and 57%, respectively. The reasons for higher effectiveness against *Trichostrongylus* spp. than found in Experiment 3 are unclear. COWP has been determined to have a limited effect on intestinal worms (Bang et al., 1990; Knox, 2002). In these studies, COWP was administered in a gelatin capsule, which has been suggested to allow the copper rods to be released and lodged in the folds of the abomasum, releasing copper ions and changing the abomasal environment (Knox, 2002). There was a slight, but insignificant advantage of the COWP in feed compared with the capsule in Experiments 1 and 3. Perhaps incorporating COWP into the feed may reduce the speed of release of the copper, allowing more of it to be shifted to the small intestine. It is acknowledged that re-infection likely occurred in the bucks and adult worm population reflects treatment and new infection.

In summary, COWP administered to goats in the feed was as effective as COWP administered in a gelatin capsule in the control of GIN. It is important that palatability of the feed is high in order to maximize intake and the effectiveness of COWP to control GIN. Caution must be exercised if COWP is incorporated into a concentrate feed to unsupplemented goats on pasture, which could cause grain overloading or acidosis if too much supplement is fed at once. Also, copper toxicity could occur if a small percentage of the goats to be treated received all of the supplemental feed.

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