

Effects of essential oils and betaine on male broilers raised on used litter seeded with coccidia oocysts

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Primary Audience: Researchers, Nutritionists

SUMMARY

An experiment was conducted to evaluate the effects of essential oils (garlic and cinnamon extracts) and betaine on growth performance and oocyst shedding of 42-day-old male broilers raised on used litter seeded with coccidia oocysts. Treatments included: negative control (NC) a nonsupplemented diet with broilers raised on fresh shavings, positive control (PC) the same nonsupplemented diet with broilers raised on used litter, the same diet formulation with 50 ppm of active salinomycin sodium (Bio-Cox 60;PC+Sal) raised on used litter, or the same diet formulation with 500 ppm of essential oils and 250 ppm of betaine (PC+EO+B) raised on used litter. The PC worsened performance (BW gain; **BWG** or mortality corrected FCR; FCRm) in comparison to NC and PC+Sal over 0 to 16 and 0 to 29 d ($P \leq 0.05$) and 0 to 42 d ($P \leq 0.10$). The PC+EO+B increased BWG relative to PC over 0 to 16 and 0 to 29 d ($P \leq 0.05$) and from 0 to 42 d ($P = 0.07$). The PC+EO+B improved FCRm in comparison to PC over 0 to 16 and 0 to 42 d ($P \leq 0.05$). The PC+EO+B was similar to NC and PC+Sal for BWG and FCRm across all time periods ($P > 0.05$). Oocyst counts were lowest in NC, highest in PC, and intermediate in PC+Sal and PC+EO+B for all periods. In conclusion, the reduced performance and increased oocyst shedding in the PC validate a mild coccidiosis infection and the combination of essential oils and betaine were able to ameliorate the negative effects.

Key words: broiler, performance, oocyst shedding, coccidiosis, feed additive

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DESCRIPTION OF PROBLEM

Coccidiosis is a host-specific protozoa and parasite of the genus *Eimeria* that can infect the intestinal mucosa of the bird from the duodenum to the ceca. Afflicted broilers can display subclinical symptoms including reduced nutrient absorption, and morbidity, or clinical

infections resulting in increased mortality (Persia et al., 2006; Vermeulen et al., 2001). The costs from both subclinical and clinical infections of coccidiosis have been estimated to cost US\$13.2 billion worldwide in 2016 (Blake et al., 2020). The reduced use of antibiotics in the poultry industry has resulted in a greater potential of coccidiosis and other enteric diseases. Therefore, the development of alternatives to antibiotics is critical to maintain an eubiotic environment within the broiler while also continuing efficient broiler production.

Several phytogetic compounds have been identified that have specialized anticoccidial

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effects in poultry. The essential oils found in cinnamon contain a bioactive compound, cinnamaldehyde, that is beneficial for broiler performance and intestinal health (Lee et al., 2011; Yang et al., 2020; Qaid et al., 2022). More specifically, 150 ppm of cinnamaldehyde reduced coccidial lesions in broiler chickens challenged with *E. acervulina* (Orengo et al., 2012). The essential oils found in garlic, contain bioactive compounds including allin, ajoene, allicin and diallyl sulfide, which have the potential to ameliorate coccidial infection in broilers (Nahed et al., 2022). Previous research has shown that garlic extract enhances broiler immunity by increasing *Eimeria* antibody responses and decreases fecal oocyst shedding (Kim et al., 2013). The supplementation of 15 g/kg of dried and ground garlic to broilers challenged with coccidiosis reduced oocyst shedding and improved BW and FCR (Ali et al., 2019). Natural betaine is a by-product of sugar beet processing and is a trimethyl molecule derived from the amino acid glycine. Supplementation of betaine has resulted in increased growth performance, muscle yield, fat metabolism, and immunity in broilers (Augustine et al., 1997; Kettunen et al., 2001; Ghasemi and Nari, 2020; Awad et al., 2022). Moreover, the use of 960 ppm of natural betaine improved nutrient digestibility and reduced intestinal lesion scores when fed to broilers that were orally gavaged with 180,000, 6,000, and 18,000 sporulated oocysts of *E. acervulina*, *E. maxima*, and *E. tenella*, respectively (Amerah and Ravindran, 2015). The supplementation of 1,000 ppm of natural betaine has the potential to exert a protective effect by ameliorating intestinal injury through the suppression of inflammatory responses, and enhancing mucosal barrier function (Alhotan et al., 2021). Overall, these feed additives individually have been shown to have beneficial effects against coccidiosis in broilers, but little research has investigated the combination of these essential oils and betaine. The differences in mode of action among these essential oils and betaine suggest potential synergistic effects when used in broilers. Therefore, the current experiment was conducted to evaluate the effects of the combination of the essential oils of

cinnamon and garlic with betaine on broiler growth performance, intestinal lesion scores, and oocyst shedding when broilers were raised on reused litter seeded with coccidia oocysts.

MATERIALS AND METHODS

Animals and Experimental Diets

This experiment was conducted according to the guidelines of the Virginia Tech Institutional Animal Care and Use Committee. A total of 1,152 male Ross 708 broiler chicks were selected from a group of chicks obtained from a commercial hatchery (Longenecker's Hatchery, Elizabethtown, PA). Broilers were assigned to 4 experimental treatment groups that were randomly assigned within 12 replicate pens that contained 24 chicks per pen. Broiler floor pens (1.372 m x 1.372 m) were stocked with birds to result in 0.090 m² per broiler at the end of the experiment (maximum of 21 birds per pen after 3 birds were euthanized for sample collection on d 16). Treatments consisted of a negative control (NC) that received a nonsupplemented diet and housed on clean pine shavings litter; a positive control (PC) that received the same diet but housed on used litter; PC+Sal was generated with a similar diet formulation supplemented with 50 ppm of active salinomycin sodium (Bio-Cox 60, Huvepharma, Peachtree City, GA 30269) and housed on used litter; and finally PC +EO+B was generated with a similar diet formulation supplemented with 500 ppm of Excential Alliin Plus (garlic and cinnamon essential oils, Orffa Additives, Breda, Netherlands) and 250 ppm of Excential BetaKey 74 (74% betaine HCL and anhydrous betaine, Orffa Additives, Breda, Netherlands) and housed on used litter. All diets were generated using a basal diet of common ingredients before feed additives were added on top. Experimental diet formulation for starter (D 0–16), grower (D 16–29), and finisher diets (D 29–42) are described in Table 1. Starter feed was provided as a crumble, while grower and finisher diets were provided as pellets. Broilers were provided ad libitum access to experimental feed and water.

This used litter model was generally based on the methods of Sizmaz and colleagues (2022). For each pen designated as used litter,

Table 1. Formulation and nutrient composition of experimental diets fed to male broiler chickens provided of essential oils and betaine and raised on used pine shaving litter seeded with coccidia oocysts.¹

Ingredient	Starter (0–16 d)	Grower (16–29 d)	Finisher (29–42 d)
Corn	59.84	63.88	64.23
Soybean meal (48% CP)	28.76	22.81	18.39
Poultry by-product meal	4.00	5.00	6.00
Dried distillers grains with solubles	2.43	3.04	5.56
Soy oil	1.00	1.86	2.83
Salt (sodium chloride)	0.16	0.15	0.09
Sodium Bicarbonate	0.25	0.25	0.30
DL-Methionine	0.34	0.30	0.24
L-Lysine•HCl (78.5%)	0.28	0.32	0.24
L-Threonine	0.12	0.09	-
Limestone	1.05	0.96	0.85
Dicalcium phosphate	0.85	0.54	0.45
Choline chloride (60%)	0.10	0.10	0.10
Vitamin and mineral premix ²	0.63	0.50	0.50
Phytase ³	0.01	0.01	0.01
Nutrient Composition ⁴	(%)		
Crude protein	22.35 (20.86)	20.60 (19.53)	19.60 (19.13)
Metabolizable energy (kcal/kg)	3000	3100	3200
Calcium	0.96	0.87	0.68
Nonphytate phosphorus	0.48	0.44	0.29
Choline (mg/kg)	2,487	2,355	2,347
Crude fat	4.44 (3.86)	5.54 (4.55)	6.78 (4.81)
Crude fiber	2.65 (3.83)	2.60 (2.36)	2.65 (2.57)
Digestible methionine + cysteine	0.95	0.87	0.80
Digestible lysine	1.24	1.15	1.02
Digestible threonine	0.86	0.77	0.66

¹Treatment diets were obtained by supplementing Bio-Cox 60 at 0.0415% to provide 50ppm of salinomycin for PC+Sal and Excential Alliin Plus at 0.05% + Excential BetaKey at 0.025% for PC+EO+B.

²Vitamin and mineral premix: provided per kg of premix: cobalt, 34 mg; copper, 540 mg; iodine, 134 mg; iron, 6,750 mg; manganese, 8,580 mg; zinc, 6,500 mg; vitamin A, 881,849 IU; vitamin D3, 295,419 ICU; vitamin E, 220 IU; vitamin B12, 0.88 mg; menadione, 154 mg; riboflavin, 551 mg; D-pantothenic acid, 811 mg; niacin, 2,646 mg; choline, 51,030 mg.

³Phytase was formulated to provide 0.10% Ca and nonphytate phosphorus, Quantum BLUE 5 G, AB Vista, Marlborough, UK.

⁴Values within parenthesis are analyzed values for complete diets.

25 d-old off-male chicks from a female broiler breeder line were provided approximately 600 g of feed treated with coccidial vaccine via a cardboard tray for the first 3 d. This treated diet was generated by premixing a vial of Coccivac B-52 (Rahway, NJ) with 900 g of mash feed before mixing the premix into the remain mash feed to generate 45 kg of treated mash feed. After the first 3 d, the seeder birds were fed common starter and grower diets until 18 d when the seeder birds and feed were removed from all pens. This 18-d period allowed for the seeder birds to shed coccidial spores into the litter before experimental birds were placed into the pens. All used litter was moved to the center

of the house, mixed and redistributed to the used litter pens. The pens randomly selected for NC remained empty until used litter was redistributed to the other pens and fresh clean pine shavings were placed into the NC pens. Experimental birds were placed into pens and the experiment started after 3 d of downtime. The pen temperature was set to 35°C for the first 3 d and gradually decreased until 20°C was reached and maintained. Continuous lighting and supplemental heat were provided via heat lamps from 0 to 3 d of age after which 20 h of light and 4 h of darkness was provided from 3 to 42 d of age. Bird checks occurred at least twice daily for health checks and mortality removal.

Growth Performance

Birds were weighed on a pen basis on d 0, 16, 29, and 42 to correspond with diet phase changes. Body weight gain (**BWG**) and feed intake (**FI**) were calculated for the 0 to 16, 0 to 29, and 0 to 42 d periods. Body weight gain was determined by the difference between initial body weight and respective body weights for each period. Feed intake was calculated by the difference between feed offered and refused for corresponding periods. Broilers that died, were sampled, or culled were weighed, recorded, and used to correct the feed conversion ratio. Mortality corrected feed conversion ratio (**FCRm**) was calculated by the total pen feed intake divided by the total pen BWG plus total pen mortality BWG.

Lesion Scoring

On d 16, three birds per pen were selected, individually weighed, and euthanized for lesion scoring. The duodenum, jejunum, and ileum were scored for lesions. Lesion scoring was performed by 3 individuals (blinded by experimental treatment), with each individual scoring one bird per pen to minimize scoring bias across treatments. Each section was scored according to the methods reported by [Johnson and Reid \(1970\)](#) using a scale of 0 to 4.

Oocyst Shedding

On d 11 to 13, 17 to 19, and 22 to 24 fresh excreta were collected from each pen to determine oocyst shedding. Approximately 2 to 4 fresh excreta samples were collected daily on three consecutive days to create one composite sample for each pen for each sample period. The method for storage and preparation of the fresh excreta was adapted from [Long \(1970\)](#). Briefly, once the excreta were weighed and recorded, a 0.9% saline solution was added on top of the excreta and stored in the refrigerator at 4°C. The composite samples were then standardized to 30 mL within the conical tube. Then, 10 mL of 5% potassium dichromate was added to each conical tube. The conical tubes were placed into an incubator for 48 h at 28°C. After the incubation process, the samples were

put back into the refrigerator at 4°C. Oocysts were counted in quadruplicate using a counting chamber (McMaster; JA Whitlock & Company, New South Wales, Australia) and microscope (Olympus CX21-FS1, Tokyo, Japan) set at 10× magnification ([Dalloul et al., 2003](#)). The total number of oocysts (sporulated and unsporulated) were calculated using the formula:

$$\text{Total oocysts/g of excreta} = (\text{oocyst counted} / \text{chamber volume}) \times \text{dilution factor} \times (\text{composite sample volume/g of excreta used}).$$

Statistical Analysis

All data were analyzed using JMP Pro 16 (SAS Institute Inc., Cary, NC) by one-way ANOVA. Each pen was considered an experimental unit. Statistical differences were considered significant if ANOVA was $P \leq 0.05$. If significant ANOVA differences were noted, means were separated using Student's *t* test ([Sarsour and Persia, 2022](#)). One replicate pen from the PC was excluded from analysis due to a water outage event and the pen potentially being without water for up to 18 h.

RESULTS AND DISCUSSION

The effects of essential oils and betaine on BWG, FCRm, and mortality of male broilers raised on used pine shaving litter seeded with coccidia are presented in [Table 2](#). There were no differences in initial BW with the average across all treatments being 43.2 g per chick ($P = 0.55$). The PC resulted in a 36 and 41 g reduction in BWG over the 0 to 16 d period in comparison to NC and PC+Sal, respectively ($P \leq 0.05$). Likewise, from 0 to 16 d, the PC worsened FCRm by 3 and 4 points, respectively, in relation to the NC and PC+Sal ($P \leq 0.05$). This response agrees with previous research as broilers are more susceptible to disease stress until the immune system maturation at d 30 ([Song et al., 2021](#)). Similarly, over 0 to 29 d, BWG in the PC was reduced by 84 g and 92 g in comparison to the NC and PC+Sal, respectively ($P \leq 0.05$). Although there were no significant differences in FCRm among the PC, NC, and PC+Sal birds from 0 to 29 d, the FCRm was reduced by 1.3 and 4.1 points in the

Table 2. Effects of essential oils and betaine on body weight gain (BWG), mortality corrected feed conversion ratio (FCRm), and mortality of male broilers raised on used pine shaving litter seeded with coccidia oocysts from 0 to 16, 0 to 29, and 0 to 42 d of age.¹

Treatments ²	D 0–16		D 0–29		D 0–42		Mortality ³ (%)
	BWG (g/bird)	FCRm (g/g)	BWG (g/bird)	FCRm (g/g)	BWG (g/bird)	FCRm (g/g)	
NC	468 ^a	1.320 ^b	1491 ^a	1.465	2999	1.568 ^{ab}	3.5
PC	432 ^b	1.354 ^a	1407 ^b	1.478	2874	1.605 ^a	2.8
PC+Sal	473 ^a	1.310 ^b	1499 ^a	1.437	3110	1.550 ^b	4.5
PC+EO+B	465 ^a	1.308 ^b	1503 ^a	1.426	3048	1.551 ^b	2.1
Pooled SEM	8.6	0.0130	21.6	0.0148	54.5	0.0139	N/A
<i>P</i> -value	0.01	0.03	0.02	0.09	0.07	0.05	N/A

¹12 replicate pens per treatment with 24 birds per replicate pen. One replicate from NC was excluded. Initial body weight = 43.2 g per chick ($P = 0.55$, SEM = 0.22).

²NC = nontreated diet with fresh pine shaving litter; PC = nontreated diet on used litter; PC+Sal = diet with salinomycin on used litter; PC+EO+B = diet with Excential Alliin Plus + Excential BetaKey on used litter.

³Mortality data were not analyzed due to limited variation across treatments and is provided for reference only.

^{a-c}Columns without a common superscript are different ($P \leq 0.05$).

PC in comparison to the NC and PC+Sal, respectively ($P = 0.09$). The 29-d period noted above includes 3 to 4 wk of age is when broilers experience the greatest coccidial infection (Snyder et al., 2021). Over the entire 42 d experiment, BWG was decreased in the PC by 125 and 236 g in comparison to NC and PC+Sal, respectively ($P = 0.07$). Over the same 0 to 42 d period, the PC increased FCRm by 5.5 points in comparison to the PC+Sal ($P \leq 0.05$), with the 3.7-point increase in FCRm in comparison to the NC an intermediate response between the two. Overall mortality remained low throughout the 42-d experiment as the NC, PC, PC+Sal, and PC+EO+B resulted in 3.5, 2.8, 4.5, and 2.1% mortality, respectively. The used litter model was able to replicate a more typical broiler industry response to sub-clinical coccidial infection with overall decreased performance without a large increase in mortality (Blake et al., 2020).

The PC+EO+B treatment improved BWG by 33 g and FCRm by 4.6 points in comparison to the PC ($P \leq 0.05$) returning performance similar to that of the NC and PC+Sal over the 0 to 16 d starter period ($P > 0.05$). Previous research has observed that 10 ppm of garlic extracts were able to improve broiler BWG by 60 g from 10 to 20 d of age when orally gavaged at 10 d of age with 1.0×10^4 sporulated oocysts of *E. acervulina* (Kim et al., 2013). Over the 0 to 29 d period, PC+EO+B increased BWG by 99 g in comparison to the PC ($P \leq$

0.05) resulting in performance similar to both the NC and PC+Sal ($P > 0.05$). However, there were no significant differences among treatments for FCRm from 0 to 29 d although PC+EO+B improved FCRm by 4.1 points in comparison to the PC ($P = 0.09$). Over the entire 0 to 42-d experimental period, there were no differences among treatments for BWG. However, the PC+EO+B broilers showed a 174 g increase compared to the PC group ($P = 0.07$). Additionally, the PC+EO+B treatment improved FCRm by 5.4 points compared to the PC broilers ($P \leq 0.05$), resulting in FCRm values similar to both the NC and PC+Sal groups ($P > 0.05$). Garlic, cinnamon, and betaine all have the potential to limit or inhibit colonization of pathogenic bacteria (Peinado et al., 2012; Park and Kim, 2017 and Nouri, 2019), which may contribute to the increased performance in broilers (Bedford, 2000). Little research has been conducted investigating the combined effects of essential oils and betaine on used litter, however, individual supplementation of garlic, cinnamon, and betaine have been reported to improve broiler BWG and FCR when those birds were exposed to coccidial challenge. Supplementation of 15,000 ppm of dried garlic to broiler chickens orally challenged with sporulated *E. tenella* resulted in significant improvements in BW and FCR (Ali et al., 2019). A 28-d floor pen study was conducted by Yang and cohorts (2020) to investigate the use of 100 ppm encapsulated cinnamaldehyde on broiler performance

when challenged with a commercial vaccine spray at day of hatch. Although the cinnamaldehyde did not increase BWG, improvements were noted in FCR compared to the control. When 1,000 ppm betaine was supplemented to 36-day old broilers that were orally inoculated with a mixture of *E. acervulina*, *E. praecox*, *E. maxima*, and *E. tenella* on d 10 showed a 144 g improvement in BWG and a 9-point improvement in FCR in comparison to the control (Waldenstedt et al., 1999). A similar experiment was conducted by Amerah and Ravindran (2015) where broilers were orally gavaged with a mixed *Eimeria* species vaccine on d 14 and were supplemented with natural betaine at 960 g/ton. The betaine improved FCR, but not BWG. The improved performance in the current experiment can be potentially attributed to the combination essential oils and betaine that have been shown to act with different modes of action in broilers (Horn et al., 2016; Wen et al., 2021; Qaid et al., 2022). However, due to limitations of individual controls, it is not possible to discern if the betaine or the essential oil product were providing the response individually, and all responses have to be attributed to the combined feed additives.

There were no differences in observed intestinal lesion scores in any section of the broiler small intestine ($P > 0.05$), regardless of used litter, anticoccidial or essential oil, and betaine treatment (Table 3). Lesion scores provide insight into intestinal damage cause by *Eimeria*; however, scoring may be subjective and has a narrow observational window for peak incidence (Chasser et al., 2020). Consequently, lesion scores should be used in combination

with other coccidial infection measurements, such as oocyst shedding (Mesa-Pineda et al., 2021). In this experiment, lesion scores were present in the NC and there is no explanation for this result. However, these data are contradictory with the performance and oocyst shedding data. Given that the performance and oocyst shedding are from multiple time periods, while the lesion score is a single time point more weight is given to the performance and oocyst shedding data as conformation of coccidial challenge. The overall lesion scores among all treatments were low, which agrees with published research when broilers were provided a coccidiosis vaccine (Cloft et al., 2019). Low lesion scores (less than 1.5 per species) are indicative of a subclinical challenge (De Gussem, 2007) which was the objective of this research. In contrast, when more virulent strains of *Eimeria* are utilized, broilers have been shown to experience more severe lesion scores (Williams, 2003). Broilers supplemented with 960 g/ton of betaine resulted in decreased lesion scores in the duodenum and the lower portion of the jejunum at d 21 (Amerah and Ravindran, 2015). Similarly, broilers supplemented with 150 ppm of cinnamaldehyde and orally inoculated with 1×10^5 sporulated *E. acervulina* oocysts at d 25 resulted in reduced duodenal lesion score in comparison to the control (Orengo et al., 2012). Additionally, broilers supplemented with 15,000 ppm of garlic extract and orally gavaged with 2×10^4 sporulated *E. tenella* on d 8 had decreased lesion scores (Ali et al., 2019). The previous literature has primarily focused on clinical infection, and it would be expected that subclinical coccidial infection,

Table 3. Effects of essential oils and betaine on lesion scores of male broilers raised on used pine shaving litter seeded with coccidia on D 16.¹

Treatments ²	Duodenum	Jejunum	Ileum
	(0-4)		
NC	1.42	1.19	0.89
PC	1.07	1.03	0.70
PC+Sal	1.15	0.91	0.88
PC+EO+B	0.94	0.81	1.06
Pooled SEM	0.15	0.13	0.13
P-value	0.13	0.14	0.30

¹12 replicate pens per treatment with 24 birds per replicate pen. One replicate from NC was excluded.

²NC = nontreated diet with fresh pine shaving litter; PC = nontreated diet on used litter; PC+Sal = diet with salinomycin on used litter; PC+EO+B = diet with Excential Alliin Plus + Excential BetaKey on used litter.

as generated in the current research, would result in lower lesion scores with limited treatment effects.

The effects of essential oils and betaine on oocyst shedding from 11 to 13, 17 to 19, and 22 to 24 d of age are presented in Figure 1. As expected, regardless of collection period, the NC resulted in the lowest coccidia oocyst counts and the PC resulted in highest oocyst shedding counts ($P \leq 0.05$). During the 11 to 13 and 17 to 19 sample periods, PC+Sal resulted in reduced oocyst shedding in comparison to the PC but were still increased in comparison to NC ($P \leq 0.05$). However, over the same 11 to 13 and 17 to 19 d sample periods, PC+EO+B did not reduce oocyst shedding in comparison to the PC ($P \leq 0.05$). During the final collection period, 22 to 24 d, PC+Sal resulted in counts similar to PC ($P > 0.05$). Conversely, PC+EO+B resulted in counts reduced in comparison to PC ($P \leq 0.05$). The oocyst shedding pattern observed in this experiment is comparable to the oocyst shedding seen in previous commercial broiler flocks vaccinated with coccidiosis vaccine at the hatchery (Snyder et al., 2021). In previous research, the individual feed additives have been shown to alter coccidial oocyst shedding. Dried garlic reduced oocyst shedding in broilers infected with coccidia positive cecal contents (Ali et al., 2019). Supplementation of 1,000 ppm betaine increased the recruitment of leukocytes locally in broilers inoculated with

E. acervulina which ultimately resulted in the disappearance of sporozoites 7 d after initial inoculation (Klasing et al., 2002). Broilers were supplemented 2,000, 4,000, and 6,000 ppm of *Cinnamomum verum* powder and orally gavaged with 40,000 *E. tenella* sporulated oocysts (Qaid et al., 2021). The inclusion of 6,000 ppm of cinnamon significantly reduced oocysts shedding compared to the control, while 2,000 ppm and 4,000 ppm were intermediate. The differences in response timing in the current experiment could be due to the different modes of action occurring between the PC+Sal and PC+EO+B treatments. The PC+Sal has direct inhibition on coccidial cell proliferation resulting in reduced shedding earlier within the cycle (Bolder et al., 1999). The combination of PC+EO+B is potentially stimulating the immune response of broilers (Klasing et al., 2002; Elmowalid et al., 2019; Nouri, 2019) resulting in the reduced oocyst shedding counts over the later 22-to-24-d collection period. The delay associated with this response is likely due to the timed response of the immune system to the challenge and stimulus (Giambrone et al., 1984). Previous research has shown that garlic has the potential to elicit this delayed response in oocyst shedding. Broilers supplemented with garlic and oregano essential oils resulted in a reduction of oocyst shedding at d 28 and a further reduction by d 37 (Sidiropoulou et al., 2020).

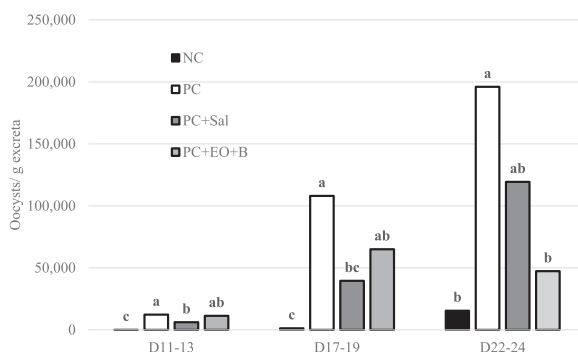


Figure 1. Effects of essential oils and betaine on oocyst shedding of male broilers raised on used pine shaving litter seeded with coccidia from 11 to 13, 17 to 19, and 22 to 24 d of age. NC = nontreated diet with fresh pine shaving litter; PC = nontreated diet on used litter; PC+Sal = diet with salinomycin on used litter; PC+EO+B = diet with Excellent Alliin Plus + Excellent BetaKey on used litter.

^{a-c}Columns without a common superscript are different ($P \leq 0.05$).

CONCLUSIONS AND APPLICATIONS

1. Growing broilers on used litter seeded with coccidial vaccine was able to reduce overall performance without increasing mortality when compared to broilers raised on clean litter, and broilers raised on the same used litter, but provided an anticoccidial treatment.
2. The combination of the essential oils and betaine was able to improve BWG and FCRm in comparison to the PC returning performance to that of the NC broilers raised on clean litter or provided an anticoccidial treatment.
3. The combination of the essential oils and betaine reduced oocyst shedding later in the coccidial shedding cycle suggesting a potentially different mode of action than direct anti-coccidial treatment.

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DISCLOSURES

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