Effect of 3 dietary phytogenic products on production performance and coccidiosis in challenged broiler chickens

W. Scheurer,* P. Spring,*[1] and L. Maertens†

**School of Agricultural, Forest and Food Sciences, Bern University of Applied Sciences, 3052 Zollikofen, Switzerland; and †Animal Science Unit, Institute for Agricultural and Fisheries Research, 9090 Melle, Belgium*

Primary Audience: Feed Manufacturers, Live Production Managers, Nutritionists, Researchers, Veterinarians

SUMMARY

A pen trial using 1,080 male Ross 308 broiler chicks (6 treatments with 6 replicates each) was conducted to examine the effects of 3 dietary phytogenic products on avian coccidiosis. The dietary treatments included (1) a negative control (NC), (2) a positive control (PC) without feed additive, (3) Narasin at 0.7 kg/t (COCC), (4) PHYT1 (oregano) at 2.0 kg/t, (5) PHYT2 (combination of *Curcuma*, saponins, and inulin) at 1.0 kg/t, and (6) PHYT3 (*Quillaja*) at 1.0 kg/t. Treatments 2 through 6 were challenged with a mixture of *Eimeria acervulina*, *Eimeria maxima*, and *Eimeria tenella* at d 15 via feed. Standard performance parameters and coccidial lesion scoring (d 22) were conducted. One week after coccidial challenge, chicks BW of the COCC treatment and the NC were higher than all other treatments. Body weights on d 39 were 2.47 (NC), 2.34 (PC), 2.51 (COCC), 2.35 (PHYT1), 2.39 (PHYT2), and 2.41 kg (PHYT3) with an SEM of 0.033. For the entire trial period, Narasin yielded a significantly better FCR in comparison with the PC and PHYT3. Overall mean lesion score was 0.54 (NC), 0.91 (PC), 0.50 (COCC), 0.81 (PHYT 1), 1.02 (PHYT 2), and 1.13 (PHYT 3) with an SEM of 0.122. It was concluded that all 3 phytogenic products were not effective at the used dosage in alleviating the negative effects observed in coccidiosis-challenged birds.

Key words: broiler, coccidiosis, phytogenic compound, lesion score

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DESCRIPTION OF PROBLEM

Coccidiosis is an important intestinal disease in broiler production. It is caused by protozoan parasites of the genus *Eimeria* [1]. Due to its multiplication in the intestinal tract, the parasite causes tissue damage. This can disturb the feeding, digestive processes, and nutrient absorption, leading to dehydration, blood loss, poor skin pigmentation, and increased susceptibility to other diseases. Clinical signs include diarrhea or soft, mucoid feces, poor growth, impaired FCR, and increased mortality [2]. The pathogenicity of the 7 species of *Eimeria* varies, with some invading deep in the intestinal mucosa, causing wide-spread damage and distinct gross

[1]Corresponding author: peter.spring@bfh.ch

lesions (e.g., *Eimeria tenella*) and others being less destructive but still having a significant effect on productive performance [3].

To prevent coccidiosis and minimize related economic losses, which are estimated at €2.3 billion ($2.97 billion) per year for the global poultry industry, anticoccidial drugs are applied via feed prophylactically [4]. Due to their regular use, drug-resistant *Eimeria* strains have been reported [5, 6]; therefore, alternative strategies for coccidiosis control are needed. Besides the application of vaccines, which are expensive to produce, the use of plant-derived compounds seems to have some potential in the control of this parasite [7].

The essential oils of *Origanum vulgare* are known to be effective in vitro against protozoa [8] and dietary supplementation of oregano has been shown to reducing clinical signs of coccidiosis in birds and to maintaining the flock performance [7]. According to Cheeke [9], saponin-containing feed additives consisting of *Yucca schidigera* and *Quillaja saponaria* have antiprotozoal activity. The ability of saponins to bind to membrane cholesterol of protozoan cells can modify membrane function and structure and account for their antiprotozoal activity [10].

Curcumin (diferuloylmethane) is a natural polyphenolic compound abundant in the rhizome of the perennial herb turmeric (*Curcuma longa*), a spice and food colorant commonly used in human food and as a medicinal herb. In published trials, the effect of this compound at different concentrations on morphological alterations, viability of *E. tenella* sporozoites, and infectivity to Madin-Darby bovine kidney cells has been tested in vitro. Compared with the untreated control, curcumin at concentrations of 100 and 200 μM led to a reduction of infectivity of 41.6 and 72.8%, respectively [11].

Today there is only limited information available about the effect of *Chichorium intybus* on coccidiosis. But chicory as a green fodder has shown promising results in the prevention of infestation with parasitic gastroenteritis, in addition to increasing live weight gain in sheep [12]. The objective of this trial was to test 3 commercially available phytogenic products consisting of 1 or more of the previously described compounds on production performances and coccidiosis in challenged broiler chickens.

MATERIALS AND METHODS

Birds, Housing, and Vaccination

The trial was conducted at the Institute for Agricultural and Fisheries Research from August to September 2011 with the approval of the animal care committee. A total of 1,080 Ross 308 male broiler chicks [13] were raised in a building in floor pens on wood shavings and were divided into 6 treatments with 6 replicates per treatment.

The birds were housed (30 per pen at placement) with an available floor area of 2.1 m^2 per pen. Infrared bulbs (1 per pen) and central heating by hot water pipes were used to maintain the required house temperature. The lighting program was 21L:3D during the experimental period. Air quality was maintained through a mechanical ventilation system, with an air inlet centrally located at the top of the building and air outlets at both sides. To minimize build-up of moisture, NH_3, and CO_2, the ventilation rate was adjusted based on the measured temperature and age of the animals.

The chicks were vaccinated after hatching against Newcastle disease (NDW spray) and infectious bronchitis [14]. At 16 d, vaccination against Newcastle disease was repeated via drinking water [15].

Feeding and Experimental Treatments

A 3-phase feeding program was applied, with starter from 0 to 11 d, grower from 11 to 22 d, and finisher from 22 to 39 d. Table 1 describes the feed composition and nutrient concentrations of the experimental diets. Diets were prepared in the Institute for Agricultural and Fisheries Research facilities. First, the basal diet for each phase was prepared in one batch. Each batch was divided in 6 equal parts and supplemented with the respective additive.

The two control treatments (NC and PC) included no measure for coccidiosis prevention, however, PC included the coccidial challenge. As a reference treatment, Narasin-Monteban [16] at 0.7 kg/t was used (**COCC**). The 3 PHYT treatments (oregano; combination of *Curcuma*, saponins, and inulin; *Quillaja*) were tested at the recommended dosage (Table 2). During the last 5 d of the trial, treatment COCC was fed

Table 1. Feed composition and calculated nutritional values of experimental diets

Item	Starter (0 to 11 d)	Grower (11 to 22 d)	Finisher (22 to 39 d)
Ingredient (%)			
Wheat	52.75	57.45	58.19
Corn	10.00	5.00	5.00
Soybean meal 48 (46)	20.72	23.84	18.42
Soybean	10.00	4.61	10.00
Animal fat	2.35	5.55	5.01
$CaCO_3$	0.60	0.42	0.39
D-Ca-phosphate	1.54	1.19	1.03
NaCl	0.22	0.21	0.24
$NaHCO_3$	0.15	0.15	0.12
L-Lys HCl	0.299	0.230	0.261
DL-Met	0.252	0.241	0.234
L-Thr	0.083	0.073	0.083
Vitamin and trace element premix[1]	1.00	1.00	1.00
Ronozyme [30]	0.02	0.02	0.02
Ronozyme WX (CT) [31]	0.02	0.02	0.02
Calculated nutrient concentration (%)			
DM	88.3	88.7	88.4
CP	20.0	19.5	19.0
Lys	1.21	1.13	1.1
Digestible Lys	1.06	1.00	0.98
Met	0.53	0.51	0.49
Digestible Met + digestible Cys	0.77	0.75	0.73
Thr	0.80	0.77	0.75
Digestible Thr	0.67	0.65	0.64
Ca	0.90	0.75	0.70
P	0.65	0.58	0.55
Na	0.14	0.14	0.14
Cl	0.26	0.24	0.25
K	0.90	0.87	0.85
ME_n (kcal/kg)	2,830	2,950	2,986
ME_n (MJ/kg)	11.86	12.35	12.50
Analyzed nutrient concentration (%)			
DM	89.2	88.6	88.9
CP	22.1	22.2	19.4
Lys	1.25	1.17	1.10
Met	0.569	0.549	0.473

[1]Provided (per kilogram of diet): 15,000 IU of vitamin A (all-*trans*-retinol); 3,000 IU of vitamin D_3; 55 IU of vitamin E (α-tocopherol); 2.0 mg of thiamin; 600 mg of choline; 5.0 mg of riboflavin; 13.5 mg of pantothenic acid; 4.0 mg of pyridoxine; 0.02 mg of cyanocobalamin; 15 mg of niacin; 0.20 mg of biotin; 1.0 mg of folic acid; 1.2 mg of I; 20 mg of Cu; 0.36 mg of Se; 1.0 mg of Co; 95.9 mg of Mn; 60 mg of Zn; 49 mg of Fe; and 33 mg of ethoxyquine.

the control diet without an anticoccidial additive (withdrawal phase).

At 15 d, birds were challenged, except the negative control (**NC**), with a defined mixture of *Eimeria* oocysts. The inoculum contained a mixture of sporulated oocysts of pathogenic strains of *Eimeria* (250,000 *Eimeria acervulina*, 25,000 *Eimeria maxima*, and 25,000 *E. tenella* per bird) and was administered via feed [17].

Live Performance

Total pen weights were recorded on 0 (at placement), 11, 22, and 39 d of age. Feed intake and FCR were measured respectively and calculated for d 0 to 11, 0 to 22, 0 to 29, 0 to 39, 11 to 22, and 22 to 39. Feed conversion was adjusted for mortality. Mortality and culls were recorded for the entire trial period (0–39 d). Performance data were analyzed by ANOVA and means were

Table 2. Experimental treatments

No.	Name	Abbreviation	Coccidial challenge	Feed additive	Concentration in feed (ppm)
1	Negative control	NC	No	None	—
2	Positive control	PC	Yes	None	—
3	Coccidiostat	COCC	Yes	Narasin Monteban [16]	700
4	Oregano	PHYT1	Yes	Oil of *Oreganum vulgare*	200
5	*Curcuma*/saponins/inulin	PHYT2	Yes	*Curcuma longa*, saponins of *Quillaja saponaria*, inulin of *Cichorium intybus*	1,000
6	*Quillaja*	PHYT3	Yes	*Quillaja saponaria*	1,000

compared by Tukey and Kramer tests. Preconditions for testing with ANOVA were assessed by the tests of Shapiro and Bartlett. In the case when the assumptions for ANOVA where not fulfilled, the Friedmann test was applied [18].

Coccidial Lesion Scoring

Coccidial lesion scoring was carried out 7 d after challenge on d 22 using the method of Johnson and Reid [19]. On d 22 (end of the grower period), 3 birds per cage were randomly selected, weighed, euthanized by cervical dislocation, and necropsied. The intestinal tract was examined for coccidial lesions by 2 veterinarians specialized in poultry diseases [20]. Lesion scores were recorded as 0, 1, 2, 3, or 4, from no lesions to most severe. Lesions typical for each of the 3 types of *Eimeria* were recorded separately.

RESULTS AND DISCUSSION

BW

Results for BW on d 0, 11, 22, 29, and 39 are presented in Table 3. Whereas BW on d 0 and 11 did not differ significantly between treatments, clear differences between treatments were measured after inoculation on d 15. On d 22, the average BW of COCC (876 g) and NC (871 g) were the highest and significantly different from all other treatments. On d 29 the birds of the COCC group still had a significantly higher BW than those of the other groups except the NC. The latter had a significantly higher BW than PHYT1 (Oregano) and PHYT2 (*Curcuma*/Saponins/Inulin). Among the 3 treatments using alternative products, the highest BW was recorded for PHYT3, but differences were small and nonsignificant. Body weight on d 39 differed significantly between COCC and the positive control (**PC**) and PHYT1.

The absence of a positive response on BW with a phytogenic product was also observed in slow-growing broiler chickens by Clavé and van der Horst [21]. They applied the following treatments: a Maxiban [22] control group, a Paracox-5 group [23], and a group treated with the plant-derived product Eimericox [24]. Birds of all treatments were inoculated with a suspension containing 100,000 to 150,000 oocysts of

Table 3. Average BW for different times of the trial by experimental treatments

	BW (g)				
Item	d 0	d 11	d 22	d 29	d 39
Treatment[1]					
NC	41.6	274	871[a]	1,456[ab]	2,472[ab]
PC	42.1	260	727[b]	1,301[c]	2,338[b]
COCC	41.9	267	876[a]	1,493[a]	2,507[a]
PHYT1	42.2	257	721[b]	1,310[c]	2,345[b]
PHYT2	41.7	274	742[b]	1,332[c]	2,388[ab]
PHYT3	42.3	278	764[b]	1,358[bc]	2,406[ab]
SEM	0.236	6.246	15.718	24.699	33.191
P-value	0.170	0.150	0.000	0.000	0.006

[a–c]Means in a column with a different superscript differ significantly ($P \leq 0.05$).

[1]NC = negative control; PC = positive control; COCC = narasin in feed; PHYT1 = oregano-based product in feed; PHYT2 = mixture of *Curcuma*, saponins, and inulin in feed; PHYT3 = *Quillaja*-based product in feed. All treatments except NC were challenged on d 15. There were 6 replications per treatment.

E. acervulina and 10,000 to 15,000 oocysts of *E. tenella* and *E. maxima* on d 15. The use of the phytogenic product did not lead to significantly higher BW in comparison to the untreated control group after inoculation.

However, Alfaro et al. [25] indicated a beneficial and synergistic effect between the coccidiosis vaccine and a saponin-containing extract of *Yucca schidigera* for improving weight gain, FCR, and maintaining the integrity of the intestinal villi in chickens. The difference between those results and the results in the present study might be explained by the lack of a severe coccidial challenge in the cited trial. It may be suggested from the work of Alfaro et al. that the *Yucca schidigera* extract was able to reduce the stress and damage that the live vaccine causes in the digestive tract [25].

ADG

Detailed results for ADG are presented in Table 4. For 0 to 22 and 11 to 22 d, ADG differed significantly between NC and PC. As the inoculation on d 15 caused a significant reduction in ADG in PC birds, the *Eimeria* challenge was considered to have worked well. Significantly higher ADG for the COCC group and the NC were observed compared with all other treatments between d 11 and 22. The ADG from 22 to 39 d did not differ significantly between treatments; thus, birds negatively affected by the challenge did not show a significant compensatory growth response. Considering the entire trial period, from 0 to 39 d, only COCC showed significantly higher ADG compared with the PC and the PHYT1 treatment.

When testing the effect of oregano oil on chicken coccidiosis, Tsinas et al. [26] reported significantly higher ADG in broilers fed diets containing oregano essential oil at levels of 300 and 600 mg/kg, respectively, compared with a challenged control group (1×10^5 *E. acervulina* and 1×10^5 *E. maxima*). However, no significant difference in ADG was recorded between the *Eimeria*-challenged treatments containing either oregano or Salinomycin. The disagreement with the data in the present study could be ascribed to differences in the *Eimeria* challenge or in the composition of the oregano-based product.

Feed Intake

The ADFI did not differ significantly between treatments in the period before the challenge (d 0–11), after the challenge (d 22–39) or for the total period (Table 5). Broilers from treatments COCC and NC had a significantly higher intake between d 0 to 22 and 11 to 22 than those in the other treatments. None of the phytogenic products were able to increase feed intake significantly when compared with the PC.

The effect of the *Eimeria* challenge (d 15) on feed intake was evident. The challenge with *Eimeria* oocysts led to a decrease in feed intake for all treatments except COCC in the period immediately after exposure. Reduced feed consumption is a typical sign for clinical coccidiosis [2].

Table 4. Average daily gain of broilers for different time periods of the trial by experimental treatments

	ADG (g/d)					
Item	0 to 11d	0 to 22 d	0 to 29 d	0 to 39 d	22 to 39 d	11 to 22 d
Treatment[1]						
NC	21.1	37.7^{a}	48.8^{ab}	62.3^{ab}	94.2	54.2^{a}
PC	19.8	31.1^{b}	43.4^{c}	58.9^{b}	94.7	42.5^{b}
COCC	20.5	37.9^{a}	50.0^{a}	63.2^{a}	95.9	55.4^{a}
PHYT1	19.5	30.8^{b}	43.7^{c}	59.1^{b}	95.6	42.2^{b}
PHYT2	21.1	31.8^{b}	44.5^{c}	60.2^{ab}	96.8	42.6^{b}
PHYT3	21.4	32.8^{b}	45.4^{bc}	60.6^{ab}	96.6	44.2^{b}
SEM	0.576	0.714	0.845	0.849	1.290	1.159
P-value	0.160	0.000	0.000	0.006	0.670	0.000

[a–c]Means in a column with a different superscript differ significantly ($P \le 0.05$).

[1]NC = negative control; PC = positive control; COCC = narasin in feed; PHYT1 = oregano-based product in feed; PHYT2 = mixture of *Curcuma*, saponins, and inulin in feed; PHYT3 = *Quillaja*-based product in feed. All treatments except NC were challenged on d 15. There were 6 replications per treatment.

However, considering the whole trial period, the effect of the *Eimeria* challenge on feed intake was limited and not significant ($P = 0.11$).

FCR

Feed conversion ratio results by treatment are presented in Table 6. From d 0 to 11 and 22 to 39, no significant differences between treatments were observed. For the entire trial period, COCC led to a significantly lower FCR in comparison to the PC and PHYT3. The *Eimeria* challenge on d 15 showed a strong effect on FCR from d 11 to 22. The unchallenged NC group with an FCR of 1.499 showed much better FE than the challenged PC group with 1.676 ($P \le 0.05$). The FCR of the 3 phytogenic treatments reached in the same period were 1.700, 1.695, and 1.676, respectively, which demonstrates that they were unable to alleviate the negative effects of the coccidiosis challenge.

In regard to the fact that FCR, BW gain, and feed intake did not differ between treatments for the period of d 22 to 39, it can be stated that infected birds recovered from the *Eimeria* challenge during this period. However, it must be noted that the treatments negatively affected by the challenge could not make up performance losses via compensatory growth.

In contrast with our results, Abbas et al. [27], reported significantly improved FCR in broilers with a 3% dietary treatment of turmeric powder

Table 5. Daily feed intake of broilers for different time periods of the trial by experimental treatments

	ADFI (g/d)					
Item	0 to 11d	0 to 22 d	0 to 29 d	0 to 39 d	22 to 39 d	11 to 22 d
Treatment[1]						
NC	29.8	55.3^{a}	72.9^{ab}	98.1	160.7	81.0^{a}
PC	28.9	49.8^{b}	68.2^{c}	95.0	161.6	71.0^{b}
COCC	28.4	54.8^{a}	73.0^{a}	97.5	159.1	81.3^{a}
PHYT1	27.9	49.5^{b}	68.2^{c}	94.0	159.9	71.5^{b}
PHYT2	28.3	50.1^{b}	68.8^{bc}	95.5	160.9	72.1^{b}
PHYT3	28.8	51.2^{b}	70.5^{abc}	97.4	165.8	74.0^{b}
SEM	0.833	0.808	0.959	1.147	2.041	1.217
P-value	0.710	0.000	0.002	0.110	0.290	0.000

[a–c]Means in a column with a different superscript differ significantly ($P \le 0.05$).

[1]NC = negative control; PC = positive control; COCC = narasin in feed; PHYT1 = oregano-based product in feed; PHYT2 = mixture of *Curcuma*, saponins, and inulin in feed; PHYT3 = *Quillaja*-based product in feed. All treatments except NC were challenged on d 15. There were 6 replications per treatment.

Table 6. Feed conversion ratio of broilers for different time periods of the trial by experimental treatments

	FCR (g/g)					
Item	0 to 11 d	0 to 22 d[1]	0 to 29 d	0 to 39 d	22 to 39 d	11 to 22 d[2]
Treatment[3]						
NC	1.410	1.469[c]	1.497[bc]	1.574[ab]	1.706	1.499[b]
PC	1.457	1.601[a]	1.572[a]	1.613[a]	1.706	1.676[a]
COCC	1.390	1.445[c]	1.461[c]	1.542[b]	1.659	1.468[b]
PHYT1	1.433	1.607[a]	1.560[a]	1.593[ab]	1.673	1.700[a]
PHYT2	1.341	1.576[ab]	1.547[ab]	1.587[ab]	1.663	1.695[a]
PHYT3	1.348	1.562[b]	1.554[ab]	1.606[a]	1.716	1.676[a]
SEM	0.041	0.019	0.014	0.014	0.015	0.023
P-value	0.310	0.001[2]	0.000	0.015	0.035	0.001

[a–c]Means in a column with a different superscript differ significantly ($P \leq 0.05$).

[1]Assumptions for ANOVA were not fulfilled (Shapiro test: $P = 0.008895$); therefore, Friedmann and Kruskal-Wallis were applied, ranking and *P*-value according to Kruskal-Wallis test.

[2]Assumptions for ANOVA were not fulfilled (Shapiro test: $P = 0.0185$); therefore, Friedmann and Kruskal-Wallis tests were applied.

[3]NC = negative control; PC = positive control; COCC = narasin in feed; PHYT1 = oregano-based product in feed; PHYT2 = mixture of *Curcuma*, saponins, and inulin in feed; PHYT3 = *Quillaja*-based product in feed. All treatments except NC were challenged on d 15. There were 6 replications per treatment.

containing *Curcuma longa L* compared with the infected control group. However, the administration of turmeric powder at lower dietary concentrations of 2 and 1% did not improve FCR significantly compared with the positive control. Therefore, the ineffectiveness of *Curcuma longa* in the present trial may be due to a suboptimal dosage. Another reason for the disparity might be the differences in challenge; birds in the cited study were only inoculated with *E. tenella* at a dosage of 100,000 oocysts/chick, whereas, in the present study, birds were challenged with a mixture of 3 strains.

Coccidiosis Lesion Scores

Results for the coccidiosis lesion scores on d 22 are listed in Table 7. Except for lesions by *E. acervulina* and the overall mean, no significant differences between treatments were recorded. The fact that lesion scores for the NC were higher than 0 indicates that animals of this group also became infected by *Eimeria* during the course of the trial. The infection might be due to native oocysts or by cross contamination from infected groups, as the trial was conducted using open pens and not isolation units.

In general, *E. acervulina* infection led to the highest lesion scores (ranging from 0.56 to 2.11), and PHYT2 and PHYT3 scores were significantly higher than NC and COCC. The PHYT 1 score (1.50) was somewhat lower than the other phytogenic products but in the same range as the PC (1.78), which demonstrates the ineffectiveness of the tested products to counteract the executed challenge. Scores for *E. maxima*, and especially *E. tenella* (ranging from 0.06 to 0.22), were relatively low and no significant differences between treatments were observed. Considering the overall mean, significant differences between COCC-treated birds and the PHYT 3 group, as well as between the uninfected group and the Quillaja treatment, were observed.

Despite the relatively strong eimeria challenge, only low lesion scores were recorded in the midregion and the cecum. This observation may partially be explained by the pathogenicity of the applied strain. Nollet et al. [28], using strains from the same source at slightly lower concentrations, also reported comparable low scores in those regions of the digestive tract. In addition, the scores are a subjective description which can be well standardized in a given trial. However, differences in how the scores are used may occur between trials. The challenge did not affect mortality, which was 3.41% on average and in a range that would be considered normal for nonchallenged birds.

To test the plant-derived product Natustat, Duffy et al. [29] challenged broiler chicken by

Table 7. Coccidiosis lesion scores on d 22 of age by treatment and by *Eimeria* species

Item	Coccidiosis lesion scores on d 22			
	Upper region (*Eimeria acervulina*)	Middle region (*Eimeria maxima*)	Cecal region[1] (*Eimeria tenella*)	Overall mean
Treatment[2]				
NC	0.56^{b}	0.95	0.11	0.54^{b}
PC	1.78^{ab}	0.78	0.17	0.91^{ab}
COCC	0.61^{b}	0.84	0.06	0.50^{b}
PHYT1	1.50^{ab}	0.78	0.17	0.81^{ab}
PHYT2	1.94^{a}	0.89	0.22	1.02^{ab}
PHYT3	2.11^{a}	1.11	0.17	1.13^{a}
SEM	0.285	0.143	—	0.122
P-value	0.001	0.58	—	0.006

[a,b]Means in a column with a different superscript differ significantly ($P \leq 0.05$).

[1]Assumptions for ANOVA were not fulfilled; due to data structure no statistical test possible.

[2]NC = negative control; PC = positive control; COCC = narasin in feed; PHYT1 = oregano-based product in feed; PHYT2 = mixture of *Curcuma*, saponins and inulin in feed; PHYT3 = *Quillaja* based product in feed. All treatments except NC were challenged on d 15. There were 6 replications per treatment.

infecting the litter with 500,000 *E. acervulina*, 70,000 *E. maxima*, and 400,000 *E.tenella* oocysts. The authors recorded significantly lower average lesion scores for the cecum of birds fed Natustat or Salinomycin in comparison to challenged control animals on d 21. Results for lesion scores for other parts of the intestine did not differ significantly between treatments. The average cecal lesion score was 2.3 for the nonsupplemented treatment, which is considerably higher than the results for *E. tenella* in this study (0.17 for PC). This difference indicates that the infection level of *E. tenella* was low in our study.

CONCLUSIONS AND APPLICATIONS

1. Challenge of broiler chickens at 15 d of age with a well-defined dose of *E. acervulina*, *E. maxima*, and *E. tenella* oocysts significantly reduced ADG and increased FCR.
2. The challenge mainly affected bird performance for 7 d, thereafter performance data between treatments did not differ.
3. The ionophore anticoccidial treatment counteracted the negative effects of the *Eimeria* challenge and performance and lesion scores were comparable with the nonchallenged birds.
4. None of the phytogenic products was effective at the tested dosage in controlling the negative effects (reduced performance and higher lesion scores) that were observed in the coccidiosis-challenged birds.
5. Testing higher inclusion rates of phytogenic products should be considered.

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