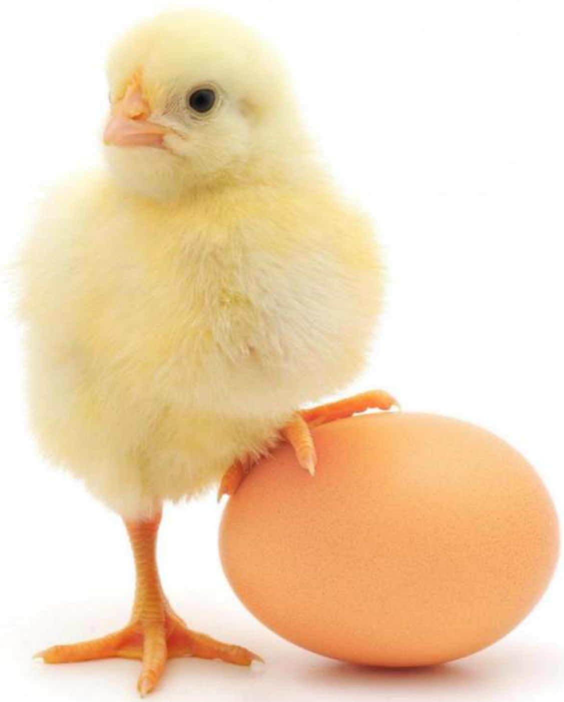
ISSN 1682-8356
ansinet.org/ijps



INTERNATIONAL JOURNAL OF POULTRY SCIENCE

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

International Journal of Poultry Science 4 (9): 612-619, 2005
ISSN 1682-8356

Evaluation of Microencapsulated Essential Oils and Organic Acids in Diets for Broiler Chickens[1]

K.Y. Zhang, F. Yan, C.A. Keen and P.W. Waldroup[2]
Poultry Science Department, University of Arkansas, Fayetteville, AR 72701, USA

Abstract: Two experiments were conducted to evaluate the use of two products containing essential oils in diets for broiler chickens. These products were RepaXol™, a mixture of essential oils (including oregano, cinnamon, thyme, and capsicum), and Avigro™, a mixture of essential oils along with organic acids (fumaric, citric, and malic). In the first experiment, conducted in litter-floor pens, eight replicate pens of 37 male and 37 female chicks of a commercial strain were fed a non-medicated corn-soybean diet, a diet containing antibiotics (bacitracin methylene disalicylate in starter and grower and virginamycin in finisher), a diet containing 0.5 kg/ton of Avigro™, and three additional treatments utilizing RepaXol™ at 100 g/ton continuously, 00 g/ton for 0-14 d, 75 g/ton for 14-35 d; 50 g/ton for 35 to 42 d, or 150 g/ton for 0-14 d, 100 g/ton for 14-35 d; 75 g/ton for 35 to 42d. All diets were in pelleted form with starter diets crumbled. Birds were grown to 42 d. In the second experiment, eight replicate pens of five male birds housed in battery brooders were fed the negative control diet with no additives, the negative control diet with 0.5 or 1.0 kg/ton of Avigro™, or diets with RepaXol™ at 100, 200, or 300 g/ton. Diets were fed as mash. Results from the first experiment indicated no positive improvements in body weight, feed consumption, mortality, or carcass yield from addition of Avigro™ or RepaXol™. Birds fed RepaXol™ at 150 g/ton had improved feed conversion at 14 d but not over the course of the experiment. Addition of the antibiotics to the diet also had no positive improvement in live performance; however birds fed the antibiotics had a higher dressing percentage. In the second experiment, birds fed 1.0 g/ton of Avigro™ or 300 g/ton of RepaXol™, higher than suggested by the supplier, had significantly lower feed intake and significantly better feed conversion than did birds fed the negative control diet. The results of this study show some beneficial effects from the use of products containing essential oils or a mixture of essential oils plus organic acids. It appears that the response may be dose-related and that levels higher than suggested by the manufacturer may be needed to elicit this response.

Key words: Essential oils, organic acids, broilers, antibiotics

Introduction

Antibiotic growth promoters (AGP) for poultry diets have been banned for use in the European Union and pressure from consumer groups and major poultry buyers has threatened their removal from diets in the US. Therefore, searches for alternate products that can aid in promotion of growth, improved feed utilization, and maintenance of gut health are taking place. Herbs, spices and various plant extracts have received increasing attention as possible AGP replacements (Hertrampf, 2001; Revington, 2002; Huyghebaert, 2003). Essential oils (EO) are volatile oils, natural vegetable products extracted by steam and /or water distillation or enzymatic activity followed by steam distillation. In addition, some essential oils are synthetically produced. There are currently some 2600 known essential oils. Most essential oils consist of mixtures of hydrocarbons, oxygenated compounds such as alcohol, esters, aldehydes, and ketones, and a small percentage of non-volatile residues such as paraffins and waxes. There is evidence to suggest that some of these components have appetite-stimulating properties, anti-bacterial effects or may provide antioxidant function (Dorman and Deans, 2000; Dorman *et al*., 1995; Botsoglou *et al*., 2002, 2003, 2004; Alçiçek *et al*., 2003, 2004; Giannenas *et al*., 2003; Lee *et al*., 2003, 2004a, 2004b, 2004c; Suk *et al*., 2003; Saricoban and Ozcan, 2004; Jang *et al*., 2004; Basmacioglu *et al*., 2004; Mitsch *et al*., 2004). Reviews of previous research have been presented by Langhout (2000), Basset (2000), Losa (2001), Williams and Losa (2002), and Lee *et al*. (2004d).

The working mechanisms of essential oils may vary greatly. Two possible mechanisms are the stimulation of endogenous enzymes and the regulation of the gut microbial flora and its help in maintaining the health of the animals (Patel and Srinivasam, 1996; Lee and Ahn, 1998; Langhout, 2000; Williams and Losa, 2002). Because essential oils are extracts of vegetable products, a mix of oils tends to be used rather than single oil. There are synergistic effects between EO and even between EO with other feed additives. Mitsch *et al*. (2004) studied two blends of EO components in field trials with broilers. Both blends of EO significantly reduced the concentration of *Clostridium perfringens* in

Table 1: Composition (g/kg) and calculated nutrient content of experimental diets

Ingredient	Starter 0-14 d	Grower 14-35 d	Finisher 35-42 d
Yellow corn	644.40	681.41	741.69
Soybean meal	299.64	258.42	204.26
Poultry oil	11.23	17.51	15.12
Dicalcium phosphate	16.89	13.98	12.74
Ground limestone	10.48	12.82	11.45
Vitamin premix[1]	5.00	5.00	5.00
Iodized salt	5.32	5.00	5.07
DL-Methionine (98%)	2.85	2.19	1.84
L-Threonine	0.73	0.51	0.57
Lysine HCl (98%)	1.71	1.41	1.26
Trace mineral mix[2]	1.00	1.00	1.00
Coban-60[3]	0.75	0.75	0.00
Total	1000.00	1000.00	1000.00
ME, kcal/kg	3001.00	3072.00	3121.00
CP, %	20.93	19.16	17.02
Ca, %	0.83	0.85	0.76
Nonphytate P, %	0.43	0.37	0.34
Met, %	0.61	0.53	0.47
TSAA, %	0.96	0.85	0.76
Lys, %	1.23	1.10	0.93
Trp, %	0.25	0.24	0.20
Thr, %	0.85	0.76	0.68

[1]Provides per kg of diet: vitamin A (from vitamin A acetate) 7714 IU; cholecalciferol 2204 IU; vitamin E (from dl-alpha-tocopheryl acetate) 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; choline 1040 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg; Se 0.1 mg.
[2]Provides per kg of diet: Mn (from $MnSO_4 \cdot H_20$) 100 mg; Zn (from $ZnSO_4 \cdot 7H_2O$) 100 mg; Fe (from $FeSO_4 \cdot 7H_2O$) 50 mg; Cu (from $CuSO_4 \cdot 5H_20$) 10 mg; I from $Ca(IO_3)_2 \cdot H_20$), 1 mg.
[3]Elanco Animal Health division of Eli Lilly & Co., Indianapolis, IN 46825.

the gut and feces of broilers. Langhout (2000) suggested that a combination of organic acids and essential oils would be beneficial as the organic acids appear to be particularly active in the feed, crop, and gizzard, whereas essential oils appear to work more in the later segments of the intestinal tract. A combination of both products might result in a stronger product and improve the digestive process throughout the digestive tract.

The effects of EO are influenced by diet type and dose-dependent (Williams and Losa, 2002; Alçiçek *et al.* 2003). Not all studies show positive response to addition of essential oils, perhaps due to the level of product used or the combination of products used. Experiments in the present report were conducted to evaluate two products containing a mixture of essential oils in broiler diets, with one product also containing organic acids. One experiment was conducted in wire-floor battery pens while the other was conducted under typical growing conditions found in the US broiler industry.

Materials and Methods

Two experiments were conducted to evaluate two different products containing essential oils. These products were RepaXol™, a mixture of essential oils (including oregano, cinnamon, thyme, and capsicum), and Avigro™, a mixture of essential oils along with organic acids (fumaric, citric, and malic). Both products were microencapsulated[3] No information regarding levels of the various organic acids and essential oils was available.

Experimental diets: A corn-soybean meal diet void of animal protein served as the test vehicle in both experiments. This diet was formulated to meet average nutrient levels currently used in the US broiler industry, based on a popular agricultural survey[4] Composition and calculated analysis of the test diets is shown in Table 1. Within each age period (0-14d, 14-35 d, 35-42 d) a large batch of diet was mixed and aliquots used to prepare the final treatment diets. All diets were considered to be nutritionally complete and were fortified with a vitamin premix and a trace mineral mix obtained from an integrated poultry producer. Monensin sodium[5] was used as an anticoccidial at 90 g/ton in all diets fed from 0-35 d of age.

Dietary treatments

Experiment 1: Six dietary treatments were compared. One treatment (negative control) consisted of the unsupplemented diet and one treatment (positive control) consisted of the most commonly used antibiotic program in the United States (50 g/ton of bacitracin methylene disalicylate[6] (BMD) from 0-35 d; 15 g/ton of virginiamycin[7] from 35-42 d). One treatment consisted of the diet fortified with 0.5 kg/Ton of Avigro™. Three additional treatments were based on the use of RepaXol™ and included 1) RepaXol™ at 100 g/ton continuously; 2) RepaXol™ at 100 g/ton for 0-14 d, 75 g/ton for 14-35 d; 50 g/ton for 35 to 42 d; 3) RepaXol™ at 150 g/ton for 0-14 d, 100 g/ton for 14-35 d; 75 g/ton for 35 to 42d. All additives were pre-blended with a portion of the basal diet before being added to the final mixture. All diets were fed in pelleted form with starter feed crumbled after pelleting. Test diets and tap water were available for *ad libitum* consumption. Eight replicate pens were assigned to each treatment in a randomized-block design.

Experiment 2: Six dietary treatments were compared. One treatment consisted of the negative control diet with no additives. Two treatments consisted of the negative control diet supplemented with 0.5 kg/ton or 1.0 kg/ton of Avigro™. Three additional treatments were based on the use of RepaXol™ at 100, 200, or 300 g/ton. All additives were pre-blended with a portion of the basal diet before being added to the final mixture. All diets were fed as

Table 2: Average body weight (g) of broilers fed diets with antibiotics, essential oil products, and essential oil products with organic acids (Experiment 1; means of eight litter-floor pens with 37 males and 37 females per treatment)

Dietary treatment	1 d	14 d	35 d	42 d
Negative control	42.8	373	1919	2503
Antibiotic program[1]	43.0	377	1936	2493
Avigro™ 500 g/ton[2]	42.8	376	1929	2490
RepaXol™ 100 g/ton[3]	42.7	376	1930	2496
RepaXol™ 100 g/ton 0-14 d; 75 g/ton 14-35 d; 50 g/ton 35 to 42 d;	43.0	371	1916	2462
RepaXol™ 150 g/ton 0-14 d; 100 g/ton 14-35 d; 75 g/ton 35 to 42d	42.9	381	1950	2502
Probability > F	0.72	0.54	0.67	0.83
SEM	0.2	4	16	23
CV	1.04	2.76	2.23	2.63

[1]Bacitracin methylene disalicylate (BMD) 50 g/ton 0-35 d; Virginiamycin 15 g/ton 35-42 d. [2]Avigro™ is a mixture of essential oils along with organic acids (fumaric, citric, and malic) [3]RepaXol™ is a mixture of essential oils (including oregano, cinnamon, thyme, and capsicum)

mash. Test diets and tap water were provided for *ad libitum* consumption. Eight replicate groups of five male birds were assigned to each treatment in a randomized block design.

Chicks and housing

Experiment 1: Sexed chicks of a commercial meat-type strain[8] (Cobb 500) were obtained from a local hatchery where they had been vaccinated *in ovo* for Marek's disease and had received vaccinations for Newcastle Disease and Infectious Bronchitis post hatch via a coarse spray. Thirty-seven (37) birds of each gender were randomly assigned to each of 48 litter-floor pens (5 M^2) in a research house of commercial design. Each pen contained two tube feeders and one bell-type automatic water font. Supplemental water jugs and feeder flats were used during the first seven days. Incandescent lamps supplemented natural daylight to provide for 23 hr light daily. Temperature was controlled by thermostatically controlled gas brooders, ventilation fans, and adjustable sidewall curtains to provide for optimal house temperature during the study.

Experiment 2: Male chicks of the same commercial strain used in the first experiment were obtained from the same hatchery and treated as previously described. Five birds were randomly assigned to each of 48 compartments in electrically heated battery brooders with raised wire floors, maintained in a temperature-controlled room. At 14 d the birds were transferred to unheated battery brooders with wire floors maintained in the same room. A 24 hr lighting program was provided. Care and management of birds in both experiments followed recommended guidelines (FASS, 1999).

Measurements: In both experiments, birds were group weighed by pen initially at day old and at 14, 35, and 42 d of age in Experiment 1 and at 14 and 35 d in Experiment 2. Feed consumption was determined at each feed change interval. In Experiment 1 litter samples were taken from each pen at 14, 35, and 42 d. Four sub-samples were taken from each pen from the surface to the full depth of the accumulation. Sub-samples were taken from the middle of the pen and in the middle of each side except the side with the door, avoiding the water fount and feeders. Side sub-samples were taken approximately 30 cm from the wall at the side of the pen. The four sub-samples were mixed together per pen for analysis for moisture. Litter moisture was determined by placing litter samples in a forced-air drying oven until constant weights were obtained.

Birds were checked for mortality twice daily. Any bird that died or was removed to alleviate suffering was weighed and the weight used to adjust feed conversion. At the conclusion of Experiment 1 three males and three females per pen, randomly selected from among five birds of each sex marked by toe slit at day of age, were processed in the University of Arkansas pilot processing plant with automatic evisceration to determine dressing percentage and breast meat yield.

Statistical analysis: In both experiments, pen means served as the experimental unit. For each treatment, body weight, feed conversion, and mortality were calculated on the basis of the following periods: 0-14 d, 15-35 d, 36-42 d, 0-35 d, and 0-42 d for Experiment 1 and 0-14 d and 0-35 d in Experiment 2. Mortality data were transformed $\sqrt{n+1}$ to before analysis. Data were processed as a one-way ANOVA using the General Linear Models option of the SAS Institute (SAS, 1991). Single-degree contrasts were made of each dietary treatment versus the negative control. Probability levels of $P<0.05$ and $P<0.10$ were considered for statistical significance.

Results

Experiment 1: Body weight at different time intervals is shown in Table 2. Birds fed the antibiotic program of

Table 3: Average feed consumption (grams/bird) during specific periods of broilers fed diets with antibiotics, essential oil products, and essential oil products with organic acids (Experiment 1; means of eight litter-floor pens with 37 males and 37 females per treatment)

Dietary treatment[1]	1-14 d	15-35 d	36-42 d	1-35 d	1-42 d
Negative control	466	2621	1226	3084	4316
Antibiotic program	470	2638	1228	3107	4325
Avigro™ 500 g/ton	465	2646	1235	3109	4335
RepaXol™ 100 g/ton	468	2656	1215	3122	4330
RepaXol™ 100 g/ton 0-14 d; 75 g/ton 14-35 d; 50 g/ton 35 to 42 d;	462	2634	1205	3094	4292
RepaXol™ 150 g/ton 0-14 d; 100 g/ton 14-35 d; 75 g/ton 35 to 42d	467	2649	1232	3114	4312
Probability > F	0.87	0.95	0.74	0.94	0.97
SEM	5	27	16	29	39
CV	2.84	2.90	3.52	2.61	2.42

[1]See Table 2 for details.

Table 4: Average feed conversion (g feed per g gain) during specific periods of broilers fed diets with antibiotics, essential oil products, and essential oil products with organic acids (Experiment 1; means of eight litter-floor pens with 37 males and 37 females per treatment)

Dietary treatment[1]	1-14d	15-35 d	36-42d	1-35 d	1-42 d
Negative control	1.412	1.696	2.134	1.644	1.755
Antibiotic program	1.394	1.705	2.147	1.648	1.765
Avigro™ 500 g/ton	1.398	1.703	2.215	1.648	1.772**
RepaXol™ 100 g/ton	1.409	1.709	2.157	1.654	1.765
RepaXol™ 100 g/ton 0-14 d; 75 g/ton 14-35 d; 50 g/ton 35 to 42 d;	1.408	1.706	2.206	1.653	1.768
RepaXol™ 150 g/ton 0-14 d; 100 g/ton 14-35 d; 75 g/ton 35 to 42d	1.381**	1.708	2.220	1.648	1.765
Probability > F	0.45	0.95	0.46	0.96	0.58
SEM	0.012	0.010	0.041	0.009	0.007
CV	2.40	1.71	5.02	1.44	1.03

[1]See Table 2 for details. **Significantly different from negative control using contrast comparisons (P<0.10).

BMD in starter and grower followed by Virginiamycin in the finisher diet did not differ significantly from those fed the negative control. There were no significant effects of either Avigro™ or RepaXol™ on body weight at any age as compared to those fed the negative control diet.

Average feed consumed by birds fed the various dietary treatments is shown in Table 3. No significant differences were observed among the birds fed the various treatments at any time interval evaluated or over the entire duration of the study. Average feed conversion (kg feed per kg gain) during specific time periods is shown in Table 4. During the first 14 d, the feed conversion of birds fed the highest RepaXol™ treatment differed significantly (P<0.10) from that of birds fed the negative control, but this was not sustained at later ages. At 42 d of age, birds fed Avigro™ at 500 g/ton had a higher overall feed conversion than those fed the negative control diet (P<0.10). None of the other treatment groups differed in feed conversion compared to that of birds fed the negative control diet, including those fed the antibiotic program.

Mortality during the trial is shown in Table 5. Overall there were no significant differences related to dietary treatment. Mortality rates were considered normal for this facility.

Effects of the various dietary treatments on dressing percentage and parts yield are shown in Table 6. The dressing percentage of birds fed the antibiotic treatment was greater than that of birds fed the negative control diet (P<0.10). It has been frequently observed that the intestinal tract of birds fed bacitracin is thinner than that of birds fed unmedicated diets, and may be responsible for this difference; however, no direct measurement of intestinal weight was taken in this study. None of the other dietary treatments appeared to influence carcass dressing percentage.

There was no treatment effect on breast meat yield or wing yield expressed as percentage of the carcass. Leg quarter yield of birds fed RepaXol™ at 100 g/ton was significantly (P<0.10) less than that of birds fed the negative control diet; however, leg quarter yield of birds fed the other RepaXol™ treatments did not differ from that of birds fed the negative control diet.

Moisture content of the litter at various ages is shown in Table 7. At 14 d the litter moisture from pens of birds fed the antibiotic treatment was significantly less (P<0.05) than that from birds fed the negative control. No other treatments had any significant effect on the litter as compared to the negative control at this age. At 35 d and 42 d there were no significant differences among dietary treatments or between any dietary treatments versus the negative control for litter moisture.

Experiment 2: The effects of the various dietary treatments on body weight, feed intake, feed conversion, and mortality in Experiment 2 are shown in Table 8.

Table 5: Average mortality (%) during specific periods of broilers fed diets with antibiotics, essential oil products, and essential oil products with organic acids (Experiment 1; means of eight litter-floor pens with 37 males and 37 females per treatment)

Dietary treatment[1]	1-14 d	1-35 d	1-42 d
Negative control	3.38	6.25	7.66
Antibiotic program	1.74	3.47	5.40
Avigro™ 500 g/ton	2.32	4.83	5.86
RepaXol™100 g/ton	5.07	6.93	8.45
RepaXol™ 100 g/ton 0-14 d; 75 g/ton 14-35 d; 50 g/ton 35 to 42 d;	2.71	4.45	5.03
RepaXol™ 150 g/ton 0-14 d; 100 g/ton 14-35 d; 75 g/ton 35 to 42d	4.22	6.42	7.26
Probability > F	0.16	0.32	0.34
SEM	1.01	1.27	1.39
CV[2]	1.28	1.58	1.60

[1]See Table 2 for details. [2]CV of transformed means.

Table 6: Carcass dressing percentage and parts yield of 42 d broilers fed diets with antibiotics, essential oil products, and essential oil products with organic acids (Experiment 1; means of eight litter-floor pens with 3 males and 3 females per treatment)

Dietary treatment[1]	Dressing Percentage %	Breast % of carcass[2]	Leg quarter % of carcass[3]	Wings % of carcass[4]
Negative control	73.72	27.20	31.23	10.93
Antibiotic program	74.25**	26.73	31.53	10.79
Avigro™ 500 g/ton	73.71	27.15	31.08	11.02
RepaXol™ 100 g/ton	73.66	26.86	30.64**	11.05
RepaXol™ 100 g/ton 0-14 d; 75 g/ton 14-35 d; 50 g/ton 35 to 42 d;	73.95	27.26	30.74	10.72
RepaXol™ 150 g/ton 0-14 d; 100 g/ton 14-35 d; 75 g/ton 35 to 42d	73.97	27.06	31.38	10.91
Probability > F	0.30	0.75	0.04	0.12
SEM	0.21	0.31	0.23	0.09
CV	1.88	7.75	4.93	5.86

[1]See Table 2 for details. [2]Skinless, boneless breast meat (combined Pectoralis major and P. minor). [3]Skin on, bone in (drumstick and thigh combined). [4]Skin on, bone in). **Significantly different from negative control using contrast comparisons (P<0.10).

There were no significant effects of any of the experimental treatments on body weight at 14 or 35 d as compared to the negative control group. Feed consumption, compared to that of birds fed the negative control, was significantly reduced over the 35 d test period for chicks fed diets with Avigro™ at 0.5 g/ton (P<0.10) or 1.0 kg/ton (P<0.05) or RepaXol™ at 200 or 300 g/ton (P<0.050. Since the body weight of the birds was similar to that of those fed the negative control, this reduction in feed consumption led to improved feed efficiency among birds fed some of the dietary treatments as compared to those fed the negative control diet. Feed efficiency of chicks fed diets containing 200 g/ton of RepXol™ was significantly (P<0.10) better than that chicks fed the negative control diet at 14 d. Over the duration of the 35 d study, significantly (P<0.10) better feed efficiency was noted for chicks fed diets with 1.0 kg/ton of Avigro™ or 300 g/ton of RepaXol™. This suggests that the addition of the products containing essential oils or essential oils plus organic acids may have improved nutrient utilization in some manner. The supplier of these products recommends 0.5 kg/ton for Avigro™ and 50 to 100 g/ton for RepaXol™, so the amount needed to obtain the responses shown in the present study are considerably higher than those suggested by the supplier.

Mortality during the second experiment was highest among those fed the negative control, and was reduced in birds fed the higher levels of the two test products. Caution should be expressed here since there were a limited number of birds involved so a difference in mortality of one or two birds has a major impact on percentage mortality. More studies with larger number of birds are needed to determine if this is a positive trend. Overall the results of this study show some beneficial effects from the use of products containing essential oils or a mixture of essential oils plus organic acids. It appears that the response may be dose-related and that levels higher than suggested by the manufacturer may be needed to elicit this response.

Discussion

Reported responses to various essential oils by has been varied, and may depend upon type of basal diet used, real or artificial disease challenge, and other factors related to stresses imposed upon the birds. Vogt (1990) fed caged broilers a mixture of essential oils or 20 mg/kg virginiamycin. Addition of virginiamycin resulted in improved growth and feed conversion but no significant response to the mixture of essential oils was

Table 7: Litter moisture (%) from pens of broilers fed diets with antibiotics, essential oil products, and essential oil products with organic acids (Experiment 1; means of eight litter-floor pens with 37 males and 37 females per treatment)

Dietary treatment[1]	14 d	35 d	42 d
Negative control	19.88	40.84	49.36
Antibiotic program	16.11*	39.43	48.57
Avigro™ 500 g/ton	17.49	41.84	49.90
RepaXol™ 100 g/ton	17.88	39.33	47.67
RepaXol™ 100 g/ton 0-14 d; 75 g/ton 14-35 d; 50 g/ton 35 to 42 d;	18.77	41.65	49.02
RepaXol™ 150 g/ton 0-14 d; 100 g/ton 14-35 d; 75 g/ton 35 to 42d	18.89	38.57	49.56
Probability > F	0.20	0.72	0.78
SEM	1.13	1.99	1.28
CV	16.43	12.11	6.40

[1]See Table 2 for details. *Significantly different from negative control using contrast comparisons (P<0.05).

Table 8: Performance of broilers fed diets with essential oil products, and essential oil products with organic acids (Experiment 2; means of 8 wire-floor pens with 5 males per treatment)

Dietary treatment[1]	Body weight (g)		Feed/bird (g)		g gain/g feed		Mortality (%)	
	14 d	35 d	1-14 d	1-35 d	1-14 d	1-35 d	1-14 d	1-35 d
Negative control	455	2119	530	3310	0.772	0.626	10.00	15.00
Avigro™ 0.5 kg/ton	447	2080	513	3183**	0.782	0.641	7.50	10.00
Avigro™ 1.0 kg/ton	454	2081	521	3113*	0.782	0.654**	5.00	5.00
RepaXol™ 100 g/ton	447	2121	517	3194	0.775	0.650	2.50	2.50
RepaXol™ 200 g/ton	464	2065	526	3140*	0.794**	0.644	2.50	2.50
RepaXol™ 300 g/ton	461	2112	525	3158*	0.790	0.654**	2.50	2.50
Probability > F	0.69	0.82	0.87	0.17	0.49	0.50	0.62	0.29
SEM	9	36	10	54	0.008	0.011	3.78	4.58
CV	5.43	4.87	5.60	4.79	3.21	4.93	213.81	207.30

[1]See Table 2 for details. *Significantly different from negative control using contrast comparisons (P<0.05).
**Significantly different from negative control using contrast comparisons (P<0.10).

noted. In a further study, Vogt (1991) conducted three experiments with caged broilers fed mixtures of various essential oils. The addition of the essential oil mixtures had no significant effect on BW or feed efficiency. Ristic and Damme (2001) evaluated a commercial product (CRINA® Poultry) in broiler diets and reported that the additive had no significant influence on performance. Botsoglou *et al.* (2002), using a wheat-soybean meal basal diet, observed no effect of an oregano essential oil on improvement in growth rate or feed conversion of Cobb broiler chickens grown to 38 d of age in litter floor pens. There was evidence that the oregano oil exerted an antioxidant effect on carcass tissues. In a further study, Botsoglou *et al.* (2004) supplemented broiler diets with a commercial preparation of essential oils (Apacox) at 0.5 or 1.0 g/kg. They concluded that the mixture of herbal essential oils exerted no growth-promoting effect but retarded lipid oxidation in both raw and heated breast and thigh muscle.

Spais *et al.* (2002) evaluated Genex, a commercial feed additive containing herb extracts and organic acids in diets fed to broilers. Results of the study indicated that supplementation of the diet with Genex exerts a growth-promoting effect comparable to that of flavomycin. Jamroz *et al.* (2003) supplemented a wheat-barley diet for broilers with avilamycin or 150 or 300 ppm of a plant extract containing capsaicin, carvacrol, and cinnamic aldehyde. Administration of the antibiotic and the two levels of the plant extract improved body weight by 4.7, 5.4, and 8.1% and improved feed conversion by 5.8, 3.1, and 7.1%, respectively. In all supplemented groups the number of *E. coli* and *C. perfringens* in rectal contents was significantly lower than in the control group. Lee *et al* (2003) used a maize-maize starch-soybean meal diet with Cobb female broiler chickens in wire floored cages to evaluate the effects of thymol, cinnamaldehyde, and a commercial essential oil product (CRINA® Poultry). The authors noted that the housing conditions were very clean. From 0 to 21 d or from 0 to 42 d, body weight gain, feed intake, and feed conversion were not significantly different among the treatments. From 18 to 21 d, fecal lipid digestibility and the ileal digestibility of crude protein and starch did not differ among treatments. Pancreatic enzyme activities were not differently affected by treatments; amylase activity of the intestinal chyme of birds given the CRINA® Poultry showed a significant increase when compared to the control group. Lee *et al.* (2004a) reported that cinnamaldehyde, but not thymol, may reverse the negative effects of addition of carboxymethyl cellulose, a non-fermentable, viscous fiber that raises the viscosity of intestinal chime. Addition of cinnamaldehyde also counteracted the antinutritional effect of rye, but without a simultaneous effect on intestinal viscosity or fat digestibility (Lee *et al.*, 2004b).

Adverse effects of mixtures of carvacrol and cinnamaldehyde in combination as compared to the two fed individually were noted in a study by Lee *et al.* (2004c).

Alçiçek *et al.* (2003) evaluated essential oils extracted from herbs growing in Turkey, using broiler diets that were composed essentially of maize and soybean meal with some wheat and sunflower meal. The birds were maintained in litter floor pens with wood shavings litter. The birds fed the essential oils had significantly better body weight, feed conversion, and carcass yields than those fed the basal diet. Suk *et al.* (2003) reported that CRINA® Poultry supplementation improved growth rate and feed conversion in broilers. The combination of CRINA® Poultry with either antibiotics or lactic acid did not show any additive or synergistic effects. Jang *et al.* (2004) reported that a blend of commercial essential oils combined with lactic acid showed significant increases in digestive enzyme activities of the pancreas and intestinal mucosa, leading to an increase in growth. Halle *et al.* (2004) reported that the addition of oregano and its essential oil reduced daily feed intake of broilers and significantly improved feed efficiency. Addition of other herbs resulted in intermittent weight gains but by the end of the study there was no significant difference between negative control groups and those treated with the essential oils or herbs. Alçiçek *et al.* (2004) investigated the effect of dietary supplementation with an essential oil mixture, an organic acid, and a probiotics on performance of broilers. The authors concluded that supplementation with the herbal essential oil mixture to broiler diets had beneficial effects on body weight gain, feed conversion, and carcass yield.

Several studies note beneficial effects of essential oils on control of intestinal diseases. Giannenas *et al.* (2003) reported that addition of oregano essential oil aided in overcoming the adverse effect of an infection with *Eimeria tenella*. Field trial studies by Mitsch *et al.* (2004) demonstrated that specific blends of essential oil components can control *Clostridium perfringens* colonization and proliferation in the gut of broilers and therefore may be of help in preventing problems with Clostridia and necrotic enteritis. Many of the essential oils are shown to have antioxidant activity in broiler carcasses (Dorman *et al.*, 1995; Saricoban and Ozcan, 2004; Basmacioglu *et al.*, 2004).

In the present study, birds were under a density stress, with birds housed at a density of 14.8 birds per M^2. Overall performance under these conditions was quite good, with a mean weight at 42 d of 2.49 kg (5.49 lbs) for straight-run birds, and a mean feed conversion of 1.765. No response was seen to either the antibiotic treatment or the essential oil treatments, suggesting that sufficient stress was not encountered during the study. It may be concluded that certain essential oils or herbs may improve performance of poultry under certain conditions but effective levels or combinations of essential oils must be present. More trials are needed to determine if essential oils or combinations of essential oils and organic acids can match the effects of antibiotics as feed additives in broiler diets.

References

Alçiçek, A., M. Bozkurt and M. Çabuk, 2003. The effect of an essential oil combination derived from selected herbs growing wild in Turkey on broiler performance. S. Afr. J. Anim. Sci., 33: 89-94.

Alçiçek, A., M. Bozkurt and M. Çabuk, 2004. The effect of a mixture of herbal essential oils, an organic acid or a probiotics on broiler performance. S. Afr. J. Anim. Sci., 34: 217-222.

Basmacioglu, H., Ö. Tokusoglu and M. Ergül, 2004. The effect of oregano and rosemary essential oils or alpha-tocopherol acetate on performance and lipid oxidation of meat enriched with n-3 PUFA's in broilers. S. Afr. J. Anim. Sci., 34: 197-210.

Basset, R., 2000. Oregano's positive impact on poultry production. World Poultry-Elsevier, 16: 31-34.

Botsoglou, N.A., E. Christaki, P. Florou-Paneri, I. Giannenas, G. Papageorgiou and A.B. Spais, 2004. The effect of a mixture of herbal essential oils or α-tocopheryl acetate on performance parameters and oxidation of body lipid in broilers. S. Afr. J. Anim. Sci., 34: 52-61.

Botsoglou, N.A., P. Florou-Paneri, E. Christaki, D.J. Fletouris and A.B. Spais, 2002. Effect of dietary oregano essential oil on performance of chickens and on iron-induced lipid oxidation of breast, thigh, and abdominal fat tissues. Br. Poult. Sci., 43: 223-230.

Botsoglou, N.A., D.J. Fletouris, P. Florou-Paneri, E. Christaki and A.B. Spais, 2003. Inhibition of lipid oxidation in long-term frozen stored chicken meat by dietary oregano essential oil and alpha-tocopheryl acetate supplementation. Food Res. Int., 36: 207-213.

Dorman, H.J.D. and S.G. Deans, 2000. Antimicrobial agents from plants: antibacterial activity of plant volatile oils. J. Appl. Microbiol., 88: 308-316.

Dorman, H.J.D., S.G. Deans and P. Surai, 1995. Evaluation in vitro of plant essential oils as natural antioxidants. J. Essential Oil Res., 7: 645-651.

FASS, 1999. Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching. 1st rev. ed. Federation of Animal Science Societies, Savoy IL.

Giannenas, I., P. Florou-Paneri, M. Papazahariadou, E. Christaki, N.A. Botsoglou and A.B. Spais, 2003. Effect of dietary supplementation with oregano essential oil on performance of broilers after experimental infection with *Eimeria tenella*. Arch. Anim. Nutr., 57: 99-106.

Halle, I., R. Thomann, U. Bauermann, M. Henning and P. Köhler, 2004. Effects of a graded supplementation of herbs and essential oils in broiler feed on growth and carcass traits. Landbauforshung Volkenrode, 54:219-229.

Hertrampf, J.W., 2001. Alternative antibacterial performance promoters. Poult. Int., 40: 50-55.

Huyghebaert, G., 2003. Replacement of antibiotics in poultry. Eastern Nutrition Conference, Québec, Canada, 8-9 May, p: 55-78.

Jamroz, D., J. Orda, C. Kamel, A. Wiliczkiewicz, T. Wertelecki and J. Skorupinska, 2003. The influence of phytogenetic extracts on performance, nutrient digestibility, carcass characteristics, and gut microbial status in broiler chickens. J. Anim. Feed Sci., 12: 583-596.

Jang, I.S., Y.H. Ko, H.Y. Yang, J.S. Ha, J.Y. Kim, J.Y. Kim, S.Y. Kang, D.H. Yoo, D.S. Nam, D.H. Kim and C.Y. Lee, 2004. Influence of essential oil components on growth performance and the functional activity of the pancreas and small intestine in broiler chickens. Asian-Aust. J. Anim. Sci., 17: 394-4000.

Langhout, P., 2000. New additives for broiler chickens. World Poult., 16: 22-27.

Lee, H.S. and Y.J. Ahn, 1998. Growth-inhibiting effects of *Cinnamomum cassia* bark-derived materials on human intestinal bacteria. J. Agri. Food Chem., 46: 8-12.

Lee, K.-W., H. Everts, H.J. Kappert, M. Frehner, R. Losa and A.C. Beynen, 2003. Effects of dietary essential oil components on growth performance, digestive enzymes and lipid metabolism in female broiler chickens. Br. Poult. Sci., 44: 450-457.

Lee, K.–W., H. Everts, H.J. Kappert, H. Wouterse, M. Frehner and A.C. Beynen, 2004a. Cinnamaldehyde, but not thymol, counteracts the carboxymethyl cellulose-induced growth depression in female broiler chickens. Int. J. Poult. Sci., 3: 608-612.

Lee, K.-W., H. Everts, H.J. Kappert, J. Van Der Kuilen, A. G. Lemmens, M. Frehner and A.C. Beynen, 2004b. Growth performance, intestinal viscosity, fat digestibility and plasma cholesterol in broiler chickens fed a rye-containing diet without or with essential oil components. Int. J. Poult. Sci., 3:613-618.

Lee, K.-W., H. Everts, H.J. Kappert, and A.C. Beynen, 2004c. Growth performance of broiler chickens fed a carboxymethyl cellulose containing diet with supplemental carvacrol and/or cinnamaldehyde. Int. J. Poult. Sci., 3: 619-622.

Lee, K.-W., H. Everts and A. C. Beynen, 2004d. Essential oils in broiler nutrition. Int. J. Poult. Sci., 3: 738-752.

Losa, R., 2001. The use of essential oils in animal nutrition. In: Feed Manufacturing in the Mediterranean Region. Improving Safety: From Feed to Food. Proceedings of the III Conference of Feed Manufacturers of the Mediterranean, Reus, Spain, March 2000, Cahiers Options Méditerranéennes, 54: 39 - 44.

Mitsch, P., K. Zitterl-Eglseer, B. Köhler, C. Gabler, R. Losa and I. Zimpernik, 2004. The effect of two different blends of essential oil components on the proliferation of *Clostridium perfringens* in the intestines of broiler chickens. Poult. Sci., 83: 669-675.

Patel, K. and K. Srinivasan, 1996. Influence of dietary spices or their active principles on digestive enzymes of small intestinal mucosa in rats. Int. J. Food Sci. Nutr., 47: 55-9.

Revington, B., 2002. Feeding poultry in the post-antibiotic era. Pages 1-14 in: Proceedings Multi-State Poultry Meeting, Indianapolis IN.

Ristic, M. and K. Damme, 2001. Changing from animal to vegetable protein at fattening: consequences on carcass and meat quality of broilers. Die Fleischwirtschaft, 81: 114-116.

Saricoban, C. and M. Ozcan, 2004. Antioxidative activity of rosemary (*Rosmarinus officinalis* L.) and sage (*Salvia fruticosa* L.) essential oils in chicken fat. J. Essential Oil Bearing Plants, 7: 91-95.

SAS Institute, 1991. SAS® User's Guide: Statistics. Version 6.03 edition. SAS Institute Inc., Cary, NC.

Spais, A.B., L.A. Giannenas, P. Fluorou-Paneri, E. Christaki and N.A. Botsoglou, 2002. Effect of Genex, a feed additive containing organic acids and herb extracts, on the performance of broiler chickens. J. Hellenic Vet. 53: 247-256.

Suk, J.C., H.S. Lim and I.K. Paik, 2003. Effects of blended essential oil (CRINA®) supplementation on the performance, nutrient digestibility, small intestine microflora and fatty acid composition of meat in broiler chickens. J. Anim. Sci. Tec., 45: 777-786.

Vogt, H., 1990. The effect of a mixture of essential oils in broiler diets. Landbauforshung Volkenrode, 40: 157-159.

Vogt, H., 1991. Essential oils in broiler diets. Landbauforshung Volkenrode, 41: 94-97.

Williams, P. and R. Losa, 2002. Blending essential oils for poultry. Feed Mix, 10: 8-9.

---

[1]Published with approval of the Director, Arkansas Agricultural Experiment Station, Fayetteville AR 72701. Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the University of Arkansas and does not imply its approval to the exclusion of other products that may be suitable.

[2]To whom correspondence should be addressed.

[3]SODA Feed Ingredients, Brookings SD 57006.

[4]Agri-Stats, Inc., Fort Wayne IN 46801.

[5]Coban 60. Elanco Animal Health division of Eli Lilly & Co., Indianapolis, IN 46825.

[6]BMD-50. Alpharma Inc., Fort Lee NJ 07024.

[7]Stafac-20. Phibro Animal Health, Fairfield NJ 07004.

[8]Cobb 500. Cobb-Vantress, Inc., Siloam Springs AR 72761.