PRODUCTION, MODELING, AND EDUCATION

Effects of a Direct-Fed Microbial (Primalac) on Turkey Poult Performance and Susceptibility to Oral *Salmonella* Challenge[1]

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ABSTRACT A study was conducted to determine 1) the effect of a dietary direct-fed microbial (DFM) on turkey poult performance, 2) the effect of a DFM on a *Salmonella* challenge, and 3) the effect of feed processing on the efficacy of the dietary DFM. Day-of-hatch Large White female poults were placed in 2 rooms in 2 Petersime batteries per room. Twelve pens of 7 birds each were used in each battery (24 pens per room, 336 birds total). One of 4 dietary feed treatments was assigned to each pen (6 pens per room for each diet). One room housed non-*Salmonella*-challenged poults, and the other room housed poults challenged with a 1-mL oral gavage of *Salmonella* (10^{10} cfu/mL). A single batch of starter ration was split into 4 parts and used to provide 4 dietary treatments: 1) mash feed with no DFM (M), 2) mash feed with DFM (Primalac; 0.9 kg/tonne of feed, MD), 3) pelleted (20-s steam conditioning at 80°C) and crumbled feed with no DFM (C), and 4) pelleted and crumbled feed with DFM (CD). Feed and deionized, distilled water were provided ad libitum. Data were collected and analyzed separately for each room. Mortality was recorded for each pen on a daily basis and totaled by week and for the 3-wk period. Individual BW and feed consumption, by pen, were measured weekly. Weekly and cumulative BW gains and feed to gain ratios (F:G) were calculated. Liver, spleen, total and lower intestinal tract weights, intestinal length, and most-probable-number *Salmonella* populations were determined for one randomly selected bird per pen. Feeding processed feed resulted in improved BW and F:G. Feeding the DFM improved 3-wk cumulative F:G in birds not gavaged and reduced relative intestinal weight in birds gavaged. *Salmonella* populations were reduced 1 log by feeding DFM. Dietary DFM improved bird performance, reduced *Salmonella* populations, and was not affected by feed processing.

Key words: direct-fed microbial, probiotic, feed pelleting, *Salmonella*, turkey

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INTRODUCTION

Feed-borne antibiotic growth promoters (**AGP**) have been fed to livestock in the United States and other countries for the last 50 yr to improve growth performance (Dibner and Richards, 2005). Early indications of improved performance in poultry were reported by Moore et al. (1946). However, most of the AGP labels list no specific claims to control disease (Gustafson and Bowen, 1997). Debate over the generation of antibiotic resistance among bacteria such as *Escherichia coli* and *Salmonella* has generated the strongest objection to using antibiotics (Evangelisti et al., 1975; Scioli et al., 1983; Gustafson and Bowen, 1997; Nayak and Kenney, 2002). Antibiotic resistance of indigenous *E. coli* of poultry has remained at a relatively high level since the 1950s (Gustafson and Bowen, 1997). In the United States, reports from the Institute of Medicine and the Council for Agricultural Science and Technology recommended reduction or elimination of AGP in livestock feeds even though neither report provided evidence proving that AGP-resistant microorganisms were responsible for contributing to antibiotic-resistant infections in humans (Dibner and Richards, 2005). Although this debate continues, there is interest in developing alternatives to AGP such as probiotics (Tellez et al., 2006).

Alternatives to antibiotics, such as competitive exclusion (**CE**) treatments, have been developed to encourage a protective barrier of bacteria in the digestive tract of poultry to prevent the colonization of growth-depressing or pathogenic microorganisms. Some CE cultures have included undefined normal avian gut microflora (Nurmi and Rantala, 1973) or have included defined cultures using bacteria such as *Lactobacillus* spp. (Francis et al., 1978). The reduction or elimination of *Salmonella* from the intes-

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tinal tract of poultry is of special interest because of the prevalence of human foodborne diseases caused by *Salmonella*, with poultry products serving as a vehicle for human salmonellosis (Persson and Jendteg, 1992; Hargis et al., 2001; FoodNet, 2005; WHO, 2006; Higgins et al., 2007).

The term "probiotic" has been used to refer to feed additives other than live cultures such as nondigestible feed ingredients that enhance host digestive tract microflora (Fuller, 1989). This would include many of the indigestible sugars such as oligosaccharides (Patterson and Burkholder, 2003). Therefore, the Association of American Feed Control Officials (AAFCO, 1999) and the US Food and Drug Administration (FDA, 2003) have recommended that the term "direct-fed microbial" (**DFM**) be used to describe live culture feed additives (Miles and Bootwalla, 1991; Elam et al., 2003). Other types of probiotics that are not live cultures have been referred to as "prebiotics" (Patterson and Burkholder, 2003). There are numerous reports of DFM, including *Lactobacillus* spp., being fed to poultry including turkeys. However, there are few reports where the feed containing the DFM was pelleted.

Therefore, the objectives of the present study were to determine 1) the effect of a dietary DFM on turkey poult performance, 2) the effect of a DFM on a *Salmonella* challenge, and 3) the effect of feed pelleting on the efficacy of the dietary DFM.

MATERIALS AND METHODS

Poults and Experimental Design

This study was conducted under Animal Care and Use guidelines established by North Carolina State University's Animal Care and Use Committee. Day-of-hatch Large White female poults (Nicholas Turkey Breeding Farms, Lewisburg, WV) were obtained from a commercial hatchery (Sleepy Creek Hatchery, Goldsboro, NC) and placed in 2 rooms (A and B) with each room containing 2 Petersime batteries (Petersime Incubator Co., Gettysburg, OH) with wire mesh floors. Twelve pens of 7 birds each were used in each battery (24 pens per room, 336 birds total). One of 4 dietary feed treatments was assigned to each pen (6 pens per room for each diet). One room (A) housed nonchallenged poults and the other room (B) housed poults that were challenged with an oral gavage of *Salmonella.* Feed and deionized, distilled water were provided ad libitum. Mortality was recorded for each pen daily and totaled by week and for the 3-wk period. Individual BW and feed consumption, by pen, were measured on a weekly basis. Weekly and cumulative BW gains and feed to gain ratios (feed conversion ratio, **FCR**) were calculated.

Dietary Treatments

An original single batch of starter ration (Table 1; NRC, 1994) was split into 4 parts and used to provide 4 dietary treatments: 1) mash feed with no DFM (**M**), 2) mash feed with DFM (**MD**), 3) pelleted (20-s steam conditioning at 80°C) and crumbled feed with no DFM (**C**), and 4) pelleted and crumbled feed with DFM (**CD**). The DFM (Primalac, Star Labs Inc., Clarksdale, MO) was added at 0.9 kg/tonne of feed and contained primarily *Lactobacillus acidophilus* and *Lactobacillus casei* (as well as other genera); microbial blends and concentrations are proprietary. To reduce the chance of cross contamination of DFM, the DFM treatment pens were kept separate from non-DFM pens so there were no shared water troughs and no shared pen dividers (Angel et al., 2005). Feed samples (2 per treatment, 8 total) were collected and sent, labeled but unidentified, to the sponsor lab (Star Labs Forage Research Inc., Clearwater, FL) for detection of lactic acid bacteria (**LAB**).

Table 1. Composition of the ration for rearing turkey poults to 21 d

Ingredient	%
Item	
Corn	43.4
Soybean meal	46.0
Poultry fat	4.0
Dicalcium phosphate	3.8
Limestone	1.0
Lysine	0.40
Salt	0.45
DL-Methionine	0.25
Choline chloride	0.2
Minerals[1]	0.2
Vitamins[2]	0.2
Selenium premix[3]	0.10
DFM[4]	
Calculated nutrient content	
Crude protein (%)	27.0
ME (kcal/kg)	2,925
Fat (%)	6.1
Methionine (%)	0.65
TSAA (%)	1.04
Lysine (%)	1.81
Calcium (%)	1.34
Available P (%)	0.73

[1]Minerals mix supplied the following per kilogram of diet: 120 mg of Zn as $ZnSO_4 \cdot H_2O$; 120 mg of Mn as $MnSO_4 \cdot H_2O$; 80 mg of Fe as $FeSO_4 \cdot H_2O$; 10 mg of Cu as $CuSO_4$; 2.5 mg of I as $Cu(IO_3)_2$; 1.0 mg of Co as $CoSO_4$.

[2]Vitamin mix supplied the following per kilogram of diet when added at 0.2%: vitamin A, 6,600 IU; vitamin D_3, 2,000 ICU; vitamin E, 33 IU; vitamin B_{12}, 19.8 μg; riboflavin, 6.6 mg; niacin, 55 mg; D-pantothenate, 11 mg; menadione, 2 mg; folic acid, 1.1 mg; thiamine, 2 mg; pyridoxine, 4 mg; D-biotin, 126 μg; ethoxyquin, 50 mg.

[3]Selenium premix supplied 0.21 mg Se, as Na_2SeO_3.

[4]Direct-fed microbial: Primalac (Star Labs, Clarksdale, MO), provided at 1 g/kg of feed. One batch of feed (454 kg) was mixed and used for the 4 treatments. One half without DFM was used for the control mash feed and the pelleted and crumbled feed. One half of the feed received Primalac (Star Labs) at 500 g/227 kg with one half of that used as a mash and the other half pelleted and then crumbled.

Oral Salmonella Challenge Protocol

Cultures of 3 *Salmonella* serotypes (Typhimurium, Kentucky, and Heidelberg) previously isolated from North Carolina commercial turkey farms (Santos et al., 2005) were prepared in brain heart infusion broth (24 h at 37°C) for oral gavage of turkey poults. A growth curve was

Table 2. Effect of dietary a direct-fed microbial[1] and feed form on performance[2] of poults with and without *Salmonella* challenge

		Week of age										
		1			2			Cum	3			Cum
Challenge[3]	Diet[4]	BW	CV	FCR	BW	CV	FCR	FCR	BW	CV	FCR	FCR
Without	Mash	141[b]	13.2[a]	1.18[a]	357[b]	8.3	1.28	1.25[a]	671[b]	6.0	1.52[a]	1.44[a]
	M+DFM	142[b]	12.3[a]	1.22[a]	345[b]	11.4	1.22	1.22[a]	657[b]	9.1	1.32[b]	1.27[b]
	Crumbled	165[a]	9.7[b]	1.01[b]	390[a]	9.2	1.21	1.14[b]	750[a]	8.6	1.52[a]	1.31[a]
	C+DFM	167[a]	7.7[b]	1.10[b]	382[a]	8.8	1.24	1.19[b]	722[a]	7.3	1.39[b]	1.28[b]
	SEM	2	1.8	0.04	8	1.1	0.04	0.03	14	0.5	0.08	0.05
P-value	Feed (F)	0.001	0.03	0.0006	0.0003	NS	NS	0.02	0.0001	NS	NS	NS
	DFM (D)	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.09	0.05
	F × D	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
With	Mash	141[b]	14.5[a]	1.25	338[b]	12.4[a]	1.24	1.23	649[b]	9.7[a]	1.37	1.30
	M+DFM	147[b]	7.4[b]	1.24	359[b]	6.8[b]	1.19	1.20	676[b]	6.0[b]	1.36	1.28
	Crumbled	158[a]	12.7[a]	1.34	379[a]	8.6[b]	1.25	1.27	711[a]	8.1[a]	1.37	1.32
	C+DFM	159[a]	9.7[b]	1.20	379[a]	11.7[a]	1.24	1.22	682[a]	6.4[b]	1.45	1.37
	SEM	2	1.3	0.04	8	1.3	0.06	0.04	17	0.8	0.04	0.03
P-value	Feed (F)	0.0002	NS	NS	0.0004	NS	NS	NS	0.05	NS	NS	NS
	DFM (D)	NS	0.001	NS	NS	NS	NS	NS	NS	0.003	NS	NS
	F × D	NS	NS	NS	NS	0.003	NS	NS	NS	NS	NS	NS

[a,b]Means within a column within challenge with different superscripts are significantly different ($P \leq 0.05$).

[1]Primalac (Star Labs, Clarksdale, MO); direct-fed microbial (DFM) provided at 1 g/kg of feed.

[2]Performance parameters: BW = body weight (g), CV = covariation of BW (%), FCR = feed to gain ratio, Cum FCR = cumulative FCR ratio.

[3]Challenge: poults were gavaged at 3 d with 1 mL of a cocktail containing 10^{10} cfu/mL of *Salmonella* Typhimurium, *Salmonella* Kentucky, and *Salmonella* Heidelberg. *Salmonella* was not recovered from poults sampled from the group of poults not gavaged.

[4]Diets: mash = mash feed; M+DFM = mash feed with DFM; crumbled = pelleted and crumbled feed without DFM; C+DFM = as for crumbled with DFM.

initially constructed for each serotype to determine the appropriate incubation time at 37°C required to reach the target gavage dosage of approximately 10^{10} cfu/mL. The cultures reached the target dose in 6 h, which was maintained through 14 h, indicating that the cells had reached the stationary phase of growth. Therefore, each serotype was cultured independently for 12 h and then mixed immediately before administering to the birds.

At 3 d, poults in room B were orally gavaged with 1 mL of the *Salmonella* culture suspended in PBS at a concentration of 10^{10} cfu/mL. To lessen the chance of cross contamination, the ungavaged birds in room A were serviced first; then, new coveralls, plastic boots, and latex gloves were worn by the investigators when working in room B.

Sampling, Enumeration, and Most-Probable-Number Technique

At 3 wk, 1 bird per pen (6 birds per treatment) was randomly chosen for organ parameter measurements and intestinal *Salmonella* content analyses. The selected poults were weighed (g), and killed. Liver, spleen, intestinal tract, and lower intestinal tract from the ileal-cecal junction to the cloaca including the ceca were aseptically removed and weighed to the nearest 0.1 g. Relative weights (g/100 g of BW) were calculated. The length (cm) of the intestinal tract was measured. The lower intestinal tract section was placed into stomacher bags, minced with sterile scissors, diluted 10-fold by weight in 0.85% saline solution and mechanically massaged (IUL Instruments S.A., Barcelona, Spain) for 1 min (Wiberg and Norberg, 1996). All samples were serially diluted in 0.85% saline solution to appropriate levels and then subjected to the most-probable-number (**MPN**) enumeration method (Moriñigo et al., 1986; Sinell et al., 1990; Tate and Miller, 1990; Davison et al., 1995; Dufrenne et al., 2001; Voogt et al., 2001) and Thomas' Approximation for estimating intestinal *Salmonella* populations (Blodgett, 2001; Swanson et al., 2001; Thomas, 1942) as described by Santos et al. (2005).

Statistical Analysis

Bacterial counts were transformed to their $\log_{10}$ values. Mortality and all percentage data were subjected to arc sine square root transformation before statistical analysis. Actual means are presented. All data were analyzed using the GLM procedure of SAS (SAS Institute, 1998). The data from each room were analyzed independently. The effects of feed processing and DFM on poult performance, relative organ weight, intestinal length, and *Salmonella* enumeration were determined. The pen (for performance data) or bird within pen (for *Salmonella* data) was used as the experimental unit. Treatment means were separated using the least square means procedure of SAS with a level of significance of $P \leq 0.05$ unless otherwise stated (SAS Institute, 1998).

RESULTS

The DFM feed samples contained 10^5 cfu of LAB/g in mash and crumbled feed. No LAB were detected in the control mash or crumbled feed samples to which no DFM was added. The expected level of LAB was 10^5 cfu/g based on the inclusion rate. There were no treatment

Table 3. Effect of a dietary direct-fed microbial[1] and feed form on organ weights[2] of 3-wk-old poults with and without *Salmonella* challenge

		Relative organ weight				
Challenge[3]	Diet[4]	RIW	RLIW	IL	RLW	RSW
Without	Mash	6.49[a]	1.03[a]	122.7[b]	2.53	0.11
	M+DFM	5.49[b]	0.80[b]	119.0[bc]	2.43	0.10
	Crumbled	5.57[b]	0.77[b]	133.4[a]	2.48	0.09
	C+DFM	5.60[b]	0.76[b]	121.1[b]	2.34	0.10
	SEM	0.19	0.03	2.5	0.09	0.01
P-value	Feed (F)	0.04	0.0006	0.02	NS	NS
	DFM (D)	0.02	0.003	0.004	NS	NS
	F × D	0.01	0.006	0.10	NS	NS
With	Mash	5.52[a]	0.82[a]	116.0	2.22	0.10
	M+DFM	4.87[b]	0.74[b]	116.8	2.30	0.12
	Crumbled	5.64[a]	0.86[a]	116.8	2.42	0.12
	C+DFM	4.74[b]	0.67[b]	116.2	2.41	0.12
	SEM	0.24	0.05	2.9	0.08	0.01
P-value	Feed (F)	NS	NS	NS	NS	NS
	DFM (D)	0.004	0.01	NS	NS	NS
	F × D	NS	NS	NS	NS	NS

[a–c]Means within a column within challenge with different superscripts are significantly different ($P \leq 0.05$).

[1]Primalac (Star Labs, Clarksdale, MO); direct-fed microbial (DFM) provided at 1 g/kg of feed.

[2]Performance parameters: RIW = relative intestinal weight (g/100 g of BW); RLIW = relative lower intestinal weight (g/100 g of BW); IL = intestinal length (cm); RLW (g/100 g of BW) = relative liver weight; RSW (g/100 g of BW) = relative spleen weight.

[3]Challenge: poults were gavaged at 3 d with 1 mL of a cocktail containing 10^{10} cfu/mL of *Salmonella* Typhimurium, *Salmonella* Kentucky, and *Salmonella* Heidelberg. *Salmonella* was not recovered from poults sampled from the group of poults not gavaged.

[4]Diets: mash = mash feed; M+DFM = mash feed with DFM; crumbled = pelleted and crumbled feed without DFM; C+DFM = as for crumbled with DFM.

effects on weekly or cumulative mortality (data not shown). The effects of feed form and DFM on poult performance by room or gavaging are presented in Table 2. Birds fed pelleted and crumbled feed were heavier than those fed mash feed. Body weight CV was improved by pelleted and crumbled feed only for wk 1 for birds not gavaged. Birds not gavaged and fed pelleted and crumbled feed had better feed to gain ratios until wk 2. There was no effect of DFM on BW for either group of birds. Cumulative FCR was improved at wk 3 for birds not gavaged when fed DFM. The effect of DFM on the FCR for wk 3 approached significance ($P = 0.09$) for these same birds. There was no DFM effect on FCR for birds gavaged. Gavaged birds fed DFM had lower CV at wk 1 and 3. There was only 1 feed form × DFM interaction in either group of birds and that was for CV at wk 2 for gavaged birds. This interaction was considered by the authors to be transitory or happenstance and not biologically meaningful.

The effects of feed form and DFM on 3-wk-old poult organ parameters by room or gavaging are presented in Table 3. In birds not gavaged, relative intestinal weight and relative lower intestinal weight were greater in birds fed mash feed with no DFM than in birds fed the other 3 treatments. Intestinal length was increased by feed processing but reduced by DFM in processed feed. Relative liver and spleen weights were not affected by dietary treatments. In gavaged birds, DFM reduced relative lower intestinal and intestinal weights. There was no DFM effect on intestinal length in gavaged birds. There was no effect of feed form or feed form × DFM interaction on any organ parameter in gavaged birds.

Birds not gavaged with *Salmonella* had no detectable *Salmonella* in the lower intestinal tract (data not shown). The effects of feed form and DFM on *Salmonella* populations in the lower intestinal tract of 3-wk-old poults gavaged with *Salmonella* are presented in Table 4. Neither feed form nor the interaction between feed form and DFM affected the lower intestinal *Salmonella* populations. However, DFM reduced *Salmonella* populations in the lower intestinal tract by 1 log.

DISCUSSION

Most turkey feed is pelleted to improve turkey performance (Dozier, 2001; Robberson, 2003) although there have been some inconsistencies reported for performance of poultry fed pellets vs. mash feed (Calet, 1965; Araba and Dale, 1990; Leeson and Summers, 2001). These inconsistencies might be due to variable feed processing conditions (Plavnik et al., 1997) and may be related to possible Maillard reactions between free sugars and free lysine (Dale, 1992; Leeson and Summers, 2001). Nutritional advantages reported for feeding pellets include reduced selective feeding, increased nutrient availability, decreased energy required for feed consumption, and reduced feed pathogen load. Other advantages from a management perspective include increased bulk density (reduced trucking cost), reduced shrinkage (less dust), and improved handling in automated feed equipment (Dozier, 2001). The regrinding of pellets has been reported to negate any benefits on poultry performance from the feed pelleting process (Arscott et al., 1957; Plavnik et al., 1997) although this is not completely supported by the report

Table 4. Effect of a dietary direct-fed microbial[1] and feed form on *Salmonella*[2] content of lower intestinal tract of 3-wk-old poults

	DFM			
Diet[3]	–	+	Mean	SEM
Mash	2.60×10^3	3.76×10^2	1.48×10^3	3.2×10^2
Crumbled	1.35×10^3	7.44×10^2	1.05×10^3	3.4×10^2
Mean	$1.97^a \times 10^3$	$5.60^b \times 10^2$		
SEM	3.55×10^2	3.06×10^2		
P-value	Feed (F)	NS		
	DFM (D)	0.008		
	F × D	NS		

[a,b]Means within a row with different superscripts are significantly different ($P \leq 0.05$).

[1]Primalac (Star Labs, Clarksdale, MO), direct-fed microbial (DFM) provided at 1 g/kg of feed.

[2]Poults were gavaged at 3 d with 1 mL of a cocktail containing 10^{10} cfu/mL of *Salmonella* Typhimurium, *Salmonella* Kentucky, and *Salmonella* Heidelberg. *Salmonella* was not recovered from poults sampled from the group of poults not gavaged.

[3]Diets: mash = mash feed, crumbled = feed was pelleted and then crumbled; both with (+) or without (–) DFM.

of Hussar and Robblee (1962). Although the feed used in this study was crumbled after pelleting, the nutritional advantages could, theoretically, remain, resulting in better or more efficient performance, which is what we observed with both groups of birds. The purpose of using pelleted and crumbled feed in this study was to test the efficacy of a DFM after undergoing feed processing and not to study the effects of pelleting per se. Therefore, possible reasons for the advantage provided by pelleted and crumbled feed were not explored. However, as observed by Angel et al. (2005), pelleting the feed containing the DFM used in this study had no detrimental effect on its usefulness in improving bird performance.

Reports on the efficacy of *Lactobacillus*-based products have been variable with positive effects on poultry performance reported by some (Francis et al., 1978; Damron et al., 1981; England et al., 1996; Zulkifli et al., 2000) and no or neutral effects reported by others (Maiolino et al., 1992; Owings, 1992). The results of this study with regard to bird performance are in general agreement with results reported by Angel et al. (2005) using the same commercial DFM product. Angel et al. (2005) reported that pelleting feed between 82.2 and 87.7°C did not destroy the DFM in the feed. In addition, broiler chicks fed pelleted feed containing DFM had greater BW, improved FCR, and improved nutrient retention at 18, 32, and 42 d. The effects observed by Angel et al. (2005) were greater in older birds when fed feeds with reduced nutrient content. England et al. (1996) sprayed male Large White turkey poults with *Lactobacillus reuteri* and included *L. reuteri* in the feed to 126 d of age. There was no mention in the report of the feed being pelleted. However, in another report that described a series of studies including that by England et al. (1996), the authors reported that in all studies the *L. reuteri* was delivered in mash feed or applied to pelleted feed (Casas et al., 1998). In the England et al. (1996) study, the DFM-treated birds were significantly heavier at 126 d than control-fed birds (15.1 vs. 14.8 kg). When adjusted to equal body weights, birds fed *L. reuteri* had improved FCR (2.678) vs. the controls (2.734). The reduction in length and weight of the intestinal tract observed in the present study also agrees with previous work (England et al., 1996).

The reduction of *Salmonella* in the lower intestinal tract because of DFM administration in the present study agrees with other reports (Tellez et al., 2006). The effect of bacteria such as *Lactobacillus* spp. to reduce or prevent colonization of undesirable bacteria such as *Salmonella* in the intestinal tract of poultry has been mostly positive (Edens et al., 1997; Tellez et al., 2006). Edens et al. (1997) reported on the usefulness of *Lactobacillus* in general, and *L. reuteri* in particular, in reducing *Salmonella* levels in the intestinal tract of poultry. Casas et al. (1998) reported a 1- to 2-log reduction in *Salmonella* Typhimurium in turkey poults when treated at 1 d of age or at hatch. Delaying treatment to 5 d resulted in less effect of the *L. reuteri.* Similar results were reported for chicks. Higgins et al. (2007) orally gavaged day-of-hatch chicks with *Salmonella* Enteritidis or *Salmonella* Typhimurium followed 1 h later by oral gavage of 1 of 11 *Lactobacillus* strains in 7 experiments. Depending on amount of LAB provided and time postadministration, reductions of *Salmonella* Enteritidis and *Salmonella* Typhimurium ranged from 60 to 99.8% in cecal tonsils and ceca compared with controls. Possible reasons suggested for these reductions were CE and stimulation of the immune system. The CE effects may include competition for receptor sites, production of volatile fatty acids that may inhibit certain microbes, production of bactericins (antimicrobial peptides), and competition for nutrients (Mead, 2000).

In conclusion, the commercial DFM product tested in this study resulted in improved poult performance similar to results reported with broilers using the same product and also reduced intestinal *Salmonella* colonization and changes in intestinal morphology. These effects were independent of feed pelleting. Further work with market-age turkeys, both in pen studies and in field trials, is warranted.

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