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Turkey Pen Trials with Dietary Mannan Oligosaccharide: Meta-analysis, 1993-2003

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Abstract: Turkey pen trial reports (1993-2003) from several countries were analyzed statistically to determine effects of *Saccharomyces cerevisiae* var. *boulardii* yeast outer cell wall mannan oligosccharide (MOS; Bio-Mos®, Alltech, Inc., Nicholasville, Kentucky USA) supplemented diets versus negative control (nCON) or antibiotic-supplemented positive control (pCON) diets. Criteria for selecting studies were: 1) pen trial, 2) written report, 3) MOS fed for entire study period, 4) negative and/or positive control, 5) antibiotic stated (for positive control), 6) replication and 7) gender, final age and body weight (BWT) given. Feed conversion ratio (FCR) and mortality (MORT) were used when reported. Typical MOS supplemental levels were 0.10% continuous, or 0.10 and 0.05% or 0.20, 0.10 and 0.05% in step-down programs. Results were averaged "by treatments" (all comparisons) and "by trials" (comparisons averaged by trial before analysis) using Paired T-test to compare nCON and pCON means with corresponding MOS means. Slightly different answers but similar patterns emerged by these methods. Considering averages by trials, MOS diets gave the following relative changes compared to nCON diets: BWT, +2.09% (P = 0.010); FCR, -1.47% (P = 0.172); and MORT, -25.13% (P = 0.016). Relative changes in live performance using MOS diets compared to pCON diets were: BWT, -0.56% (P = 0.157); FCR, -0.26% (P = 0.502); and MORT, -15.53% (P = 0.202). The MOS diets significantly improved BWT and MORT compared to nCON diets. The mortality-lowering effect of supplemental MOS was its strongest attribute. The MOS diets gave statistically similar live performance to pCON diets.

Key words: Antibiotic, Bio-Mos, mannan oligosaccharide, meta-analysis, turkey

Introduction

Saccharomyces cerevisiae var. *boulardii* yeast outer cell wall component, mannan oligosaccharide (MOS), was introduced commercially as an alternative growth promoter for market turkeys in 1993 (Bio-Mos®, Alltech, Inc., Nicholasville, Kentucky USA). Since then MOS has been demonstrated to improve live performance of turkeys.

The MOS supplement is considered to have at least three probable modes of action, each of which may be of benefit depending on a particular turkey production situation: 1) adsorption (agglutination) of pathogenic bacteria containing Type 1 fimbrae with mannose-sensitive lectins (sometimes referred to as the "receptor analog" mechanism, strongly binding to and decoying pathogens away from the "sugar-coated" intestinal lining) (Oyofo *et al*., 1989; Spring *et al*., 2000); 2) improved intestinal function or gut health (for example, increased villi height, uniformity and integrity) (Iji *et al*., 2001; Loddi *et al*., 2002) and immune modulation stimulates gut associated and systemic immunity by acting as a non-pathogenic microbial antigen, giving an adjuvant-like effect (Ferket *et al*., 2002).

The purpose of this article is to summarize body weight, feed conversion ratio and mortality results from turkey pen trial reports worldwide, 1993-2003, in order to quantify the effects. With these results, it is possible for readers to then evaluate the benefit to cost ratio of dietary MOS and compare its economics and efficacy with those of subtherapeutic antibiotics.

Materials and Methods

Criteria for Selecting Studies: The following minimum selection criteria were used in deciding which pen trial results to include in the meta-analysis.

1. Market turkey pen trials only were used; no commercial field trials were included in this comparison.
2. Written research reports regarding MOS from around the world (France, Poland, U.K. and USA) were evaluated.
3. The MOS was fed during the entire study period (except one trial started on day three) and supplementation levels stated.
4. There must have been a negative control and/or a positive control treatment.
5. For positive control treatments, the name of the antibiotic must have been mentioned.
6. Final age and body weight must have been stated; feed conversions ratio and mortality were used when given. Feed conversion ratio was acceptable if corrected for mortality (given preference) or regular.

Table 1: Market turkey body weight results from pen trials worldwide comparing antibiotic-free negative control (nCON) versus mannan oligosaccharide (MOS) diets.

Age (d)	Strain[4]	Sex	Litter (new or used)	MOS level (%) [to given age]	nCON Body wt (kg)	MOS Body wt (kg)	Rel. Change w/MOS (%)[7]	Reference
21	BUTA	M	Wire	0.10	0.560	0.586	+4.64	Fairchild *et al.*, 2001
21[1]	BUTA	M	Wire	0.10	0.542	0.569	+4.98	Fairchild *et al.*, 2001
21	BUTA	M	Wire	0.10	0.582	0.570	-2.06	Fairchild *et al.*, 2001
21[1]	BUTA	M	Wire	0.10	0.547	0.552	+0.91	Fairchild *et al.*, 2001
21			Wire	0.10	0.503	0.496	-1.39	Edens & Doerfler, 1998
21[2]			Wire	0.10	0.201	0.274	+36.32	Edens & Doerfler, 1998
30	BUT	M	Wire	0.10[3-30d][6]	0.751	0.743	-1.07	Juskiewicz *et al.*, 2003
30	BUT	M	Wire	0.20[3-30d][6]	0.751	0.788	+4.93	Juskiewicz *et al.*, 2003
30	BUT	M	Wire	0.40[3-30d][6]	0.751	0.775	+3.20	Juskiewicz *et al.*, 2003
53	Wrolstad	M	Wire	0.11	1.295	1.382	+6.72	Savage & Zakrzewska, 1996
56	Nicholas	M	Wire	0.11	3.035	3.435	+13.18	Savage & Zakrzewska, 1996
56	Hybrid	M	Wire	0.05	3.237	3.361	+3.83	Savage *et al.*, 1997
56	Hybrid	M	Wire	0.10	3.237	3.885	+20.02	Savage *et al.*, 1997
56	Hybrid	M	Wire	0.20	3.237	3.206	-0.96	Savage *et al.*, 1997
56	Hybrid	M	Wire	0.30	3.237	3.441	+6.30	Savage *et al.*, 1997
84	Hybrid	M	New	0.10	7.090	7.140	+0.71	Stanley *et al.*, 2000
84		F		0.05	7.257	7.282	+0.34	Hulet, 1999a
91	Nicholas	F		0.10	6.898	7.230	+4.81	Hulet & Lorenz, 2001
98	Nicholas	M	Used[5]	0.10	9.311	9.630	+3.43	Hulet, 2003
111	BUT	M	New	0.20[28d]; 0.10[111d]	12.265	12.401	+1.11	Valancony *et al.*, 2001
112		M		0.2[28d]; 0.1[84d]; 0.05[112d]	11.815	11.780	-0.30	Valancony *et al.*, 2000
112[3]	Nicholas	M	Used	0.05	13.044	12.802	-1.86	Fritts & Waldroup, 2003
112[3]	Nicholas	M	Used	0.10	13.044	13.299	+1.95	Fritts & Waldroup, 2003
113	BUT	M	New	0.20[28d]; 0.10[113d]	12.917	12.913	-0.03	Valancony *et al.*, 2001
124	Orlopp	F	Used[5]	0.10[14d]; 0.05[124d]	6.895	6.759	-1.97	Bagley & Frame, 2002
126	Hybrid	F	New	0.10[21d]; 0.05[126d]	11.868	12.563	+5.86	Sims *et al.*, 1999
140	Hybrid	M		0.11[42d]; 0.055[140d]	17.480	17.940	+2.63	Ferket *et al.*, 2002
68.7	Average by treatment (n = 27; P = 0.006)				5.643[b]	5.770[a]	+2.25	
84.2	Average by trial (n = 17; P = 0.010)				7.416[b]	7.571[a]	+2.09	

[1]Poults challenged with 0.1 ml oral gavage containing four serotypes of *E. coli* at about 10^8 cfu/ml (or sterile carrier broth as control).

[2]Poults challenged with 0.1 ml oral gavage of a 10% suspension of fecal material from PEMS-infected poults.

[3]The 16-week data was used because both MOS group weights were lower than pCON at 20 weeks, not consistent with 16-week results, due to atypical growth pattern after 8 weeks on MOS 0.05% and after 16 weeks on MOS 0.10% diets.

[4]Blanks indicate missing information (not stated). [5]New litter in brooding phase and used litter in growing-finishing phases.

[6]Feeding trial with MOS diets began on day 3 and lasted for 28 days (age 30 days). [7]Change as a result of MOS diets relative to nCON diets.

Table 2: Feed conversion ratios (FCR) of market turkeys from pen trials worldwide comparing antibiotic-free negative control (nCON) versus mannan oligosaccharide diets (MOS)

Age (d)	Strain[2]	Sex	Litter (new or used)	MOS level (%) [to given age]	nCON FCR (kg/kg)	MOS FCR (kg/kg)	Rel. Change w/MOS[3] (%)	Reference
21	BUTA	M	Wire	0.10	1.340	1.330	-0.75	Fairchild *et al.*, 2001
21[1]	BUTA	M	Wire	0.10	1.400	1.470	+5.00	Fairchild *et al.*, 2001
21	BUTA	M	Wire	0.10	1.310	1.380	+5.34	Fairchild *et al.*, 2001
21[1]	BUTA	M	Wire	0.10	1.390	1.480	+6.47	Fairchild *et al.*, 2001
30	BUT	M	Wire	0.20[3-30d][3]	1.637	1.730	+5.68	Edens & Doerfler, 1998
30	BUT	M	Wire	0.20[3-30d][3]	1.637	1.696	+3.60	Edens & Doerfler, 1998
30	BUT	M	Wire	0.20[3-30d][3]	1.637	1.683	+2.81	Edens & Doerfler, 1998
56	Nicholas	M	Wire	0.11	1.950	1.856	-4.82	Savage & Zakrzewska, 1996
56	Hybrid	M	Wire	0.05	1.890	1.770	-6.35	Savage *et al.*, 1997
56	Hybrid	M	Wire	0.10	1.890	1.700	-10.05	Savage *et al.*, 1997
56	Hybrid	M	Wire	0.20	1.890	1.770	-6.35	Savage *et al.*, 1997
56	Hybrid	M	Wire	0.30	1.890	1.740	-7.94	Savage *et al.*, 1997
84	Hybrid	M	New	0.10	2.880	2.890	+0.35	Stanley *et al.*, 2000
84		F		0.05	1.951	1.916	-1.79	Hulet, 1999a
91	Nicholas	F		0.10	2.066	2.016	-2.42	Hulet & Lorenz, 2001
98	Nicholas	M	Used[3]	0.10	1.761	1.772	+0.62	Hulet, 2003
111	BUT	M	New	0.20[28d]; 0.10[111d]	2.220	2.250	+1.35	Valancony *et al.*, 2001
112		M		0.2[28d]; 0.1[84d]; 0.05[112d]	2.270	2.280	+0.44	Valancony *et al.*, 2000
112	Nicholas	M	Used	0.05	2.677	2.594	-3.10	Fritts & Waldroup, 2003
112	Nicholas	M	Used	0.10	2.677	2.539	-5.16	Fritts & Waldroup, 2003
113	BUT	M	New	0.20[28d]; 0.10[113d]	2.370	2.340	-1.27	Valancony *et al.*, 2001
124	Orlopp	F	Used[3]	0.10[14d]; 0.05[124d]	1.908	1.987	+4.14	Fritts & Waldroup, 2003
126	Hybrid	M	New	0.10[21d]; 0.05[126d]	3.370	3.122	-7.36	Sims *et al.*, 1999
140	Hybrid	M		0.11[42d]; 0.055[140d]	2.440	2.400	-1.64	Ferket *et al.*, 2002
73.4	Average by treatment (n = 24; P = 0.125)				2.019	1.988	-1.55	
90.5	Average by trial (n = 15; P = 0.172)				2.183	2.151	-1.47	

[1]Poults challenged with 0.1 ml oral gavage containing four serotypes of *E. coli* at about 10^8 cfu/ml (or sterile carrier broth as control).
[2]Blanks indicate missing information (not stated).
[3]New litter in brooding phase and used litter in growing-finishing phase.
[4]Feeding trial with MOS diets began on day 3 and lasted for 28 days (age 30 days).
[5]Change as a result of MOS diets relative to nCON diets.

Table 3: Mortality percentages of market turkeys from pen trials worldwide comparing antibiotic-free negative control (nCON) versus mannan oligosaccharide (MOS) diets.

Age (days)	Strain[4]	Sex	Litter (new or used)	MOS level (%) [to given age]	nCON Mort. (%)	MOS Mort. (%)	Rel. Change w/MOS (%)[5]	Reference
21	BUTA	M	Wire	0.10	0	1.79	?	Fairchild *et al.*, 2001
21[1]	BUTA	M	Wire	0.10	0	0	0	Fairchild *et al.*, 2001
21	BUTA	M	Wire	0.10	0	0	0	Fairchild *et al.*, 2001
21[1]	BUTA	M	Wire	0.10	0	0	0	Fairchild *et al.*, 2001
21			Wire	0.10	3.81	4.16	+9.20	Edens & Doerfler, 1998
21[2]			Wire	0.10	60.00	42.20	-29.67	Edens & Doerfler, 1998
56	Nicholas	M	Wire	0.11	13.30	6.30	-52.63	Stanley *et al.*, 2000
84		F		0.05	8.36	8.36	0	Hulet, 1999a
91	Nicholas	F		0.10	8.56	6.85	-19.98	Hulet & Lorenz, 2001
98	Nicholas	M	Used[5]	0.10	13.49	7.32	-45.74	Hulet, 2003
112[3]	BUT	M	New	0.20[28d]; 0.10[111d	2.40	3.40	+41.67	Valancony *et al.*, 2001
112		M		0.2[28d]; 0.1[84d]; 0.05[112d]	3.90	2.80	-28.21	Valancony *et al.*, 2000
112	Nicholas	M	Used	0.05	8.66	6.67	-22.98	Fritts & Waldroup, 2003
112	Nicholas	M	Used	0.10	8.66	6.67	-22.98	Fritts & Waldroup, 2003
124	Orlopp	F	Used[5]	0.10[14d]; 0.05[124d]	16.90	12.40	-26.63	Bagley & Frame, 2002
126	Hybrid	M	New	0.10[21d]; 0.05[126d]	17.22	15.63	-9.23	Sims *et al.*, 1999
72.1	Average by treatment (n = 16; P = 0.049)[6]				10.329[a]	7.784[b]	-24.64	
87.0	Average by trial (n = 11; P = 0.016)[6]				11.336[a]	8.487[b]	-25.13	

[1]Poults challenged with 0.1 ml oral gavage containing four serotypes of *E. coli* at about 108 cfu/ml (or sterile carrier broth as control).
[2]Poults challenged with 0.1 ml oral gavage of a 10% suspension of fecal material from PEMS-infected poults.
[3]Mortality was reported as combined for two turkey trials in France (111 and 113 days) although body weight and feed conversion ratios were presented separately by trial. [4]Blanks indicate missing information (not stated).
[5]New litter in the brooding phase and used litter in the growing-finishing phases.
[6]Using arcsine transformation, probability levels were P = 0.182 by treatments and P = 0.027 by trials.
[7]Change as a result of MOS diets relative to nCON diets.

Reports from 20 pen trials on new or recycled litter, or raised wire floors, from the U.S. and Europe were analyzed statistically to quantify the improvements in body weight, feed conversion ratio and mortality due to MOS addition. Unsupplemented negative control (nCON) diets and/or antibiotic-supplemented positive control (pCON) diets were used for comparison to MOS diets. In some of the 20 trials, pCON diets were run side-by-side with nCON diets for comparison to MOS-supplemented feeds. Therefore, the experimental models sometimes included nCON, pCON and MOS diets. Antibiotics, when used, included avilamycin, bacitracin methylene disalicylate, bambermycins, terramycin, virginiamycin, or zinc bacitracin. Turkey strains involved were BUT (or BUTA), Hybrid, Nicholas, Orlopp and Wrolstad. Considerably more studies were conducted with males (toms) than with females (hens).

Statistical Analysis: The means of the three parameters of interest - body weight, feed conversion ratio and mortality - were analyzed statistically as pairs of observations, using either negative control (nCON) or positive control (pCON) diets versus MOS diets by the Paired T-test (Statistic for Windows 7.0, 2000). The resulting levels of probability were stated. The same database was used as that of Hooge (2003) except that feed conversion ratio results that had been unavailable for the turkey pen trial reported by Stanley *et al.* (2000) were received and included in the evaluation reported herein.

Table 4: Market turkey body weight results from pen trials worldwide comparing antibiotic-supplemented positive control (pCON) versus mannan oligosaccharide (MOS) diets.

Age (d)	Strain[1]	Sex	Litter (new or used)	MOS level (%) [to given age]	pCON Body wt (kg)	MOS Body wt (kg)	Rel. Change w/MOS (%)[3]	Reference
vs Avilamycin								
63		F		0.2[21d]; 0.1[56d]; 0.05[63d]	3.640	3.660	+0.55	Kenyon, 1999
84		M		0.2[21d]; 0.1[56d]; 0.05[84d]	6.870	6.920	+0.73	Kenyon, 1999
111	BUT	M	New	0.2[28d]; 0.1[111d]	12.535	12.401	-1.07	Valancony *et al.*, 2001
112		M		0.2[28d]; 0.1[84d]; 0.05[112d]	12.247	11.780	-3.81	Valancony *et al.*, 2000
113	BUT	M	New	0.2[28d]; 0.1[113d]	12.930	12.913	-0.13	Valancony *et al.*, 2001
vs Bacitracin MD								
98	Hybrid	F	New	0.10[21d]; 0.05[98d]	7.655	7.612	-0.56	Sims *et al.*, 1999
112	Nicholas	M	Used	0.05	13.118	12.802	-2.41	Fritts & Waldroup, 2003
112	Nicholas	M	Used	0.10	13.118	13.299	+1.38	Fritts & Waldroup, 2003
126	Hybrid	M	New	0.10[21d]; 0.05[126d]	12.455	12.563	+0.87	Sims *et al.*, 1999
140	Hybrid	M		0.11[42d]; 0.055[140d]	17.810	17.940	+0.73	Ferket *et al.*, 2002
vs BMD, VM[2]								
84		F		0.05	7.274	7.282	+0.11	Hulet, 1999a
98		F	New	0.11[28d]; 0.055[98d]	8.790	8.480	-3.53	Hulet, 1999b
vs Flavomycin								
112	Nicholas	M	Used	0.05	13.228	12.802	-3.22	Fritts & Waldroup, 2003
112	Nicholas	M	Used	0.10	13.228	13.299	+0.54	Fritts & Waldroup, 2003
vs Virginiamycin								
42	Hybrid	F		0.10	2.299	2.223	-3.31	Sims, 2001
98	Hybrid	F	New	0.10[21d]; 0.05[93d]	7.842	7.612	-2.93	Sims, 1999
124	Orlopp	F	Used[3]	0.10[14d]; 0.05[124d]	6.804	6.759	-0.66	Bagley & Frame, 2002
140	Hybrid	M		0.11[42d]; 0.055[140d]	17.850	17.940	+0.50	Ferket *et al.*, 2002
vs Terramycin								
84	Hybrid	M	New	0.10	7.230	7.140	-1.24	Stanley *et al.*, 2000
vs Zinc Bacitracin								
147	BUTA	M		0.10	17.418	17.631	+1.22	Sefton & Connolly, 2000
105.6	Average by treatment (n = 20; P = 0.158)				10.717	10.653	-0.60	
104.9	Average by trial (n = 17; P = 0.157)				10.444	10.386	-0.56	

[1]Blanks indicate missing information (not stated).
[2]BMD = bacitracin MD followed by VM = virginiamycin (see Table 7 for details).
[3]New litter in the brooding phase and used litter in the growing-finishing phase.
[4]Change as a result of MOS diets relative to pCON diets.

Table 5: Feed conversion ratios (FCR) of market turkeys from pen trials worldwide comparing antibiotic-supplemented positive control (pCON) versus mannan oligosaccharide (MOS) diets

Age (days)	Strain[1]	Sex	Litter (new or used)	MOS level (% [to given age])	pCON FCR (kg/kg)	MOS FCR (kg/kg)	Rel. Change w/MOS (%)[3]	Reference
vs Avilamycin								
63		F		0.2[21d]; 0.1[56d]; 0.05	1.957	1.978	+1.07	Kenyon, 1999
84		M		0.2[21d]; 0.1[56d]; 0.05	2.260	2.200	-2.65	Kenyon, 1999
111	BUT	M	New	0.2[28d]; 0.1[111d]	2.210	2.250	+1.81	Valancony *et al.*, 2001
112		M		0.2[28d]; 0.1[84d]; 0.05	2.270	2.280	+0.44	Valancony *et al.*, 2000
113	BUT	M	New	0.2[28d]; 0.1[113d]	2.400	2.340	-2.50	Valancony *et al.*, 2001
vs Bacitracin MD								
98	Hybrid	F	New	0.10[21d]; 0.05[98d]	2.244	2.196	-2.14	Sims, 1999
112	Nicholas	M	Used	0.05	2.554	2.594	+1.57	Fritts & Waldroup, 2003
112	Nicholas	M	Used	0.10	2.554	2.539	-0.59	Fritts & Waldroup, 2003
126	Hybrid	M	Used	0.10[21d]; 0.05[126d]	3.154	3.122	-1.01	Sims *et al.*, 1999
140	Hybrid	M		0.11[42d]; 0.055[140d]	2.410	2.400	-0.41	Valancony *et al.*, 2000
vs BMD, VM[2]								
84		F		0.05	1.951	1.916	-1.79	Hulet, 1999a
98		F	New	0.11[28d]; 0.055[98d]	2.140	2.080	-2.80	Hulet, 1999b
vs Flavomycin								
112	Nicholas	M	Used	0.05	2.603	2.594	-0.35	Fritts & Waldroup, 2003
112	Nicholas	M	Used	0.10	2.603	2.539	-2.46	Fritts & Waldroup, 2003
vs Virginiamycin								
42	Hybrid	F		0.10	1.621	1.644	+1.42	Sims, 2001
98	Hybrid	F	New	0.10[21d]; 0.05[98d]	2.190	2.196	+0.27	Sims, 1999
124	Orlopp	F	Used[3]	0.10[14d]; 0.05[124d]	1.947	1.987	+2.05	Bagley & Frame, 2002
140	Hybrid	M		0.11[42d]; 0.055[140d]	2.360	2.400	+1.69	Ferket *et al.*, 2002
vs Terramycin								
84	Hybrid	M	New	0.10	2.850	2.890	+1.40	Stanley *et al.*, 2000
vs Zinc Bacitracin								
147	BUTA	M		0.10	2.520	2.520	0	Sefton & Connolly, 2000
105.6	Average by treatment (n = 20; P = 0.449)				2.340	2.333	-0.30	
104.9	Average by trial (n = 18; P = 0.502)				2.313	2.307	-0.26	

[1]Blanks indicate missing information (not stated).
[2]BMD = bacitracin MD followed by VM = virginiamycin (see Table 7 for details).
[3]New litter in the brooding phase and used litter in the growing-finishing phase.
[4]Change in results with MOS diets relative to pCON diets.

Table 6: Mortality percentages of market turkeys from litter pen trials worldwide comparing antibiotic-supplemented positive control (pCON) versus mannan oligosaccharide (MOS) diets.

Age (d)	Strain[2]	Sex	Litter (new or used)	MOS level (%) [to given age]	pCON Mort. (%)	MOS Mort. (%)	Rel. Change w/MOS (%)[4]	Reference
vs Avilamycin								
63		F		0.2[21d]; 0.1[56d]; 0.05[63d]	3.48	4.07	+16.95	Kenyon, 1999
84		M		0.2[21d]; 0.1[56d]; 0.05[84d]	7.75	4.26	-45.03	Kenyon, 1999
112[1]	BUT	M	New	0.2[28d]; 0.1[112d]	4.70	3.40	-27.66	Valancony *et al.*, 2001
112		M		0.2[28d]; 0.1[84d]; 0.05[112d]	4.24	2.80	-33.96	Valancony *et al.*, 2000
vs Bacitracin MD								
98	Hybrid	F	New	0.10[21d]; 0.05[98d]	5.19	2.22	-57.23	Sims, 1999
112	Nicholas	M	Used	0.05	14.00	6.67	-52.36	Fritts & Waldroup, 2003
112	Nicholas	M	Used	0.10	14.00	6.67	-52.36	Fritts & Waldroup, 2003
126	Hybrid	M	Used	0.10[d]; 0.05[126d]	14.40	15.63	+8.54	Sims *et al.*, 1999
vs BMD; VM[3]								
84		F		0.05	3.41	8.36	+145.16	Hulet, 1999a
vs Flavomycin								
112	Nicholas	M	Used	0.05	8.66	6.67	-22.98	Fritts & Waldroup, 2003
112	Nicholas	M	Used	0.10	8.66	6.67	-22.98	Fritts & Waldroup, 2003
vs Virginiamycin								
42	Hybrid	F		0.10	0.67	0.33	-50.75	Sims, 2001
98	Hybrid	F	New	0.10[21d]; 0.05[98d]	1.48	2.22	+50.00	Sims, 1999
124	Orlopp	F	Used[4]	0.10[14d]; 0.05[124d]	15.50	12.40	-20.00	Bagley & Frame, 2002
vs Zinc Bacitracin								
147	BUTA	M		0.10	8.61	8.76	+1.74	Sefton & Connolly, 2000
102.5	Average by treatment (n = 15; P = 0.074)[5]				7.650	6.075	-20.59	
101.1	Average by trial (n = 13; P = 0.202)[5]				7.084	5.984	-15.53	

[1]Mortality was reported as combined for two turkey trials in France (111 and 113 days) although body weight and feed conversion ratios were presented separately by trial.
[2]Blanks indicate missing information (not stated).
[3]BMD = bacitracin MD to 8 weeks of age, followed by VM = virginiamycin to market.
[4]New litter in brooding phase and used litter in growing-finishing phase.
[5]Using arcsine transformation, probability levels were P = 0.074 by treatments and P = 0.200 by trials.
[6]Change in results with MOS diets relative to pCON diets.

Table 7: Age, dietary antibiotic and level, cocciostat and reference cited concerning market turkey pen trials worldwide comparing antibiotic-supplemented positive control (pCON) versus mannan oligosaccharide diets (MOS) during the entire study periods; corresponds to Tables 4, 5 and 6

Age (d)	Dietary Antibiotic	Antibiotic level (mg/kg) [to given age][2]	Coccidiostat	Reference
63	Avilamycin			Kenyon, 1999
84	Avilamycin			Kenyon, 1999
111	Avilamycin	10		Valancony *et al.*, 2001
112	Avilamycin	10		Valancony *et al.*, 2000
113	Avilamycin	10		Valancony *et al.*, 2001
98	Bacitracin-MD	55	Monensin	Sims, 1999
126	Bacitracin-MD	55, 27.5		Sims *et al.*, 1999
140	Bacitracin-MD	55	Monensin	Fritts & Waldroup, 2003
140	Bacitracin-MD	55	Monensin	Fritts & Waldroup, 2003
84	Bac.-MD, Virginiamycin[1]	55, 22	Monensin	Hulet, 1999a
98	Bac.-MD, Virginiamycin[2]	55, 22		Hulet, 1999b
140	Flavomycin	2.2	Monensin	Fritts & Waldroup, 2003
140	Flavomycin	2.2	Monensin	Fritts & Waldroup, 2003
42	Virginiamycin	22	Monensin	Sims, 2001
98	Virginiamycin	22	Monensin	Sims, 1999
124	Virginiamycin	(Stafac, 0.05%)		Bagley & Frame, 2002
84	Terramycin	50		Stanley *et al.*, 2000
147	Zinc Bacitracin	(Baciferm, 0.05%)	Lasalocid	Sefton & Connolly, 2000

[1]Bacitracin-MD to 8 weeks of age, followed by virginiamycin.
[2]Bacitracin-MD to 4 weeks of age, followed by virginiamycin.
[3]Blanks indicate missing information (not stated).

Results

Negative Control Versus MOS Diets: Results of 17 turkey pen trials, including those on new or used litter or wire, comparing negative control (nCON) and MOS diets are reported in Table 1, 2 and 3. The final ages ranged from 21 to 140 days in the negative control comparisons. Average ages were 68.7 to 84.2 days for by treatment and by trial analyses.

Body weight was significantly improved with MOS addition when averaged by treatment (P = 0.006, +0.127 kg or +2.25%) or by trial (P = 0.010, +0.155 kg +2.09%). Two of the 27 comparisons by treatment had *E. coli* inoculation and one of the comparisons by treatment had PEMS inoculation (suspension of fecal material from infected poults), resulting in reduced performance. Feed conversion ratio was not significantly changed due to MOS addition when averaged by treatment (P = 0.125, -0.031 kg feed/kg body weight, -1.55%) or by trial (P = 0.172, -0.032 kg feed/kg body weight, -1.47%). Mortality was significantly reduced with MOS supplementation when averaged by treatment (P = 0.049, -2.545% actual, -24.64% relative) and by trial (P = 0.016, -2.849 actual, -25.13% relative). When the raw mortality data, which had several 0% values in it, was analyzed using the arcsine transformation procedure, the mortality comparisons had probabilities of P = 0.182 (nonsignificant in this case) and P = 0.027 when averaged by treatment and by trial, respectively.

Positive (Antibiotic) Control Versus MOS Diets: Results of 17 pen trials comparing antibiotic-supplemented positive control (pCON) and MOS diets are presented in Table 4, 5 and 6 and known antibiotics used in the experiments are listed in Table 7. In the pCON control versus MOS diets trials, the final ages ranged from 63 to 147 days. Average ages were 105.6 to 104.9 days, depending on the number of data points. Compared to the antibiotic control results, body weight was not significantly influenced due to dietary MOS when averaged by treatment (P = 0.158, -0.064 kg, -0.60%) or by trial (P = 0.157, -0.058 kg, -0.56%). Feed conversion ratio was not significantly affected by MOS addition, compared to antibiotic control, when averaged by treatment (P = 0.449, -0.007 feed/body weight, -0.30%) or by trial (P = 0.502, -0.006 feed/body weight, -0.26%). The mortality was not significantly different between pCON and MOS diets when averaged by treatment (P = 0.074, -1.575% actual, -20.59% relative) or by trial (P = 0.200, -1.100% actual, -15.53% relative).

Discussion

In this evaluation, the most commonly used level of MOS supplementation for turkeys was 0.10% in all feed phases. A step-down program involving a 0.10% MOS level initially followed by 0.05% was also typical. Alternately, MOS levels of 0.20, 0.10 and 0.05% were sometimes used in the experiments.

The feed formulas and environmental conditions varied considerably in these trials. The MOS mode(s) of action may have involved adsorption of pathogenic bacteria, healthy gut and/or immune stimulation.

Compared to nCON diet results, significant improvements with MOS diets were found in body weight, +2.09 averaged by treatment and +2.25% by trial (Table 1).

As shown in Table 2, treatment differences between nCON and MOS diets for feed conversion ratio were nonsignificant (-1.32% improvement due to MOS diets averaged by treatment and -1.62% by trial). Mortality was significantly lowered by MOS diets compared to nCON diets, -24.64% relative to control by treatment and -25.13% by trial (Table 3).

In 19 out of 27 comparisons, or 70.4% of the cases, MOS diets increased body weight (+ direction of change %). In 9 out of 16 comparisons, or 56.3% of the cases, MOS diets reduced mortality (- direction of change %).

Live performance results for pCON and MOS diets were statistically similar, indicating that MOS can replace subtherapeutic antibiotics in turkey feeds. The MOS diets had slightly lower body weight when averaged by treatment (-0.064 kg) or by trial (-0.058) compared to pCON diets (105.6 and 104.9 days of age, respectively). Feed conversion ratios for the MOS diets were slightly lower than pCON diets when averaged by treatment (-0.07 kg feed/kg body weight) or by trial (-0.006 kg feed/kg body weight). Compared to the pCON diets, the reduction in percent mortality using the MOS diets was approaching significance (P = 0.074) when averaged by treatment (-1.575% actual, -20.59% relative). By trial, the change in percent mortality using MOS diets was slightly less (-15.53%) compared to pCON diets.

A few other turkey pen trials, not included in this report, have involved combination treatments of a dietary antibiotic plus MOS. Beneficial additive effects on live performance were observed in some cases; for example, bacitracin-MD plus MOS for turkeys (Sims *et al.*, 1999; Sims, 1999).

In conclusion, MOS was an effective alternative growth promoter for improving live performance of turkeys based on meta-analysis results of pen trials conducted in several countries over a decade.

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