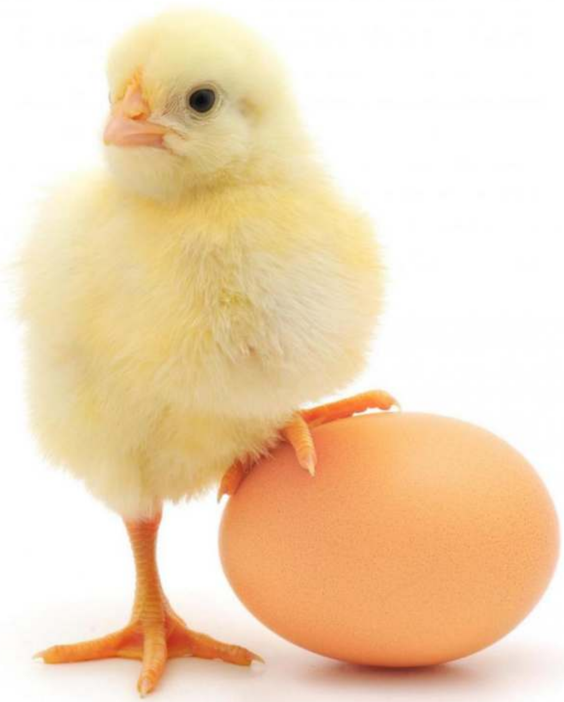
ISSN 1682-8356
ansinet.org/ijps



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 2 (1): 44-52, 2003

Utilization of Bio-Mos® Mannan Oligosaccharide and Bioplex® Copper in Broiler Diets[1]

P. W. Waldroup, C. A. Fritts and Fenglan Yan
Poultry Science Department, University of Arkansas, Fayetteville, AR 72701, USA
Email: Waldroup@uark.edu

Abstract: A study was conducted to evaluate the effects of combinations of antibiotics, mannan oligosaccharides, and organic forms of copper in the diet of broilers. Male broilers in litter floor pens were fed nutritionally complete diets with a 2 x 2 x 3 arrangement of treatments including two antibiotic programs (none; 55 mg/kg bacitracin methylene disalicylate from 0 to 42 d followed by 16.5 mg/kg virginiamycin to 63 d), two levels of mannan oligosaccharide (none; 1 g/kg Bio-Mos® from 0 to 42 d followed by 0.75 g/kg to 63 d) and three copper programs (none; copper sulfate to provide 250 mg/kg from 0 to 42 d followed by 62.5 mg/kg to 63 d; Bioplex® Cu to provide 55 mg/kg from 0 to 42 d followed by 27.5 mg/kg to 63 d). This resulted in a total of 12 experimental treatments, each fed to eight pens of 50 male chicks. Birds and feed were weighed at intervals during the study and samples of birds processed at 63 d to determine dressing percentage and parts yield. Body weight and feed conversion at 21 d was significantly improved by addition of the antibiotics but did not prove to be significantly improved at later ages. Addition of copper from either copper sulfate or Bioplex® Cu had no significant effect on any parameter tested. Addition of Bio-Mos® at the levels tested had no significant effect on any parameter but did interact with some of the other factors. Carcass characteristics were not improved by any of the factors tested. It is possible that the level of Bio-Mos® used in this study was not sufficient to elicit a positive response.

Key words: Copper, mannan oligosaccharides, antibiotics, broilers

Introduction

It has been more than 50 years since Moore *et al.* (1946) reported an improvement in growth when streptomycin was added to the diet of chickens. Since that time, antibiotics have been widely used in poultry feeds to control disease and more recently to promote growth and improve feed conversion. However, the non-prescription use of antibiotics in poultry feeds has been eliminated or severely limited in many countries because of concerns related to development of antibiotic-resistant human pathogenic bacteria, and legislative action to limit their use is probable in many others. Therefore, alternatives to antibiotics are of great interest to the poultry industry.

Bio-Mos®[2], a mannan oligosaccharide derived from the cell wall of the yeast *Saccharomyces cerevisiae*, has shown promise in suppressing enteric pathogens, modulating the immune response, improving the integrity of the intestinal mucosa, and promoting improved growth and feed conversion in studies with chickens and turkeys (Olsen, 1996; Spring, 1999a, 1999b; Iji *et al.*, 2001; Sonmez and Eren *et al.*, 1999; Spring *et al.*, 2000; Savage and Zakrzewska, 1997; Valancony *et al.*, 2001) although not all studies are in agreement (Shafey *et al.*, 2001a).

Copper has been added to poultry diets in excess of its nutritional needs as an antimicrobial and growth promoter for many years (Aldinger, 1967; Smith, 1969; Jenkins *et al.*, 1970; Fisher, 1973; Fisher *et al.*, 1973; Doerr *et al.*, 1980; Pesti and Bakali, 1996). Hawbaker *et al.* (1961) and Bunch *et al.* (1965) stated that copper acts in an antibiotic-like fashion by influencing microbial growth in the intestine. However, high levels of copper sulfate may interfere with the use of antibiotics, arsenicals, and histomoniastats in poultry diets (Carlson *et al.*, 1979; Bowen and Sullivan, 1971; Bowen *et al.*, 1971a, 1971b). The influence of form of supplemental copper on performance of animals has been well documented. Transition elements such as copper, iron, manganese, and zinc form organic and inorganic coordination complexes at physiological pH and are considered to be more bioavailable to the animal than inorganic sources of these minerals (Madsen and Lyons, 1988). Aoyagi and Baker (1993) reported that the relative bioavailability of Cu in a Lys-Cu complex was 126% although this was not significantly different from copper sulfate. Studies with broiler chicks indicated that an organic form such as cupric citrate was more effective in stimulating growth at lower concentrations than copper sulfate (Pesti and Bakali, 1996; Ewing *et al.*, 1998). Guo *et al.* (2001) reported that the bioavailability of several organic copper products was significantly greater than that of copper

[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]Alltech Inc., Nicholasville KY.

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

Ingredients	0-3 wk	3-6 wk	6-9 wk
Yellow corn	655.11	717.08	756.27
Soybean meal (48%)	253.93	181.41	147.48
Pro-Pak[1]	50.00	50.00	50.00
Poultry oil	12.61	22.70	23.28
Ground limestone	7.94	11.23	10.26
Dicalcium phosphate	9.07	5.17	2.96
DL-Methionine (98%)	2.29	1.58	0.76
L-Lysine HCl (98%)	1.55	2.20	1.57
L-Threonine	0.02	0.96	0.98
Feed grade salt	3.73	3.92	2.69
Coban-60[2]	0.75	0.75	0.75
Trace minerals[3]	1.00	1.00	1.00
Vitamin premix[4]	2.00	2.00	2.00
Nutrient content[5]			
ME, kcal/kg	3080.00	3200.00	3250.00
Crude protein, % (calculated)	21.18	18.22	16.77
Crude protein, % (analyzed)	22.16	18.46	16.53
Methionine, %	0.62	0.50	0.40
Lysine, %	1.27	1.10	0.95
Met + Cys, %	0.95	0.79	0.67
Threonine, %	0.85	0.81	0.76

[1]H. J. Baker & Bro., Stamford, CT 06901-1407. [2]Elanco Animal Health division of Eli Lilly & Co., Indianapolis, IN 46285. [3]Provides per kg of diet: Mn (from $MnSO_4 \cdot H_2O$) 100 mg; Zn (from $ZnSO_4 \cdot 7H_2O$) 100 mg; Fe (from $FeSO_4 \cdot 7H_2O$) 50 mg; Cu (from $CuSO_4 \cdot 5H_2O$) 10 mg; I (from $Ca(IO_3)_2 \cdot H_2O$) 1 mg. [4]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; choline 465 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; thiamin (from thiamine mononitrate) 1.54 mg; pyridoxine (from pyridoxine hydrochloride) 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg; Se 0.1 mg. [5]After NRC (1994).

sulfate for chicks. Paik *et al.* (1999) reported that Cu from a Cu-methionine complex was better absorbed and accumulated more in breast muscle and less in liver of chicks than Cu from copper sulfate. Studies with pigs suggested that copper sulfate and organic complexes of copper appeared to be equal in bioavailability (Stansbury *et al.*, 1990; Van Heugten and Coffey, 1992; Coffey *et al.*, 1994; Apgar *et al.*, 1995) while Zhou *et al.* (1994) reported that pigs fed a copper-lysine complex grew faster than those fed copper sulfate. Lee *et al.* (2001) reported that metal-amino acid chelates and complexes of Cu at low levels (60 mg/kg) are not different from high levels (120 mg/kg) from copper sulfate when maintaining growth performance and serum concentration, but resulted in greatly reduced fecal excretion of Cu.

As high levels of copper sulfate are known to interfere with sulfur amino acid metabolism (Baker *et al.*, 1982) and can cause irritation of the lining of the gizzard, precipitating gizzard erosion (Poupoulis and Jensen, 1976) the use of copper compounds with greater bioavailability can be of benefit by use of lower dietary levels. The objective of the present study was to compare the response to Bio-Mos® and Bioplex®[3], Cu in broiler diets in comparison to diets with copper sulfate or a growth-promoting antibiotic. Bioplex® Cu is a mineral chelate of amino acids and short-chain peptides from soy protein.

Materials and Methods

The Institutional Animal Care and Use Committee of the University of Arkansas approved all procedures in this study. Bird management and care followed approved guidelines (FASS, 1999). Diets were formulated that provided a minimum of 110% of the amino acids recommended for broilers by NRC (1994). Starter diets (0 to 3 wk) contained minimal added fat with reduced energy levels in an attempt to reduce the incidence of ascites (Dale and Villacres, 1986; Arce *et al.*, 1992). Corn and soybean meal of known composition were used as the primary source of energy and protein in the diets. All diets contained 5% of a blended animal protein[4] as most commercial poultry diets in the United States contain some type of animal protein. The diets were supplemented with complete vitamin and trace mineral mixes obtained from a commercial poultry integrator. The trace mineral

[3]Alltech, Inc., Nicholasville KY.

[4]Pro-Pak; H. J. Baker & Bro., Stamford CT 06901.

Table 2: Effects of source of copper, antibiotics, and inclusion of Bio-Mos® mannan oligosaccharide in broiler diets on body weight (means of eight pens of 50 male broilers per treatment)

Antibiotic Program[1]	Bio-Mos[2]	21 d BW (g)				42 d BW (g)				49 d BW (g)				63 d BW (g)			
		No Cu	Copper Sulfate[3]	Bio-Plex[4]	Mean	No Cu	Copper sulfate	Bio-Plex	Mean	No Cu	Copper Sulfate	Bio-Plex	Mean	No Cu	Copper Sulfate	Bio-Plex	Mean
None	No	741	722	707	723	2470	2440	2398	2436	3119	3025	3008	3050	4319	4217	4288	4275
	Yes	719	712	718	716	2441	2464	2454	2453	3158	3092	3002	3084	4320	4350	4298	4323
	Mean	730	717	713	720[b]	2455	2452	2426	2445	3138	3058	3005	3067	4319	4284	4293	4299
BMD/Stafac	No	745	738	724	736	2465	2491	2479	2478	3074	3149	3032	3085	4281	4353	4231	4288
	Yes	728	728	746	734	2466	2451	2514	2466	3090	2965	2957	3004	4234	4144	4353	4243
	Mean	736	733	735	735[a]	2449	2471	2496	2472	3082	3057	2995	3045	4257	4248	4292	4266
Mean	No	743	730	715	729	2468	2466	2439	2457	3096	3087	3020	3068	4300	4285	4259	4281
	Yes	723	720	732	725	2437	2458	2484	2460	3124	3028	2980	3044	4277	4247	4325	428
	Mean	733	725	724	727	2452	2462	2461	2458	3110	3058	3000	3056	4288	4266	4292	4282

Source of variation	21 d Probability > F	42 d Probability > F	49 d Probability > F	63 d Probability > F
Antibiotic (A)	0.02	0.11	0.56	0.41
Copper source (C)	0.44	0.88	0.07	0.84
Bio-Mos (B)	0.51	0.89	0.54	0.96
A x C	0.58	0.18	0.82	0.82
A x B	0.67	0.40	0.14	0.25
B x C	0.06	0.19	0.62	0.52
A x B x C	0.93	0.75	0.44	0.07
SEM	11	32	71	72

[ab]Within comparisons, means with common superscripts do not differ significantly ($P < 0.05$). [1]Antibiotic program consisted of 55 mg/kg bacitracin methylene disalicylate (BMD; Alpharma, Fort Lee NJ 07024) followed by 16.5 mg/kg virginiamycin (Stafac; Pfizer Animal Health, Exton PA 19341). [2]Bio-Mos® program consisted of 0.1% Bio-Mos® (Alltech, Inc., Nicholasville KY 40356) to 42 d followed by 0.075% to 63 d. [3]Copper sulfate ($CuSO_4 \cdot 5H_2O$) to provide 250 mg/kg Cu from day-old to 42 d followed by 62.5 mg/kg from 42 d to 63 d. [4]Bioplex® Cu (Alltech, Nicholasville KY 40356) to provide 55 mg/kg Cu from day-old to 42 d followed by 27.5 mg/kg Cu to 63 d.

mix provided 10 mg/kg of copper in the form of copper sulfate, sufficient to meet the nutrient requirements for this mineral (NRC, 1994). Composition and nutrient content of the diets is given in Table 1. For each age period, a large lot of the basal diet was mixed and aliquots used to mix the test diets. Starter diets were fed as crumbles; diets fed from 3 to 9 wk were pelleted with steam. Samples of each diet were analyzed for crude protein and copper content and were found to be within expected range.

The dietary treatments involved a 2 x 2 x 3 factorial arrangement with the factors including 1) antibiotic program; 2) Bio-Mos® program; and 3) copper program. The two-factor antibiotic program included either a negative control (no growth promoters) or a popular antibiotic program that consisted of 55 mg/kg of bacitracin methylene disalicylate[5] fed from day-old to 42 d followed by 16.5 mg/kg virginiamycin[6] to 63 d. The two-factor Bio-Mos® program consisted of either no supplementation or addition of 0.1% Bio-Mos® to 42 d followed by

[5]BMD-50; Alpharma, Inc., Ft. Lee, NJ 07024. [6]Stafac-10; Pfizer Animal Health, Exton PA 19341.

Table 3: Effects of source of copper, antibiotics, and inclusion of Bio-Mos® mannan oligosaccharide in broiler diets on feed conversion (means of eight pens of 50 male broilers per treatment)

Antibiotic Program[1]	Bio-Mos[2]	0-21 d FCR (feed:gain)				0-42 d FCR (feed:gain)				0-49 d FCR (feed:gain)				0-63 d FCR (feed:gain)			
		No Cu	Copper Sulfate[3]	Bio-Plex[4]	Mean	No Cu	$CuSO_4$	Bio-Plex	Mean	No Cu	$CuSO_4$	Bio-Plex	Mean	No Cu	$CuSO_4$	Bio-Plex	Mean
None	No	1.376	1.415	1.420	1.404^{ab}	1.698	1.699	1.713	1.704	1.861	1.865	1.849	1.858	1.971	1.976	1.988	1.978
	Yes	1.427	1.395	1.422	1.415^{a}	1.712	1.676	1.717	1.702	1.806	1.807	1.909	1.841	1.991	1.968	2.004	1.988
	Mean	1.402	1.405	1.421	1.409	1.705	1.688	1.715	1.703	1.834	1.836	1.879	1.849	1.981	1.972	1.996	1.983
BMD/Stafac	No	1.408	1.408	1.399	1.405^{ab}	1.722	1.692	1.694	1.703	1.870	1.832	1.885	1.862	2.003	1.975	2.002	1.993
	Yes	1.392	1.384	1.378	1.385^{b}	1.722	1.691	1.691	1.701	1.841	1.818	1.926	1.862	1.984	2.021	2.018	2.008
	Mean	1.400	1.396	1.389	1.395	1.722	1.691	1.692	1.702	1.856	1.825	1.905	1.862	1.994	1.998	2.010	2.001
Mean	No	1.392	1.412	1.409	1.404	1.710	1.696	1.704	1.703	1.866^{ab}	1.849^{b}	1.867^{ab}	1.860	1.987	1.975	1.995	1.986
	Yes	1.409	1.389	1.400	1.400	1.717	1.683	1.704	1.701	1.824^{b}	1.812^{b}	1.917^{a}	1.851	1.988	1.994	2.011	1.998
	Mean	1.401	1.400	1.405	1.402	1.714	1.690	1.704	1.702	1.845^{y}	1.831^{y}	1.892^{x}	1.856	1.987	1.985	2.003	1.992

Source of variation	Probability > F	Probability > F	Probability > F	Probability > F
Antibiotic (A)	0.06	0.93	0.44	0.14
Copper source (C)	0.87	0.09	0.01	0.39
Bio-Mos (B)	0.52	0.85	0.57	0.32
A x C	0.24	0.17	0.59	0.88
A x B	0.04	0.97	0.60	0.84
B x C	0.10	0.68	0.04	0.79
A x B x C	0.24	0.69	0.73	0.28
SEM	0.014	0.016	0.03	0.023

[ab, xy]Within comparisons, means with common superscripts do not differ significantly ($P < 0.05$). [1]Antibiotic program consisted of 55 mg/kg bacitracin methylene disalicylate (BMD; Alpharma, Fort Lee NJ 07024) followed by 16.5 mg/kg virginiamycin (Stafac; Pfizer Animal Health, Exton PA 19341). [2]Bio-Mos® program consisted of 0.1% Bio-Mos® (Alltech, Inc., Nicholasville KY 40356) to 42 d followed by 0.075% to 63 d. [3]Copper sulfate ($CuSO_4 \cdot 5H_2O$) to provide 250 mg/kg Cu from day-old to 42 d followed by 62.5 mg/kg from 42 d to 63 d. [4]Bioplex® Cu (Alltech, Nicholasville KY 40356) to provide 55 mg/kg Cu from day-old to 42 d followed by 27.5 mg/kg Cu to 63 d.

0.075% Bio-Mos® to 63 d. The three-factor copper program consisted of either no supplemental copper; copper sulfate ($CuSO_4 \cdot 5H_2O$) to provide 250 mg/kg Cu from day-old to 42 d followed by 62.5 mg/kg from 42 d to 63 d; or Bioplex® Cu to provide 55 mg/kg Cu from day-old to 42 d followed by 27.5 mg/kg Cu from 42 to 63 d. The combination of two antibiotic programs, two Bio-Mos® programs, and three copper programs resulted in a total of twelve dietary treatments.

Male chicks of a commercial broiler strain cross (Ross[7] x Cobb[8]) were obtained from a local hatchery where they had been vaccinated *in ovo* for Marek's virus and had received vaccinations for Newcastle Disease and Infectious Bronchitis post hatch via a coarse spray. Fifty birds were placed in each of 96 pens at a density of 11.2 birds/m^2. Previously used softwood shavings top-dressed with new litter served as bedding. No copper sulfate had previously been fed to chicks on this litter, other than the 10 mg/kg provided in the trace mineral mix. Each pen was equipped with one automatic water fount and two tube-type feeders. Eight

[7]Ross Breeders, Huntsville AL 35805. [8]Cobb-Vantress, Inc., Siloam Springs AR 72761.

Table 4:Effects of source of copper, antibiotics, and inclusion of Bio-Mos® mannan oligosaccharide in broiler diets on mortality (means of eight pens of 50 male broilers per treatment)

Antibiotic Program[1]	Bio-Mos[2]	0-21 d Mortality (%)				0-42 d Mortality (%)				0-49 d Mortality (%)				0-63 d Mortality (%)			
		No Cu	Copper Sulfate[3]	Bio-Plex[4]	Mean	No Cu	$CuSO_4$	Bio-Plex	Mean	No Cu	$CuSO_4$	Bio-Plex	Mean	No Cu	$CuSO_4$	Bio-Plex	Mean
None	No	2.00	2.00	4.00	2.67	21.25	15.75	14.50	17.17	26.29	23.25	21.50	23.68	37.25	28.50	28.50	31.42
	Yes	3.00	3.14	2.86	3.00	17.50	19.75	14.86	17.37	28.25	27.25	22.00	25.83	34.00	32.25	26.29	30.85
	Mean	2.50	2.57	3.43	2.83	19.38	17.75	14.68	17.27	27.27	25.25	21.75	24.76	35.63	30.38	27.39	31.13
BMD/Stafac	No	3.43	2.50	2.75	2.89	16.75	14.25	19.00	16.67	24.50	21.50	24.00	23.33	28.75	27.00	32.25	29.33
	Yes	1.75	2.86	2.00	2.20	18.25	20.25	17.75	18.75	27.75	27.50	25.00	26.75	38.25	33.50	30.75	34.17
	Mean	2.59	2.68	2.38	2.55	17.50	17.25	18.38	17.71	26.13	24.50	24.50	25.04	33.50	30.25	31.50	31.75
Mean	No	2.71	2.25	3.38	2.78	19.00	15.00	16.75	16.92	25.39	22.38	22.75	23.51	33.00	27.75	30.28	30.38
	Yes	2.38	3.00	2.43	2.60	17.88	20.00	16.30	18.06	28.00	27.38	23.50	26.29	36.13	32.88	28.52	32.51
	Mean	2.54	2.63	2.90	2.69	18.44	17.50	16.53		26.70	24.88	23.13		34.56	30.31	29.45	

Source of variation	Probability > F	Probability > F	Probability > F	Probability > F
Antibiotic (A)	0.48	0.75	0.86	0.74
Copper source (C)	0.75	0.54	0.25	0.06
Bio-Mos (B)	0.66	0.42	0.11	0.26
A x C	0.41	0.25	0.60	0.39
A x B	0.21	0.50	0.71	0.15
B x C	0.23	0.15	0.60	0.30
A x B x C	0.30	0.61	0.98	0.38
SEM	0.74	2.60	3.16	3.47

[1]Antibiotic program consisted of 55 mg/kg bacitracin methylene disalicylate (BMD; Alpharma, Fort Lee NJ 07024) followed by 16.5 mg/kg virginiamycin (Stafac; Pfizer Animal Health, Exton PA 19341). [2]Bio-Mos® program consisted of 0.1% Bio-Mos® (Alltech, Inc., Nicholasville KY 40356) to 42 d followed by 0.075% to 63 d. [3]Copper sulfate ($CuSO_4{\cdot}5H_2O$) to provide 250 mg/kg Cu from day-old to 42 d followed by 62.5 mg/kg from 42 d to 63 d. [4]Bioplex® Cu (Alltech, Nicholasville KY 40356) to provide 55 mg/kg Cu from day-old to 42 d followed by 27.5 mg/kg Cu to 63 d.

pens were assigned to each dietary treatment.

Birds were group weighed by pen at 21, 42, 49, and 63 days of age. Samples of birds (5 per pen) were selected to be within one-half standard deviation of the treatment mean and processed at 63 days to determine dressing percentage and parts yield as described by Izat *et al.* (1990). Pen means served as the experimental unit. Mortality data were transformed to $\sqrt{n+1}$ for analysis; data are presented as natural numbers. The data were analyzed as a complete factorial arrangement including the main effects of antibiotics, source of copper, and Bio-Mos®, with all possible two-way and three-way interactions. The General Linear Models procedure of SAS (SAS Institute, 1991) was used to carry out the statistical analysis. Statements of statistical significance are based upon a probability of $P < 0.05$ unless stated otherwise.

Results and Discussion

Body weight: The body weight of chicks at different ages is shown in Table 2. At 21 d, body weight of chicks fed the antibiotic program was significantly heavier than those fed the diets without antibiotics. At 42 d, chicks fed the antibiotic program continued to have higher body weights ($P = 0.11$) but at 49 and 63 d no significant differences in body weight were noted between those fed diets with or without antibiotics. Addition of copper in excess of the minimum recommended

Table 5. Effects of source of copper, antibiotics, and inclusion of Bio-Mos® mannan oligosaccharide in broiler diets on 63-day processing parameters (means of eight pens of five male broilers per treatment)

Antibiotic program[1]	Bio-Mos[2]	Dressing percentage (%)				Breast yield (%)				Leg quarters (%)				Abdominal fat (%)			
		No Cu	Copper Sulfate[3]	Bio-Plex[4]	Mean	No Cu	$CuSO_4$	Bio-Plex	Mean	No Cu	$CuSO_4$	Bio-Plex	Mean	No Cu	$CuSO_4$	Bio-Plex	Mean
None	No	76.01	75.42	74.81	75.41	27.42	26.96	26.60	27.00	32.16	32.72	32.53	32.47	2.72	2.85	3.05	2.87
	Yes	75.82	75.86	75.91	75.86	26.67	27.20	26.25	26.71	32.63	32.67	32.41	32.57	3.11	3.01	3.11	3.08
	Mean	75.92	75.64	75.36	75.64	27.05[ab]	27.08[a]	26.43[b]	26.85	32.40	32.69	32.47	32.52	2.91	2.93	3.08	2.97
BMD/Stafac	No	75.97	75.84	75.91	75.91	27.30	26.68	27.10	27.02	32.99	32.79	31.88	32.55	3.15	3.09	3.07	3.10
	Yes	75.31	76.45	75.77	75.84	26.74	26.88	27.56	27.06	32.63	32.51	32.86	32.67	3.28	3.01	3.11	3.13
	Mean	75.64	76.14	75.84	75.87	27.02[ab]	26.78[ab]	27.33[a]	27.04	32.81	32.65	32.37	32.61	3.22	3.05	3.09	3.12
Mean	No	75.99	75.63	75.36	75.66	27.36	26.82	26.85	27.01	32.58	32.76	32.20	32.51	2.94	2.97	3.06	2.99
	Yes	75.56	76.15	75.84	75.85	26.71	27.04	26.70	26.88	32.63	32.59	32.63	32.62	3.19	3.01	3.11	3.10
	Mean	75.78	75.89	75.60		27.03	26.93	26.88		32.60	32.67	32.42		3.06	2.99	3.08	

Source of variation	Dressing percentage: Probability > F	Breast yield: Probability > F	Leg quarters: Probability > F	Abdominal fat: Probability > F
Antibiotic (A)	0.33	0.29	0.63	0.06
Copper source (C)	0.62	0.77	0.52	0.58
Bio-Mos (B)	0.42	0.48	0.57	0.14
A x C	0.33	0.02	0.46	0.30
A x B	0.29	0.36	0.97	0.25
B x C	0.19	0.10	0.42	0.43
A x B x C	0.49	0.62	0.10	0.78
SEM	0.45	0.39	0.37	0.14

[ab]Within comparisons, means with common superscripts do not differ significantly ($P < 0.05$). [1]Antibiotic program consisted of 55 mg/kg bacitracin methylene disalicylate (BMD; Alpharma, Fort Lee NJ 07024) followed by 16.5 mg/kg virginiamycin (Stafac; Pfizer Animal Health, Exton PA 19341). [2]Bio-Mos® program consisted of 0.1% Bio-Mos® (Alltech, Inc., Nicholasville KY 40356) to 42 d followed by 0.075% to 63 d. [3]Copper sulfate ($CuSO_4 \cdot 5H_2O$) to provide 250 mg/kg Cu from day-old to 42 d followed by 62.5 mg/kg from 42 d to 63 d. [4]Bioplex® Cu (Alltech, Nicholasville KY 40356) to provide 55 mg/kg Cu from day-old to 42 d followed by 27.5 mg/kg Cu to 63 d.

needs (NRC, 1994) from either copper sulfate or from Bioplex® copper had no significant influence on body weight at any age. Addition of Bio-Mos® had no effect on body weight at any age. There were no significant interactions among or between any of the main effects related to body weight.

Feed conversion: The feed conversion of chicks at different ages, expressed as kg feed/kg gain, is shown in Table 3. The feed conversion was adjusted to include the weight of birds that died during the study. At 21 d, chicks fed the antibiotic program had better feed conversion ($P = 0.06$) than those fed the negative control; however no significant effect of antibiotics were noted at other ages. Response to copper was variable; at 21, 42, and 63 d there were no significant differences related to copper source while at 49 d chicks fed the Bioplex® Cu had significantly higher feed conversion than those fed the diets with no copper or from copper sulfate. Overall, Bio-Mos® had no significant effect on feed conversion but interacted with some of the other factors. At 21 d there was an interaction between the antibiotic program and inclusion of Bio-Mos®; adding Bio-Mos® in the absence of antibiotics tended to increase feed conversion while adding Bio-Mos® in the presence of antibiotics tended to decrease feed conversion. This interaction was not observed at other ages. An interaction between copper sources and Bio-Mos® was observed at 49 d; addition of Bio-Mos® improved feed conversion when added to diets with no copper or with copper sulfate but impaired conversion when added to diets with Bioplex® Cu. However, this was not observed at other ages.

Mortality: Mortality during the study is shown in Table 4. None of the dietary factors had any significant effects on mortality, although chicks fed copper from either copper sulfate or Bioplex® Cu had reduced mortality ($P = 0.06$) at 63 d compared to those fed diets without copper. A high incidence of mortality from ascites occurred during the 21 to 42 d period, associated with extreme cold weather that was difficult to overcome in the test facilities.

Processing characteristics: Dressing percentage, breast meat yield, leg quarter yield, wing yield, and abdominal fat content are shown in Table 5. None of the main effects had any significant effect on any processing parameters. There was a significant interaction between antibiotic programs and source of copper on breast meat yield, but this followed no consistent trend.

Published reports on the use of Bio-Mos® in broiler diets are sparse and show inconsistent results, perhaps due to variability in the levels used in the diets. Kumprecht and Zobac (1997) incorporated Bio-Mos® at levels up to 3 g/kg in broiler finisher diets and observed significant improvements in body weight and feed conversion. A level of 2 g/kg was said to be the most effective level. Iji *et al.* (2001) reported that feeding broilers diets containing 5 g/kg Bio-Mos® led to minor improvements in body weight but no improvement in feed conversion. Jamroz *et al.* (1997) reported improved performance of broilers when Endofeed, an enzyme additive, was included in the feed but not when 2 g/kg of Bio- Mos® was added. Eren *et al.* (1999) fed chicks diets containing 1 g/kg of Bio-Mos® to 35 d and reported no significant improvements in body weight gain, feed conversion, or carcass dressing percentage. Shafey *et al.* (2001b) reported that supplementation of broiler diets with 3 g/kg of Bio-Mos® did not influence body weight gain, feed utilization, or nutrient utilization. Waldroup *et al.* (2002) were unable to detect improvements in body weight when 1 g/kg Bio-Mos® was fed to broilers, but did note improved feed utilization.

Ryan *et al.* (2002) reported that sheep supplemented with Bioplex® copper had significantly greater increase in plasma copper level than sheep given copper sulfate, indicating that copper from the Bioplex® was more readily absorbed than the inorganic source. Turkeys given Bioplex® copper in the drinking water had higher blood hematocrit and glucose content than those not given copper supplements (Makarski and Polonis, 2001). Addition of Bioplex® copper to diets of stocker cattle prior to transport to a feedlot increased body weight that was maintained during a 42-d receiving period in the feedlot (Gunter *et al.*, 2000). However, because no other sources of Cu were utilized in the studies by Gunter *et al.* (2000) or Makarski and Polonis (2001), it is not possible to state that these sources were more biologically available than inorganic forms of copper. Kessler and de Faria (1998) fed organic and inorganic sources of Cu, Mn, Zn, and Se to dairy cattle and measured milk yield, milk composition, somatic cell count, and concentration in the liver, kidney, outer hair coat, and phalanx proximalis. No significant differences were observed between organic and inorganic forms of the minerals.

No indications of interactions between Bio-Mos® and the various copper sources was noted in this study. Previous reports have indicated that high levels of copper sulfate may interfere with the use of antibiotics, arsenicals, and histomoniastats in poultry diets (Carlson *et al.*, 1979; Bowen and Sullivan, 1971; Bowen *et al.*, 1971a, 1971 b).Overall performance of birds in this study was quite exceptional, except for the higher than anticipated mortality. Lack of response to antibiotics in later stages of growth suggests that the birds were performing well with minimal stress, and perhaps is the reason for the lack of response to Bio-Mos® or to the copper sources. It is also possible that the levels of Bio-Mos® or Bioplex® Cu used in this study were not sufficient to elicit a positive response. This warrants further study with higher levels of inclusion in the diet.

Acknowledgements

This study was supported in part by a grant from Alltech, Inc., Nicholasville KY.

References

Aldinger, S., 1967. Feeding high level copper improves growth rate. Poult. Meat, Jan., pp: 51-52.

Aoyagi, S. and D. H. Baker, 1993. Nutritional evaluation of copper-lysine and zinc-lysine complexes for chickens. Poult. Sci., 72: 165-171.

Apgar, G. A., E. T. Kornegay, M. D. Lindemann and D. R. Notter, 1995. Evaluation of copper sulfate and a copper lysine complex as growth promoters for weanling swine. J. Anim. Sci., 73: 2640-2646.

Arce, J., M. Berger and C. Lopez-Coello, 1992. Control of ascites syndrome by feed restriction techniques. J. Appl. Poult. Res., 1: 1-5.

Baker, D. H., K. R. Robbins and G. M. Willis, 1982. Amino acid utilization as influenced by antibacterial and anticoccidial drugs. Fed. Proc., 41: 2824-2827.

Bowen, T. E. and T. W. Sullivan, 1971. Influence of dietary cupric sulfate on the response of young turkeys to penicillin-streptomycin (1:3). Poult. Sci., 50: 273-278.

Bowen, T. E., T. W. Sullivan and O. D. Grace, 1971a. Effect of cupric sulfate on the prophylactic efficacy of three arsonic compounds against histomoniasis in young turkeys. Poult. Sci., 50: 861-866.

Bowen, T. E., T. W. Sullivan and O. D. Grace, 1971b. Effect of cupric sulfate on the prophylactic efficacy of 2-acetylamino-5-nitrothiazole, nifursol, and ipronidazole against histomoniasis in turkeys. Poult. Sci., 50: 1668-1672.

Bunch, R. J., J. T. McCall, V. C. Speer and V. W. Hays, 1965. Copper supplementation for growing pigs. J. Anim. Sci., 24: 995-1000.

Carlson, C. W., E. Guenther, R. J. Emerick and R. A. Nelson, 1979. Growth promoting effects of copper salts in poultry. Pages 101-111 in: Proceedings Maryland Nutr. Conf., College Park, MD.

Coffey, R. D., G. L. Cromwell and H. J. Monegue, 1994. Efficacy of copper-lysine complex as a growth promotant for weanling pigs. J. Anim. Sci., 72: 2880-2886.

Dale, N. and J. Villacres, 1986. Influence of dietary density, calorie:protein ratio, and supplemental fat on the incidence of ascites in broilers. Poult. Sci., 66(Suppl. 1):163.

Doerr, J. A., J. L. Nicholson and E. Johnson, 1980. Influence of dietary copper on litter quality and broiler performance. Pages 61-65 in: Proc. Maryland Nutr. Conf., College Park, MD.

Eren, M., G. Deniz, H. Birickik, S. S. Gezen, I. I. Turkemen and H. M. Yavuz, 1999. Effects of supplementation of zinc bacitracin, Mannanoligosaccharide and probiotic in broiler feeds on fattening performance. Vet. Fak. Derg. Ulu. Univ., 18:73-84.

Ewing, H. P., G. M. Pesti, R. I. Bakali and J. F. M. Menten, 1998. Studies on the feeding of cupric sulfate pentahydrate, cupric citrate and copper oxychloride to broiler chickens. Poult. Sci., 77: 445-448.

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.

Fisher, C., 1973. Use of copper sulfate as a growth-promoter for broilers. Feedstuffs, July 16, pp: 24-25.

Fisher, C., A. P. Laursen-Jones, K. J. Hill and W. S. Hardy, 1973. The effect of copper sulphate on performance and the structure of the gizzard in broilers. Br. Poult. Sci., 14: 55-68.

Gunter, S., P. Beck, B. Kegley, K. Malcom-Callis, G. Duff, Z. B. Johnson and D. W. Kellogg, 2000. Performance of growing calves supplemented with Bioplex® copper pre- or post-shipping to a feedlot. Ark. Agri. Exp. Sta. Res. Series, 470: 111-115.

Guo, R., P. R. Henry, R. A. Holwerda, J. Cao, R. C. Littell, R. D. Miles and C.B. Ammerman, 2001. Chemical characteristics and relative bioavailability of supplemental organic copper sources for poultry. J. Anim. Sci., 79: 1132-1141.

Hawbaker, J. A., V. C. Speer, V. W. Hays and D. V. Catron, 1961. Effects of copper sulfate and other chemotherapeutics in growing swine rations. J. Anim. Sci., 20: 163-167.

Iji, P. A., A. A. Saki and D. R. Tivey, 2001. Intestinal structure and function of broiler chickens on diets supplemented with a mannan oligosaccharide. J. Sci. Food Agri., 81: 1186-1192.

Izat, A. L., M. Colberg, M. A. Reiber, M. H. Adams, J. T. Skinner, M. C. Cabel, H. L. Stilborn and P. W. Waldroup, 1990. Effects of different antibiotics on performance, processing characteristics, and parts yield of broiler chickens. Poult. Sci., 69: 1787-1791.

Jamroz, D., A. Wiliczkiewicz, J. Skorupinska and J. Orda, 1997. Using enzymatic additive Endofeed and mannan oligosaccharide BIO-MOS in mixtures for slaughter chickens. Roczniki-Naukowe-Zootech., 24: 251-263.

Jenkins, N. K., T. R. Morris and D. Valamotis, 1970. The effect of diet and copper supplementation on chick growth. Br. Poult. Sci., 11: 241-248.

Kessler, J. and A. de Faria, 1998. The effect of an organic trace element supplement on metabolic parameters, milk yield, and milk composition of dairy cows. Rev. Suisse d'Agri., 30: 147-150.

Kumprecht, I. and F. Zobac, 1997, The effect of mannan-oligosaccharides in feed mixtures on the performance of broilers. Zivocisna Vyroba, 42: 117-124.

Lee, S. H., S. C. Choi, B. J. Chae, J. K. Lee, and S. P. Acda, 2001. Evaluation of metal-amino acid chelates and complexes at various levels of copper and zinc in weanling pigs and broiler chicks. Asian-Aust. J. Anim. Sci., 14: 1734-1740.

Madsen, F. C. and T. P. Lyons, 1988. Essential mineral nutrition: a role for coordination chemistry. Pages 151-161 in: Biotechnology in the Feed Industry. Proc. Alltech 4th Annual Symposium, Nicholasville KY.

Makarski, B. and A. Polonis, 2001. Effect of Bioplex-Cu on the level of biochemical indices of turkey blood. Polish J. Food Nutr. Sci., 10: 49-51.

Moore, P. R., A. Evanson, T. D. Luckey, E. McCoy, C. A. Elvehjem and E. B. Hart, 1946. Use of sulfasuxidine, streptothricin, and streptomycin in nutritional studies with the chick. J. Biol. Chem., 165: 437-441.

National Research Council, 1994. Nutrient Requirements of Poultry. 9th rev. ed. National Academy Press, Washington, DC.

Olsen, R., 1996. Experience with mannan oligosaccharides in commercial turkey production. Zootech. Int., 19 :38-39.

Paik, I. K., S. H. Seo, J. S. Um, M. B. Chang and B. H. Lee, 1999. Effects of supplementary copper-chelate on the performance and cholesterol level in plasma and breast muscle of broiler chicks. Asian-Aust. J. Anim. Sci., 12: 794-798.

Pesti, G. M. and R. I. Bakali, 1996. Studies on the feeding of cupric sulfate pentahydrate and cupric citrate to broiler chickens. Poult. Sci., 75: 1086-1091.

Poupoulis, C. and L. S. Jensen, 1976. Effect of high dietary copper on gizzard integrity of the chick. Poult. Sci., 55: 113-121.

Ryan, J. P., P. Kearns and T. Quinn, 2002. Bioavailability of dietary copper and zinc in adult Texel sheep; a comparative study of the effects of sulphate and Bioplex supplementation. Irish Vet. J., 55: 221-224.

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

Savage, T. F. and E. I. Zakrzewska, 1997. The performance of male turkeys fed a starter diet containing a mannan oligosaccharide. Zootech. Int., 20: 30-32.

Shafey, T. M., S. Al-Mufarej, M. I. Shalaby and A. J. Jarelnabi, 2001a. Effects of mannan oligosaccharides on antibody response to infectious bronchitis, infectious bursal disease and Newcastle disease in chickens. J. Appl. Anim. Res., 19: 117-127.

Shafey, T. M., S. Al-Mufarej, M. I. Shalaby and A. J. Jarlenabi, 2001b. The effect of feeding mannan-oligosaccharides (Bio-Mos) on the performance of meat chickens under two different vaccination programs. Asian-Aust. J. Anim. Sci., 14: 559-563.

Smith, M. S., 1969. Responses of chicks to dietary supplements with copper sulphate. Br. Poult. Sci., 10: 97-108.

Sonmez, G. and M. Eren, 1999.Effects of supplementation of zinc bacitracin, mannan oligosaccharide, and probiotic into the broiler feeds on morphology of the small intestine. Vet. Fac. Dergisi Uludag Univ., 18: 125-138.

Spring, P., 1999a. Mannanoligosaccharides as an alternative to antibiotic use in Europe. Zootech. Int., 22: 38-41.

Spring, P., 1999b. Modes of action of dietary mannan oligosaccharide R as a growth enhancer. Zootech. Int., 22: 34-36.

Spring, P., C. Wenk, K. A. Dawson and K. E. Newman, 2000. The effects of dietary mannanoligosaccharides on cecal parameters and the concentrations of enteric bacteria in the ceca of salmonella-challenged broiler chicks. Poult. Sci., 79: 205-211.

Stansbury, W. F., L. F. Tribble and D. E. Orr, Jr., 1990. Effect of chelated copper sources on performance of nursery and growing pigs. J. Anim. Sci., 68: 1318-1322.

Valancony, H., F. Humbert, J. Rukelibuga, M. Bougon, L. Balaine and F. Lalande, 2001. Comparison of some substitutes for antibiotic additives in diets for turkey poults. Effects on production and on resistance to salmonella colonization. Sci. Tech. Avicoles, 35: 25-34.

Van Heugten, E. and M. T. Coffey, 1992. Efficacy of a copper-lysine chelate as growth promotant in weanling swine. J. Anim. Sci., 70(Supp.):18.

Waldroup, P. W., E. O. Oviedo-Rondon and C. A. Fritts, 2002. Comparison of Bio-Mos® and antibiotic feeding programs in broiler diets containing copper sulfate. Int. J. Poult. Sci., Submitted for publication.

Zhou, W., E. T. Kornegay, H. van Laar, J. W. G. M. Swinkels, E. A. Wong and M. D. Lindemann, 1994. The role of feed consumption and feed efficiency in copper-stimulated growth. J. Anim. Sci., 72: 2385-2394.