# Effect of Mannan-Endo-1,4-$\beta$-Mannosidase on the Growth Performance of Turkeys Fed Diets Containing 44 and 48% Crude Protein Soybean Meal[1,2]

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**ABSTRACT** Soybean meal (SBM) contains heat-resistant mannans. Domesticated turkeys are sensitive to mannans because of the high inclusion rate of SBM in their diets, causing increased chyme viscosity, wet droppings, and reduced feed conversion. Three experiments of similar design were conducted to determine the effect of mannan-endo-1,4-$\beta$-mannosidase supplementation of corn-SBM diets on market turkeys. Experiment 1 was conducted at North Carolina State University using Nicholas hens raised from 1 to 98 d of age. Experiments 2 and 3 were conducted at PARC Institute Inc. using Large White turkey toms raised from 1 to 126 d of age. In each experiment, birds were randomly assigned to litter floor pens. Each pen was assigned to one of four experimental treatments in 2 × 2 factorial arrangement of two basal diets containing 44% CP and 48% CP SBM (SBM-44 and SBM-48, respectively) with or without 100 million units (MU) Hemicell/tonne (1 MU = $10^6$ enzyme activity U). Birds fed SBM-44 had lower final BW (14.9 vs. 14.56 kg 18 wk BW / tom; 7.66 vs. 7.46 kg 14 wk BW/hen, $P < 0.05$) and higher final cumulative feed/gain than those fed the SBM-48. Hemicell supplementation generally improved performance of all birds, with a greater response in birds fed SBM-44. Hemicell improved BW and feed/gain by 1% ($P = 0.779$) and 3% ($P = 0.377$) in hens and 2.5% ($P = 0.0016$) and 4% ($P = 0.0001$) in toms, respectively. The results of these experiments indicate that some of the adverse effects of antinutritional factors of SBM of on turkey growth performance can be alleviated by dietary mannan-endo-1,4-$\beta$-mannosidase supplementation.

(*Key words*: turkey; soybean meal; enzyme; mannan-endo-1,4-$\beta$-mannosidase; growth performance)

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## INTRODUCTION

Soybean meal (SBM), a soybean oil extraction by-product, has long been used as a major protein source in poultry and livestock feeds (McEllhiney, 1994). Two commercial products of SBM are available in the market: one containing 48% CP (SBM-48) and the other containing 44% CP (SBM-44). Toasting ground soybean hulls and blending them with the SBM-48 produces the SBM-44 product. The SBM-44 product is less expensive, contains less CP and ME, and has higher levels of fiber than the SBM-48 product.

SBM contains several antinutritional factors. The most widely known of these are the trypsin inhibitors, which are deactivated by heat during the drying-toasting phase of processing. Other antinutritional factors that are also present include ureases, goitrogens, antivitamins, phytates, saponins, and estrogens. The SBM contains appreciable amounts of carbohydrates (40%). The polysaccharide portion of SBM (15 to 22%) is made up of acidic polysaccharides (8 to 10%), arabinogalactans (5%), and cellulosic materials (1 to 2%) (MacMasters et al., 1941; Honing and Rackis, 1979), whereas the lesser-known portion (1 to 2%) is the heat insensitive antinutritional mannans (Dierick, 1989).

$\beta$-Mannans are a group of closely related heat-resistant compounds that survive the drying-toasting phase of processing soybeans (Dale, 1997). $\beta$-Mannans compose about 1.3% in the SBM-48 product and 1.5 to 1.7% of the SBM-44 product with an estimated $\beta$-galactomannan content of 1.83 and 2.22% in the SMB-48 and the SBM-44 products, respectively (Dierick, 1989). Mannans, mainly associated with the hull and fiber fraction of SBM (Reid, 1985), are intensely antinutritional due to their highly viscous properties. The high viscosity of $\beta$-mannans reduces feed conversion and decreases the efficiency of carbohydrate utilization of monogastric animals by partially blocking receptor sites on the intestinal surface (Dale, 1997). $\beta$-Mannan is a linear


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**Abbreviation Key:** +E = with enzyme; FCR = feed conversion ratio; MU = million units; SBM-44 = soybean meal with 44% CP content; SBM-48 = soybean meal with 48% CP content.

polysaccharide composed of repeating β-1-4 mannose and 1-6 galactose and glucose units attached to the β-mannan backbone. A large number of oriented associations have been found between mannan heteropolysaccharides (glucomannan, galactomannan, and galactuglucomannan), cellulose, and cellulose-like polymers (Chanzy and Voung, 1985).

Mannan from guar gum, a galactomannan, has been shown to be a strong antinutritional factor for monogastric animals (Jackson et al., 1999). The inclusion rate of 2 to 4% in feed severely retards growth and decreases feed efficiency in broilers (Couch et el., 1967; Ray et al., 1982; Verma and McNab, 1982). Research with swine (Leeds et al., 1980) has demonstrated that β-galacto-mannan interferes with glucose metabolism and insulin secretion rates.

β-D-Mannanase (Hemicell, EC 3.2.1.78, mannan endo-1,4-β-mannosidase)[4] is an endohydrolase enzyme and is a fermentation product of *Bacillus lentus*, that degrades β-Mannans. Hemicell cleaves randomly within the 1,4-β-D-mannan main chain of galactomannan, galactugluco-mannan, and mannan (McCleary, 1988). Pen and field trials with corn-SBM diets supplemented with β-mannanase (D. W. Fodge, 2000, ChemGen Corp., Gaithesburg, MD, personal communication) have shown promising results in turkeys. Mannans are more concentrated in the hull than in any other fraction of soybeans. Because β-endo-mannosidases improve the digestibility of all types of mannan, they could be particularly more effective when supplemented to diets containing SBM-44. Broilers fed low-energy diets (as low as 3,003, 3,080, and 3,157 kcal/kg for starter, grower, and finisher, respectively) supplemented with β-Mannanase performed slightly better than broilers fed high-energy diets (3,146, 3,223, and 3,300 kcal for starter, grower, and finisher, respectively) without β-mannanase (McNaughten et al., 1998). Dietary mannanase supplementation of corn-soybean diets also improved feed conversion of swine (Hahn et al., 1995, Chen et al., 1998) and broilers (Ward and Fodge, 1996). Most recently, dietary β-mannanase (Hemicell) supplementation increased egg weight in commercial layers at early stages of production and increased total egg production by delaying the postpeak decline (Jackson et al., 1999). Hemicell was also observed to improve BW gain and feed efficiency in turkeys (D. W. Fodge, 1999, personal communication).

Turkeys may be more adversely affected by mannans because of the high dietary inclusion of SBM, especially during early growth. Therefore, β-mannanase may be particularly effective in turkey diets. To test this hypothesis, experiments were designed to determine the effect of mannan-endo-1,4-β-mannosidase (Hemicell) supplementation of corn-SBM diets on the growth performance of market turkeys and to compare the efficacy of the mannanase supplementation in diets containing SBM-44 and SBM-48.

[4]ChemGen Corp., Gaithesburg, MD.
[5]British United Turkeys of America, Inc., Lewisburg, WV.
[6]MU = $10^6$ Hemicell enzyme activity units determined by ChemGen Corp., Gaithesburg, MD.

## MATERIALS AND METHODS

Three experiments of similar design were conducted. Experiment 1 was conducted at North Carolina State University using Nicholas hens raised from 1 to 98 d of age. Experiments 2 and 3 were conducted at PARC Institute Inc. using British United Turkeys of America[5] turkey toms raised from 1 to 126 d of age. Birds received either four- (Experiment 1, Table 1), or five- (Experiments 2 and 3) phase feed regimen ad libitum (Tables 2 and 3, respectively). In each experiment, birds were randomly assigned to litter floor pens providing 0.24 $m^2$/hen (Experiment 1) and 0.36 $m^2$/tom (Experiments 2 and 3). Each pen was assigned to one of four experimental treatments in a $2 \times 2$ factorial arrangement of two basal diets containing SBM-44 or SBM-48 and two levels of β-endomannanase [0 or 100 million units (MU[6]) Hemicell/tonne).

### Experiment 1

This experiment was conducted in accordance to the North Carolina State University Institute Animal Care and Use Committee guidelines and procedures (Federation of Animal Science Societies, 1999). The facility used in this experiment was an industry-standard curtain-sided house containing forty-eight pens in total. Used litter (from a previous flock) was left in each pen and top-dressed with a 4-cm layer of clean pine shavings. Caked litter was removed, and additional bedding material was added as necessary to maintain satisfactory litter condition throughout the trial. Ventilation was provided by natural air movement through appropriately adjusted curtain sides and air-mixing fans located on the ceiling throughout the house. Feed and water were provided ad libitum throughout the study. Incandescent lighting was applied continuously for the first wk and subsequently by natural length daylight. Standard infrared gas brooders provided supplemental heat for each pen. House temperature was kept at 26 to 29 C during the first 2 week and then gradually decreased to the ambient outside temperature.

Commercial Nicholas hens were randomly assigned to each of 48 pens initially stocked with 30 poults per pen at 1 d of age. Each pen received one of four treatments in a completely randomized block design. Pens were assigned to four blocks of 12 pens each. The four dietary treatments were randomly assigned to pens within each of the four blocks using the procedures of SAS software (1996). Data were analyzed as a $2 \times 2$ factorial arrangement using ANOVA of SAS software. The four treatments were composed of two basal diets containing SBM-44 or SBM-48 with or without 100 MU Hemicell/tonne (Table 1). The four experimental treatments were SBM-48, SBM-48 + 100 MU Hemicell/tonne, SBM-44, and SBM-44 + 100 MU Hemicell/tonne.

Four feeding phases were used during the course of this experiment. All feeds were formulated using least-cost linear programming software, such that the diets were slightly above the NRC (1994) recommendations (Table 1). All feed was pellet-processed and fed in crumble form up

**TABLE 1. Formulas and calculated nutrient analysis of diets fed to turkey hens from 1 to 98 d of age (Experiment 1)**

| | Days of age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0–21 | | 22–42 | | 43–70 | | 71–98 | |
| | Dietary treatment[1] | | | | | | | |
| Ingredient | 1 & 2 | 3 & 4 | 1 & 2 | 3 & 4 | 1 & 2 | 3 & 4 | 1 & 2 | 3 & 4 |
| | (% of Diet) | | | | | | | |
| Corn | 36.47 | 37.83 | 39.71 | 39.63 | 47.25 | 47.27 | 53.84 | 53.81 |
| Soybean meal (48% CP) | 43.70 | 38.90 | 40.56 | 36.15 | 34.44 | 30.14 | 25.63 | 22.84 |
| Poultry fat | 3.36 | 3.36 | 5.08 | 5.08 | 4.58 | 4.58 | 6.32 | 6.32 |
| Poultry meal (60% CP) | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 6.00 | 6.00 |
| Limestone | 1.12 | 1.12 | 1.15 | 1.15 | 0.93 | 0.93 | 0.84 | 0.84 |
| Dicalcium P (18.5% P) | 2.53 | 2.52 | 2.02 | 2.02 | 1.50 | 1.50 | 1.31 | 1.31 |
| D,L-Methionine | 0.27 | 0.27 | 0.26 | 0.26 | 0.11 | 0.11 | 0.04 | 0.04 |
| L-Lysine-HCL | 0.14 | 0.14 | 0.14 | 0.14 | 0.10 | 0.10 | 0 | 0 |
| Salt | 0.26 | 0.26 | 0.28 | 0.27 | 0.29 | 0.29 | 0.29 | 0.29 |
| Choline Cl (60% Choline) | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Mineral premix[2] | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| Vitamin Premix[3] | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Coban-60[4] | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0 | 0 |
| BMD-50[5] | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0 | 0 |
| Selenium Premix[6] | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| Bakery by product | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Stafac-44[7] | 0 | 0 | 0 | 0 | 0 | 0 | 0.025 | 0.025 |
| Soy hulls | 0 | 4.8 | 0 | 4.5 | 0 | 3.83 | 0 | 2.82 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Nutrient analysis | | | | | | | | |
| Crude protein, % | 28.10 | 26.16 | 26.60 | 24.93 | 24.10 | 22.67 | 20.90 | 19.85 |
| ME, (kcal/kg) | 1,350 | 1,303 | 1,400 | 1,362 | 1,425 | 1,393 | 1,500 | 1,476 |
| Crude fat, % | 6.56 | 6.56 | 8.26 | 8.29 | 7.99 | 8.01 | 10.00 | 10.02 |
| Crude fiber, % | 2.70 | 4.20 | 2.62 | 4.04 | 2.60 | 3.79 | 2.48 | 3.36 |
| Calcium, % | 1.25 | 1.25 | 1.15 | 1.16 | 0.95 | 0.96 | 0.90 | 0.91 |
| Nonphytate P, % | 0.70 | 0.69 | 0.60 | 0.59 | 0.50 | 0.49 | 0.48 | 0.48 |
| Methionine, % | 0.70 | 0.67 | 0.67 | 0.65 | 0.50 | 0.48 | 0.40 | 0.38 |
| Methionine + cysteine, % | 1.15 | 1.09 | 1.10 | 1.05 | 0.90 | 0.86 | 0.76 | 0.73 |
| Lysine, % | 1.70 | 1.57 | 1.60 | 1.49 | 1.40 | 1.31 | 1.10 | 1.03 |
| Threonine, % | 1.05 | 0.97 | 0.99 | 0.92 | 0.90 | 0.84 | 0.78 | 0.73 |
| Sodium, % | 0.18 | 0.19 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |

[1]Each pen received one of the following four dietary treatments; 1) soybean meal (SBM) with 48% CP content (SBM-48), 2) SBM-48 plus enzyme (+E), 3) SBM with 44% CP content (SBM-44), or SBM-48+E.

[2]The mineral premix was obtained from Eastern Minerals Inc., Henderson, NC, and provided the following per kilogram of diet: 120 mg Zn from $ZnSO_4$, 120 mg Mn from $MnSO_4$, 80 mg Fe from $FeSO_4C5H_2O$, 10 mg Cu from $CuSO_4$, 2.5 mg I from $CaIO_4$, and 1 mg Co from $CoSO_4$.

[3]The vitamin premix was obtained from Roche, Nutley, NJ, and provided the following per kilogram of diet: 13,200 IU vitamin A, 4,000 ICU vitamin D, 66 IU vitamin E, 39.6 $\mu$g vitamin B12, 13.2 mg riboflavin, 110 mg niacin, 22 mg d-pantothenate, 0.4 mg vitamin K, 2.2 mg folic acid, 4.0 mg thiamin, 7.9 mg pyridoxine, 0.253 mg biotin, and 100 mg ethoxyquin.

[4]Coban-60 (Elanco Animal Health, Indianapolis, IN) provided 66 mg monensin sodium per kilogram of diet.

[5]BMD-50 (Alpharma, Inc., Fort Lee, NJ) provided 66 mg bacitracin methylene disalicylate per kilogram of diet.

[6]The selenium premix provided 0.2 mg Se/kg diet as $Na_2SeO_3$.

[7]Stafac-44 (Pfizer Animal Health, Exton, PA) provided 22 mg virginiamycin per kilogram diet.

to 4 wk of age and subsequently as a whole 5/16 pellet form. The basal diets (without enzyme) were mixed in one batch mixer, thus eliminating treatment variation due to batch mixing error. The enzyme was applied to the feed in a 500-kg-capacity horizontal double ribbon mixer and then bagged into 25-kg bags. The enzyme dosage was diluted with distilled water up to a volume of 500 mL/tonne (250 mL/500 kg feed) immediately before application onto the feed with a plant mister during mixing. Two products of Hemicell are commercially available: a solid product containing about 140 MU of $\beta$-mannanase active U/kg, and a liquid product containing about 720 MU active/L. In this experiment, 70 mL of the liquid Hemicell was diluted with 180 mL of water. To the control feeds, 250 mL of distilled water was applied, with the garden mister, to account for any effects due to remixing the pellets and liquid application.

Composite feed samples from each diet were taken at the time of mixing each feed batch as well as at the time of each feed phase change at the mill site. The samples

**TABLE 2. Formulas and calculated nutrient analysis of diets fed to turkey toms from 1 to 126 d of age (Experiment 2)**

| | Days of age | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0–21 | | 22–42 | | 43–70 | | 71–98 | | 99–126 | |
| Ingredient | 1 & 2 | 3 & 4 | 1 & 2 | 3 & 4 | 1 & 2 | 3 & 4 | 1 & 2 | 3 & 4 | 1 & 2 | 3 & 4 |
| | (% of Diet) | | | | | | | | | |
| Corn | 42.30 | 42.30 | 46.56 | 46.56 | 48.21 | 48.21 | 58.00 | 58.00 | 65.28 | 65.28 |
| Soybean meal (48% CP) | 44.67 | 39.75 | 40.74 | 36.24 | 37.46 | 33.34 | 27.26 | 24.27 | 19.55 | 17.40 |
| Poultry fat | 3.91 | 3.91 | 4.02 | 4.02 | 6.47 | 6.47 | 7.6 | 7.6 | 8.28 | 8.28 |
| Meat-bone meal (50% CP) | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Limestone | 1.18 | 1.18 | 1.06 | 1.06 | 0.91 | 0.91 | 0.70 | 0.70 | 0.73 | 0.73 |
| Dicalcium P (18.5% P) | 1.98 | 1.98 | 1.69 | 1.69 | 1.34 | 1.34 | 0.88 | 0.88 | 0.62 | 0.62 |
| DL-Methionine | 0.27 | 0.27 | 0.29 | 0.29 | 0.06 | 0.06 | 0 | 0 | 0.02 | 0.02 |
| L-Lysine-HCl | 0.09 | 0.09 | 0.06 | 0.06 | 0 | 0 | 0 | 0 | 0 | 0 |
| Salt | 0.35 | 0.35 | 0.35 | 0.35 | 0.30 | 0.30 | 0.31 | 0.31 | 0.27 | 0.27 |
| Mineral premix[2] | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Vitamin premix[2] | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Coban-60[3] | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| Soy hulls | 0 | 4.91 | 0 | 4.48 | 0 | 4.12 | 0 | 3.00 | 0 | 2.15 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Nutrient analysis | | | | | | | | | | |
| Crude protein, % | 28.10 | 27.26 | 26.50 | 25.80 | 25.00 | 24.43 | 21.00 | 20.70 | 18.00 | 17.85 |
| ME (kcal/kg) | 1,325 | 1,292 | 1,350 | 1,319 | 1,425 | 1,393 | 1,500 | 1,475 | 1,550 | 1,531 |
| Crude Fat, % | 6.5 | 6.40 | 6.68 | 6.64 | 9.16 | 9.12 | 10.56 | 10.53 | 11.44 | 11.42 |
| Crude Fiber, % | 2.67 | 4.27 | 2.61 | 4.08 | 2.52 | 3.86 | 2.34 | 3.31 | 2.20 | 2.90 |
| Calcium, % | 1.42 | 1.37 | 1.30 | 1.26 | 1.16 | 1.14 | 0.96 | 0.94 | 0.90 | 0.89 |
| Nonphytate P, % | 0.71 | 0.68 | 0.65 | 0.62 | 0.58 | 0.56 | 0.48 | 0.47 | 0.42 | 0.41 |
| Copper, mg/kg | 12.56 | 12.72 | 12.63 | 12.78 | 12.62 | 12.76 | 12.76 | 12.86 | 12.86 | 12.93 |
| Methionine, % | 0.69 | 0.66 | 0.69 | 0.66 | 0.44 | 0.43 | 0.33 | 0.32 | 0.30 | 0.30 |
| Methionine+cysteine, % | 1.12 | 1.07 | 1.10 | 1.06 | 0.83 | 0.80 | 0.67 | 0.66 | 0.61 | 0.60 |
| Lysine, % | 1.74 | 1.69 | 1.60 | 1.56 | 1.45 | 1.42 | 1.15 | 1.13 | 0.93 | 0.92 |
| Arginine, % | 2.02 | 1.95 | 1.90 | 1.84 | 1.78 | 1.73 | 1.46 | 1.43 | 1.22 | 1.20 |
| Isoleucine, % | 1.38 | 1.33 | 1.30 | 1.26 | 1.22 | 1.18 | 1.00 | 0.98 | 0.84 | 0.83 |
| Sodium, % | 0.20 | 0.19 | 0.20 | 0.19 | 0.18 | 0.17 | 0.18 | 0.17 | 0.16 | 0.16 |

[1]Each pen received one of the following four dietary treatments; 1) soybean meal (SBM) with 48% CP content (SBM-48), 2) SBM-48 plus enzyme (+E), 3) SBM with 44% CP content (SBM-44), or SBM-48+E.

[2]Proprietary vitamin and mineral premixes were formulated to slightly exceed NRC (1994) recommendations and were supplied by ChemGen Corp., Gaithesburg, MD.

[3]Coban-60 (Elanco Animal Health, Indianapolis, IN) provided 92 mg monensin sodium per kilogram of diet.

were analyzed for CP, fat, ash, Ca, and P. Basal feed samples were sent to a commercial laboratory[7] for similar nutrient analysis. Feed samples from all feed batches were also sent to the laboratories of ChemGen Corp.[4] for enzyme analysis.

Body weight and feed consumption were recorded at 21, 42, 70, and 98 d of age. Feed conversion ratio (feed-to-gain; FCR), corrected for mortality and culls, was calculated at coterminous intervals. Mortality and morbidity rates and causes were recorded as they occurred.

## Experiments 2 and 3

The facility used in these experiments was an industry-standard curtain-sided house containing 42 pens in total. Ventilation was provided by positive pressure. Wall fans were used to enhance air exchange. Feed and water were provided ad libitum throughout the study. Incandescent lighting was applied continuously the first week and subsequently by natural length daylight. Warm room brooding with forced-air heaters was provided, and infrared lamps provided supplemental heat during the first week of life. House temperature was kept at 34.5 C during the first week and then gradually decreased weekly by increments of 2.5 to 21 C and maintained until the end of the trial.

Commercial Large White male turkeys[5] were randomly assigned to pens initially stocked with 22 poults at 1 d of age and then adjusted to 17 birds per pen after 28 d of age. Starting at 1 d of age, turkeys were subjected to one of four experimental treatments with seven replicate pens per treatment. The four experimental treatments were the same as in Experiment 1 and were randomly assigned to the pens in each of the two main blocks (Experiments 2 or 3) using the procedures of SAS software (1996). Data were analyzed as a factorial arrangement using ANOVA of SAS software (1996). Five feeding phases were used during the course of this experiment. All feeds were formulated using least-cost linear programming software according to NRC (1994) recommendations (Tables 2 and 3). All feed was pellet-processed and fed in crumble form up to 3 wk of age and subsequently as a whole 5/16 pellet form until the end of the trial. Enzyme application to the feed was the same as in Experiment 1. Composite feed samples from each diet were taken at the time of bagging (out of the mixer- five samples) at the mill site and after bags were placed in pens after each feed change on Days 1, 21, 42,

[7]Woodson Tenent Labs, Inc., Goldston, NC.

**TABLE 3. Formulas and calculated nutrient analysis of diets fed to turkey toms from 1 to 126 d of age (Experiment 3)**

| | Days of age | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0–21 | | 22–42 | | 43–70 | | 71–98 | | 99–126 | |
| | Dietary treatment[1] | | | | | | | | | |
| Ingredient | 1 & 2 | 3 & 4 | 1 & 2 | 3 & 4 | 1 & 2 | 3 & 4 | 1 & 2 | 3 & 4 | 1 & 2 | 3 & 4 |
| | (% of Diet) | | | | | | | | | |
| Corn | 41.93 | 41.93 | 46.02 | 46.02 | 47.60 | 47.60 | 57.06 | 57.06 | 64.08 | 64.08 |
| Soybean meal (48% CP) | 44.74 | 39.82 | 40.96 | 36.41 | 37.80 | 33.64 | 27.84 | 24.78 | 20.36 | 18.12 |
| Poultry fat | 3.77 | 3.77 | 3.90 | 3.90 | 6.36 | 6.36 | 7.51 | 7.51 | 8.23 | 8.23 |
| Meat-bone meal (50% CP) | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Limestone | 1.29 | 1.29 | 1.16 | 1.16 | 1.01 | 1.01 | 0.80 | 0.80 | 0.83 | 0.83 |
| Dicalcium P (18.5% P) | 2.28 | 2.28 | 1.98 | 1.98 | 1.63 | 1.63 | 1.17 | 1.17 | 0.91 | 0.91 |
| DL-methionine | 0.23 | 0.23 | 0.24 | 0.24 | 0.01 | 0.01 | 0 | 0.00 | 0.02 | 0.02 |
| L-Lysine-HCl | 0.12 | 0.12 | 0.09 | 0.09 | 0 | 0 | 0 | 0.00 | 0 | 0 |
| Salt | 0.41 | 0.41 | 0.42 | 0.42 | 0.37 | 0.37 | 0.38 | 0.38 | 0.33 | 0.33 |
| Mineral premix[2] | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Vitamin premix[2] | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Coban-60[3] | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| Soy hulls | 0 | 4.92 | 0 | 4.51 | 0 | 4.16 | 0 | 3.06 | 0 | 2.24 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Nutrient analysis | | | | | | | | | | |
| Crude protein, % | 28.10 | 27.26 | 26.60 | 25.90 | 25.00 | 24.42 | 21.00 | 20.69 | 18.00 | 17.84 |
| ME (kcal/kg) | 1,325 | 1,292 | 1,350 | 1,319 | 1,425 | 1,393 | 1,500 | 1,474 | 1,550 | 1,530 |
| Crude Fat, % | 6.27 | 6.22 | 6.51 | 6.47 | 9.00 | 8.96 | 10.41 | 10.38 | 11.32 | 11.30 |
| Crude Fiber, % | 2.67 | 4.27 | 2.61 | 4.07 | 2.52 | 3.87 | 2.34 | 3.34 | 2.20 | 2.93 |
| Calcium, % | 1.42 | 1.37 | 1.30 | 1.26 | 1.16 | 1.13 | 0.96 | 0.94 | 0.90 | 0.89 |
| Nonphytate P, % | 0.71 | 0.68 | 0.65 | 0.62 | 0.58 | 0.56 | 0.48 | 0.47 | 0.42 | 0.41 |
| Copper, mg/kg | 12.37 | 12.54 | 12.44 | 12.60 | 12.43 | 12.58 | 12.56 | 12.67 | 12.66 | 12.73 |
| Methionine, % | 0.64 | 0.61 | 0.64 | 0.62 | 0.39 | 0.38 | 0.32 | 0.31 | 0.30 | 0.30 |
| Methionine+cysteine, % | 1.12 | 1.07 | 1.10 | 1.06 | 0.83 | 0.80 | 0.72 | 0.70 | 0.66 | 0.65 |
| Lysine, % | 1.74 | 1.69 | 1.60 | 1.56 | 1.43 | 1.40 | 1.14 | 1.12 | 0.92 | 0.91 |
| Arginine, % | 2.02 | 1.95 | 1.90 | 1.84 | 1.80 | 1.75 | 1.48 | 1.45 | 1.24 | 1.23 |
| Isoleucine, % | 1.40 | 1.35 | 1.32 | 1.27 | 1.25 | 1.21 | 1.03 | 1.01 | 0.87 | 0.86 |
| Sodium, % | 0.20 | 0.19 | 0.20 | 0.19 | 0.18 | 0.17 | 0.18 | 0.17 | 0.16 | 0.16 |

[1]Each pen received one of the following four dietary treatments; 1) soybean meal (SBM) with 48% CP content (SBM-48), 2) SBM-48 plus enzyme (+E), 3) SBM with 44% CP content (SBM-44), or SBM-48+E.

[2]Proprietary vitamin and mineral premixes formulated to slightly exceed NRC (1994) recommendations and were supplied by ChemGen Corp., Gaithesburg, MD.

[3]Coban-60 (Elanco Animal Health, Indianapolis, IN) provided 92 mg monensin sodium per kilogram of diet.

70, 98, and 126. Feed samples were sent to Woodson Tenent Labs, Inc.[7] for nutrient analysis and to ChemGen Corp.[4] for enzyme analysis.

Body weight and feed consumption were recorded at Days 21, 42, 70, 98, and 126 (individual BW). Periodic and cumulative FCR were calculated. Mortality and morbidity rates and causes were recorded as they occurred.

## RESULTS AND DISCUSSION

### *Enzyme Activity*

Feed samples from each batch of feed mixed for each feed phase in the three experiments were sent to ChemGen Corp.[4] for enzyme activity analysis. Enzyme activities were determined from each batch of feed in the SBM-48 and SBM-44 diets, respectively, and mean values and variability were determined from these numbers. Results of activity analysis were then used to calculate means and standard deviations. The results (data not shown) indicated that all diets supplemented with the enzyme contained a minimum of 100 MU of Hemicell enzyme activity units/tonne feed. Means ± SD of the enzyme activity (MU of Hemicell enzyme activity/tonne of feed) for all diets combined were 128.2 ± 27.2 and 131.8 ± 32.2 for SBM-48 with enzyme (+E) and SBM-44+E, respectively. Data also indicated that diets not supplemented with the enzyme had very low enzyme activity levels (17.2 ± 11.8 and 13.6 ± 5.4 for SBM-48 and SBM-44, respectively), which could have been due to natural microorganisms present in the feed.

### *Experiment 1*

All birds were weighed on Days 7, 21, 42, 70, and 98 and results are shown in Table 4. There was a significant main effect of SBM on BW of poults through the whole duration of study. Birds fed SBM-48 had significantly ($P < 0.01$) higher body weight than those fed SBM-44 starting Day 7 and through to the end of the experiment. At Day 98, birds fed SBM-48 had 264 g higher BW than those fed the SBM-44 (7.7 kg vs. 7.4 kg, $P < 0.011$). In contrast, there was no significant main effect of enzyme supplementation on BW. However, there was a significant SBM × enzyme interaction at different times of study. The effect was mainly conspicuous upon supplementing the SBM-44 with Hemicell. Supplementing the diet containing SBM-44 with Hemicell resulted in higher BW at 70 d of age (4.5 kg vs. 4.3 kg for SBM-44 vs. SBM-44+E, respectively). However,

**TABLE 4. Body weight[1] (kg) of turkey hens fed 44 or 48% soybean meal (SBM)-based rations with or without supplemental mannan-endo-1,4-$\beta$-mannosidase[2]**

| Treatment | SBM | Enzyme | Day 7 | Day 21 | Day 42 | Day 70 | Day 98 |
|---|---|---|---|---|---|---|---|
| 1 | 48 | – | 0.121 | 0.398 | 1.620 | 4.661 | 7.690 |
| 2 | 48 | + | 0.123 | 0.400 | 1.598 | 4.577 | 7.641 |
| 3 | 44 | – | 0.114 | 0.362 | 1.520 | 4.278 | 7.426 |
| 4 | 44 | + | 0.118 | 0.379 | 1.546 | 4.471 | 7.497 |
| Statistical analysis | | | | | *P*-value | | |
| SBM | | | 0.001 | 0.001 | 0.001 | 0.001 | 0.011 |
| Enzyme | | | 0.106 | 0.089 | 0.733 | 0.104 | 0.779 |
| SBM × enzyme | | | 0.390 | 0.158 | 0.058 | 0.001 | 0.143 |
| SEM (44) [3] | | | 0.002 | 0.005 | 0.013 | 0.034 | 0.041 |

[1]Approximately 30 hen poults per pen, four pens per treatment.

[2]Hemicell was added (+) at 100 million units/tonne or not added (–) to the feed.

[3]Standard error of the mean with 44 degrees of freedom.

at the end of the experiment, the effect of enzyme supplementation was no longer significant (7.4 kg vs. 7.5 kg for SBM-44 vs. SBM-44+E, respectively). Supplementing the SBM-44 diet with Hemicell did improve 98-d BW of birds over those on the SBM-44 alone. However, the BW of birds receiving the SBM+E treatment were still lower than those of birds fed diets containing the SBM-48 without enzyme supplementation (7.497 kg vs. 7.69 kg for SBM-44 + E vs. SBM-48, respectively).

There was a significant main effect of SBM on feed consumption from 7 to 70 d of age (Table 5). Hens fed the SBM-48 consumed more feed than did hens fed the SBM-44 ($P < 0.05$). There were no enzyme, or SBM × enzyme interaction effect observed throughout the whole experiment. Supplementing the diets with the enzyme had no effect on feed consumption, regardless of the SBM type (Table 5).

Calculated FCR is presented in Table 6. There was a significant ($P < 0.05$) main effect of SBM on FCR at 7, 21, and 42 and on the overall cumulative FCR (0 to 98 d of age). Birds receiving the SBM-48 had significantly ($P = 0.013$) better cumulative FCR at 98 d of age compared to those receiving the SBM-44 feed. Mannans are mainly associated with the hull fraction of soybean meal (Reid, 1985). Because hulls are returned to the SBM-48 to produce the SBM-44, the diets formulated with SBM-44 should have higher mannan content. The mannans are suspected to have adverse effects on nutrient digestibility, thus numerically higher FCR was expected when SBM-44 was included in the diet. We recognize, however, the effect of increased dietary mannans and the dilution by hull addition on FCR are confounded in the current experimental design.

There was no main effect of supplementing the feed with enzyme on FCR, but SBM by enzyme interaction was evident. Supplementing the SBM-48 feed with Hemicell had no effect on FCR throughout the experiment, but supplementing the SBM-44 with Hemicell gave better FCR at 7 to 21 d of age (2.23 vs. 2.28 for the SBM-44+E vs. SBM-44, respectively, $P = 0.089$). Dietary Hemicell supplementation apparently improved caloric utilization of SBM-44 by degrading the endo-mannan portion of the fiber.

Mortality was recorded daily (Table 7). There were no significant differences among treatment groups through the whole experiment. Supplementation of the feed with Hemicell did not have any effect on mortality regardless of diet composition.

## Experiments 2 and 3

Experiments 2 and 3 were replicated experiments of identical design in the same facility using turkey toms from the same source, thus data were combined and analyzed as a completely randomized block design. All birds were weighed on Days 21, 42, 70, 98, and 126 (Table 8).



**TABLE 5. Feed consumption (kg/pen)[1] of turkey hens fed 44 or 48% soybean meal (SBM) rations with or without supplemental mannan-endo-1,4-$\beta$-mannosidase[2]**

| Treatment | SBM | Enzyme | 0–7 d | 7–21 d | 21–42 d | 42–70 d | 70–98 d | 0–98 d |
|---|---|---|---|---|---|---|---|---|
| 1 | 48 | – | 2.58 | 17.52 | 55.39 | 166.26 | 243.49 | 485.24 |
| 2 | 48 | + | 2.58 | 17.95 | 55.11 | 171.17 | 241.08 | 487.89 |
| 3 | 44 | – | 2.54 | 16.90 | 53.34 | 158.83 | 240.04 | 471.65 |
| 4 | 44 | + | 2.57 | 17.32 | 54.19 | 162.73 | 236.26 | 473.08 |
| Statistical analysis | | | | | | *P*-value | | |
| SBM | | | 0.689 | 0.008 | 0.001 | 0.009 | 0.160 | 0.007 |
| Enzyme | | | 0.890 | 0.064 | 0.142 | 0.14 | 0.290 | 0.687 |
| SBM × enzyme | | | 0.690 | 0.715 | 0.581 | 0.863 | 0.812 | 0.905 |
| SEM(44)[3] | | | 0.086 | 0.225 | 0.502 | 2.886 | 2.889 | 5.023 |

[1]Approximately 30 hen poults per pen, four pens per treatment.

[2]Hemicell was added (+) at 100 million units/tonne or not added (–) to the feed.

[3]Standard error of the mean with 44 degrees of freedom.

**TABLE 6. Feed conversion[1] ratio of turkey hens fed 44 or 48% soybean meal (SBM)-based rations with or without supplemental mannan-endo-1,4-$\beta$-mannosidase[2]**

| Treatment | SBM | Enzyme | 1–7 d | 7–21 d | 21–42 d | 42–70 d | 70–98 d | 0–98 d |
|---|---|---|---|---|---|---|---|---|
| 1 | 48 | – | 1.226 | 2.110 | 1.526 | 1.860 | 2.743 | 2.155 |
| 2 | 48 | + | 1.196 | 2.164 | 1.546 | 1.936 | 2.790 | 2.205 |
| 3 | 44 | – | 1.338 | 2.279 | 1.583 | 1.973 | 2.747 | 2.234 |
| 4 | 44 | + | 1.271 | 2.227 | 1.593 | 1.903 | 2.816 | 2.212 |
| Statistical analysis | | | *P*-value | | | | | |
| SBM | | | 0.009 | 0.001 | 0.001 | 0.245 | 0.745 | 0.013 |
| Enzyme | | | 0.164 | 0.089 | 0.141 | 0.942 | 0.211 | 0.377 |
| SBM × enzyme | | | 0.589 | 0.158 | 0.581 | 0.036 | 0.814 | 0.034 |
| SEM (44)[3] | | | 0.034 | 0.024 | 0.010 | 0.034 | 0.046 | 0.017 |

[1]Approximately 30 hen poults per pen, four pens per treatment.

[2]Hemicell was added (+) at 100 million units/tonne or not added (–) to the feed.

[3]Standard error of the mean with 44 degrees of freedom.

**TABLE 7. Mortality[1] rate of turkey hens fed 44 or 48% soybean meal (SBM)-based rations with or without supplemental mannan-endo-1,4-$\beta$-mannosidase[2]**

| Treatment | SBM | Enzyme | 1–7 d | 7–21 d | 21–42 d | 42–70 d | 70–98 d | 0–98 d |
|---|---|---|---|---|---|---|---|---|
| 1 | 48 | – | 6.94 | 0.0 | 0.57 | 0.59 | 0.0 | 8.10 |
| 2 | 48 | + | 5.83 | 0.0 | 0.57 | 0.29 | 0.59 | 7.28 |
| 3 | 44 | – | 5.83 | 0.0 | 2.34 | 0.29 | 0.31 | 8.77 |
| 4 | 44 | + | 4.17 | 0.29 | 1.72 | 0.60 | 0.60 | 7.37 |
| Statistical analysis | | | *P*-value | | | | | |
| SBM | | | 0.239 | 0.323 | 0.015 | 0.994 | 0.628 | 0.517 |
| Enzyme | | | 0.155 | 0.323 | 0.799 | 0.994 | 0.170 | 0.632 |
| SBM × enzyme | | | 0.551 | 0.323 | 0.799 | 0.393 | 0.640 | 0.826 |
| SEM (44)[3] | | | 1.49 | 1.44 | 0.567 | 0.345 | 0.316 | 1.834 |

[1]Percentage data were subjected to ANOVA after arcsine square root percentage transformation. The means were separated using least significant difference according to the procedures of SAS software (SAS, Cary, NC).

[2]Hemicell was added (+) at 100 million units/tonne or not added (–) to the feed.

[3]Standard error of the mean with 44 degrees of freedom.

There were significant main effects of SBM and enzyme supplementation on BW throughout the experiments. Up until 42 d of age, BW were significantly heavier ($P < 0.05$) for toms fed the SBM-44 than those fed the SBM-48 diets. However, toms fed the SBM-48 weighed more ($P < 0.05$) than the SBM-44 after 42 d of age (Table 8). In the current experiments, turkey toms seemed to respond to higher fiber content in their diet during the very first few weeks of their lives than at older ages. This finding might explain the better response with the SBM-44 treatments at younger ages than with the SBM-48 treatments. Body weights of toms fed the SBM-44 supplemented with the enzyme in these experiments were marginally lower than that of those fed the SBM-48 with no enzyme supplementation (14.769 kg vs. 14.914 kg for the SBM-44+E vs. the SBM-48, respectively, $P = 0.0866$).

There was a significant ($P < 0.05$) experiment main effect on BW through to the end of the study, except at Day 70 ($P = 0.1828$, Table 8). Regardless of treatment, birds in Experiment 2 were heavier than birds in Experiment 3

**TABLE 8. Body weight (kg) of turkey toms fed 44 or 48% soybean meal (SBM)-based rations with or without supplemental mannan-endo-1,4-$\beta$-mannosidase[1]**

| Treatment | SBM | Enzyme | Day 21 | Day 42 | Day 70 | Day 98 | Day 126 |
|---|---|---|---|---|---|---|---|
| 1 | 48 | – | 0.625 | 2.042 | 6.223 | 10.535 | 14.914 |
| 2 | 48 | + | 0.646 | 2.067 | 6.317 | 10.281 | 15.030 |
| 3 | 44 | – | 0.654 | 2.090 | 5.746 | 10.194 | 14.398 |
| 4 | 44 | + | 0.675 | 2.125 | 6.221 | 10.411 | 14.768 |
| Statistical analysis | | | *P*-value | | | | |
| Experiment[2] | | | 0.0001 | 0.0001 | 0.1828 | 0.0001 | 0.0027 |
| SBM | | | 0.0001 | 0.0004 | 0.1008 | 0.0001 | 0.0001 |
| Enzyme | | | 0.0001 | 0.0386 | 0.1039 | 0.0220 | 0.0016 |
| SBM × enzyme | | | 0.9042 | 0.7733 | 0.2734 | 0.3517 | 0.0866 |
| SEM (51)[3] | | | 0.008 | 0.031 | 0.378 | 0.144 | 0.160 |

[1]Hemicell was added (+) at 100 million units/tonne or not added (–) to the feed.

[2]Two statistically identical experiments. Each experiment had seven replicate pens of 17 birds per treatment.

[3]Standard error of the mean with 44 degrees of freedom.

**TABLE 9. Feed consumption (kg/bird) of turkey toms fed diets containing 44% CP or 48% CP soybean meal (SBM) with or without supplemental mannan-endo-1,4-$\beta$-mannosidase[1]**

| Treatment | SBM | Enzyme | Day 21 | Day 42 | Day 70 | Day 98 | Day 126 |
|---|---|---|---|---|---|---|---|
| 1 | 48 | – | 0.80 | 3.39 | 11.76 | 23.89 | 41.65 |
| 2 | 48 | + | 0.81 | 3.32 | 11.77 | 23.62 | 41.00 |
| 3 | 44 | – | 0.80 | 3.37 | 12.03 | 24.11 | 41.81 |
| 4 | 44 | + | 0.81 | 3.37 | 11.93 | 23.72 | 41.25 |
| Statistical analysis | | | | | *P*-value | | |
| Experiment[2] | | | 0.8796 | 0.0001 | 0.0030 | 0.0039 | 0.6520 |
| SBM | | | 0.6438 | 0.5105 | 0.0625 | 0.4478 | 0.4827 |
| Enzyme | | | 0.1059 | 0.2146 | 0.6888 | 0.1130 | 0.0468 |
| SBM × enzyme | | | 0.8762 | 0.2320 | 0.6209 | 0.7776 | 0.8748 |
| SEM (51)[3] | | | 0.011 | 0.058 | 0.243 | 0.458 | 0.651 |

[1]Hemicell was added (+) at 100 million units/tonne or not added (–) to the feed.

[2]Two statistically identical experiments. Each experiment had seven replicate pens of 17 birds per treatment.

[3]Standard error of the mean with 51 degrees of freedom.

through 70 d of age (70 d BW = 6.243 kg vs. 6.172 kg for Experiment 2 vs. Experiment 3, respectively, $P < 0.05$). Subsequent to 70 d, however, birds in Experiment 3 became heavier than birds in Experiment 2 (126 d BW = 14.9 vs. 14.7 kg for Experiment 3 vs. Experiment 2, respectively, $P < 0.05$). The starting date of Experiment 2 was March 7, whereas that of Experiment 3 was August 22. Because the experiments were started in a relatively warm season (spring, Experiment 2) and a hot season (summer, Experiment 3), birds were expected to grow better for the first few weeks of their lives under less stress (i.e., Experiment 2). However, because the birds in Experiment 2 approached market weight in late spring-early summer (July 11), their risk of being exposed to heat stress was greater than birds in Experiment 3, which approached market weight during the cooler season (late fall, experiment terminated on December 26). This result might explain, in part, why all birds in Experiment 3 had a slightly higher final BW than those in Experiment 2.

Feed consumption data are presented in Table 9. There were no significant treatment effects on feed consumption through the end of the experiment. Feed conversion ratios were calculated and presented in Table 10. Treatment effects on FCR were due to differences in BW gain rather than differences in feed consumption. There was a significant ($P < 0.05$) main effect of SBM on FCR from the beginning and through to the end of the study. As with BW, turkey toms responded favorably to the SBM-44, resulting in significantly lower ($P < 0.05$) FCR through to 70 d of age. Subsequently, this trend changed such that birds fed the SBM-44 diet had higher FCR than those fed the SBM-48 diet. The SBM-44 is basically SBM-48 + soy hulls. Therefore, it contains more fiber than the SBM-48 (6.5 vs. 3.0% for SBM-44 vs. SBM-48, respectively). Feeding the SBM-44 to turkey toms in these experiments did give a significantly ($P < 0.05$) lower FCR than the SBM-48 through to 70 d of age, which might indicate that turkey toms need more dietary fiber when they are young than when they are older.

There was a significant main effect of enzyme supplementation on FCR at all periods except at 70 d of age. Supplementing both SBM-type diets with Hemicell did improve the FCR ratio ($P < 0.05$), although positive effect was greater in the SBM-44 diet (Table 10). It is noteworthy that, supplementing the SBM-44 with Hemicell improved the FCR of toms to the level of feeding the SBM-48 with no enzyme supplementation (2.695 vs. 2.704 for the SBM-44+E vs. SBM-48, respectively). There may be an economic advantage to feed turkey toms the SBM-44 diet supplemented with $\beta$-mannanase enzyme over feeding the SBM-48 diet alone. Caloric density of the diets may influence this economic advantage.

**TABLE 10. Feed conversion of turkey toms fed diets containing 44% CP or 48% CP soybean meal (SBM) with or without supplemental mannan-endo-1,4-$\beta$-mannosidase[1]**

| Treatment | SBM | Enzyme | 1–21 d | 1–42 d | 1–70 d | 1–98 d | 1–126 d |
|---|---|---|---|---|---|---|---|
| 1 | 48 | – | 1.260 | 1.597 | 1.827 | 2.117 | 2.704 |
| 2 | 48 | + | 1.239 | 1.553 | 1.861 | 2.145 | 2.633 |
| 3 | 44 | – | 1.216 | 1.561 | 1.781 | 2.259 | 2.794 |
| 4 | 44 | + | 1.195 | 1.528 | 1.815 | 2.194 | 2.695 |
| Statistical analysis | | | | | *P*-value | | |
| Experiment[2] | | | 0.0001 | 0.0001 | 0.0086 | 0.1605 | 0.2317 |
| SBM | | | 0.0001 | 0.0001 | 0.0001 | 0.0127 | 0.0001 |
| Enzyme | | | 0.0047 | 0.0001 | 0.0007 | 0.6132 | 0.0001 |
| SBM × enzyme | | | 0.9536 | 0.4605 | 0.9881 | 0.2173 | 0.2409 |
| SEM (51)[3] | | | 0.007 | 0.007 | 0.010 | 0.037 | 0.012 |

[1]Hemicell was added (+) at 100 million units/tonne or not added (–) to the feed.

[2]Two statistically identical experiments. Each experiment had seven replicate pens of 17 birds per treatment.

[3]Standard error of the mean with 44 degrees of freedom.

**TABLE 11. Mortality[1] rate of turkey toms fed diets containing 44% CP or 48% CP soybean meal (SBM) rations with or without supplemental mannan-endo-1,4-β-mannosidase[2]**

| Treatment | SBM | Enzyme | 1–21 d | 1–42 d | 1–70 d | 1–98 d | 1–126 d |
|---|---|---|---|---|---|---|---|
| 1 | 48 | – | 7.25 | 7.24 | 7.70 | 8.08 | 8.08 |
| 2 | 48 | + | 5.30 | 4.22 | 4.64 | 4.64 | 5.06 |
| 3 | 44 | – | 2.68 | 1.62 | 2.88 | 2.88 | 2.88 |
| 4 | 44 | + | 3.96 | 3.90 | 4.32 | 4.32 | 4.74 |
| Statistical analysis | | | | | *P*-value | | |
| Experiment[3] | | | 0.2659 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| SBM | | | 0.0661 | 0.0489 | 0.1061 | 0.0804 | 0.0861 |
| Enzyme | | | 0.8336 | 0.8011 | 0.6112 | 0.5198 | 0.7132 |
| SBM × enzyme | | | 0.3101 | 0.0783 | 0.1573 | 0.1217 | 0.1287 |
| SEM (51)[4] | | | 1.58 | 1.47 | 1.55 | 1.55 | 1.58 |

[1]Percentage data were subjected to ANOVA after arcsine square root percentage transformation. The means were separated using least significant difference according to the procedures of SAS software (SAS, Cary, NC).

[2]Hemicell was added (+) at 100 million units/tonne or not added (–) to the feed.

[3]Two statistically identical experiments. Each experiment had seven replicate pens of 17 birds per treatment.

[4]Standard error of the mean with 44 degrees of freedom.

Overall mortality rate was within industry standards for Experiment 2. However, mortality rate for Experiment 3 was very low. Mortality rate was 12 and 3% for Experiments 2 and 3, respectively. There were no significant differences among all treatment groups throughout the study period (Table 11).

The results of the three experiments reported herein indicate that dietary replacement of SBM-44 in place of the SBM-48 (wt/wt) significantly reduced market weight and overall feed efficiency in turkeys. The effect in toms was more pronounced after 3 wk of age through market age, whereas the effect in hens was clear throughout the experiment.

These experiments also showed remarkable positive effects of dietary supplementation of turkey feed with β-mannanase (Hemicell at 100 MU/tonne) on turkey performance. Dietary Hemicell supplementation generally improved performance in all birds, with a greater response in birds fed the SBM-44. The results however, cannot be explained only by improvement in dietary energy available from β-galactomannans after β-mannanase supplementation. The β-galacto-mannan content of soybean meal is less than 1.5% (D. W. Fodge, 1999, personal communication) and only about 0.4% in the complete diets (Jackson et al., 1999). Degrading this small quantity by enzyme supplementation could not produce as much improvement as observed in this study.

The mode of action of β-mannanase is very complicated (McNaughton et al., 1998; Jackson et al., 1999). It has been observed that β-galacto-mannan inhibits insulin secretion in humans (Morgan et al., 1985) and swine (Leeds et al., 1980; Sambrook and Rainbird, 1985). β-Mannans have also been shown to reduce glucose and water absorption in swine (Rainbird et al., 1984). Jackson et al. (1999) hypothesized the positive effect of β-mannanase on layer hen performance was due to the stimulation of insulin secretion by β-mannanase or the blocking of the inhibitory function of β-galacto-mannan on glucose absorption. The increase in insulin secretion could explain the stimulation in feed intake and a corresponding increase in egg production observed in the study of Jackson et al. (1999). Similarly, McNaughton et al. (1998) reported that the adventitious inclusion of β-mannanase into broiler diets may improve feed efficiency by a similar complex mechanism as hypothesized by Jackson et al. (1999). In contrast, we did not observe a significant increase in feed consumption upon supplementing the feed with β-mannanase.

It is more likely that the β-mannans had adverse effects on the digestive system mainly due to their highly viscous nature. These adverse effects were apparently relieved by β-mannanase degradation of this polysaccharide β-mannan. Viscosity reduction achieved by endolytic enzyme activity is hypothesized to be responsible for the majority of the improvement observed in young birds fed high-viscosity cereals (Rotter et al., 1989, 1990). The ingestion of viscous polysaccharides may produce hyperplasia and hypertrophia of digestive organs and increase the secretion of pancreatic juice (Ikegami et al., 1990), which increase energy demand of the gut.

The economic feasibility of the use of β-mannanase to improve growth performance is dependent on the cost of feed calories. In our experiment, supplementing the SBM-44 with β-mannanase at 100 MU/tonne was more economical than feeding turkeys the SBM-48 (data not shown). A significant ($P < 0.05$) improvement in feed efficiency by supplementing diets containing SBM-44 with β-mannanase is of economical value, even with no effect on BW.

In conclusion, Hemicell (endo-1,4-β-mannosidase) can alleviate some of the adverse effects of antinutritional factors of SBM on turkey growth performance and enhance the nutritional value of the less expensive SBM-44.

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