

## Metabolism and Nutrition IV: Vitamins and Minerals and Feed Manufacturing

**155 Effect of source and level of trace minerals on performance and eggshell quality.** M. Daley\*<sup>1</sup>, A. E. Sefton<sup>2</sup>, and S. Leeson<sup>1</sup>, <sup>1</sup>University of Guelph, Guelph, ON, Canada, <sup>2</sup>Alltech Canada Inc., Guelph, ON, Canada.

Research on which NRC trace mineral requirements are based was done with inorganic transitional minerals and purified and semi-purified diets. Research with organic trace minerals and standard rations have demonstrated that requirements are much lower than the levels set by NRC, due to the greater availability of these organic minerals. Further, not all organic minerals are the same. Pullets from day-old through a laying cycle were fed diets with conventional inorganic minerals at conventional levels or reduced trace mineral, either as inorganic trace mineral or organic trace minerals (Bioplex<sup>®</sup> and Sel-Plex<sup>®</sup>, Alltech, Inc. Lexington, KY). Standard production parameters were recorded. Shell defects, were investigated using optical and electron microscopy. Diet had no effect on pullet growth up to 133 days of age or on average feed intake in the growing phase. Egg production was not significantly affected. Egg weight was significantly reduced in the 4th, 28 day lay period by both reduced mineral levels; in the subsequent periods the conventional mineral levels were significantly different with the Bioplex/Sel-Plex reduced level being intermediate and not different from either conventional level. Both zinc and manganese levels in the reduced supplement rations were lower in the excreta due to the lower supplement levels; copper and iron were not. This failure to influence copper and iron excretion levels is due to the relatively high endogenous level of these minerals in the basal ration. Level and source influenced shell quality. The number of mottled eggs was not influenced by mineral source or level, while the degree of mottling decreased when organic minerals were used. Streaked eggs (very fine crack-like defects) were not influenced by level or source of minerals.

**Key Words:** shell quality, trace minerals, organic minerals

**156 Tissue lipid and vitamin E status of broiler chicks: Effect of in ovo feeding of vitamin E.** T. Schaal\* and G. Cherian, Oregon State University, Corvallis.

In ovo feeding of vitamin E during incubation may enhance tissue lipid and polyunsaturated fatty acid content by altering the antioxidant status of the broiler chicken embryo during development. This hypothesis was evaluated with Cobb broiler breeder eggs receiving in ovo feeding of 10 or 20 IU of vitamin E on day 14 of incubation. Two treatments were injected with 10 µL of vegetable oil or not injected to act as controls. At hatch, body weights for all chicks were recorded and 6 chicks per treatment were sampled to determine tissue weight, vitamin E, total lipids, and fatty acid content. Tissues selected were liver, heart, brain, yolk sac, and blood plasma. These tissues were selected due to their respective roles in lipid assimilation (liver), as a major oxidation site (heart), as a site enriched with long chain polyunsaturates for function (brain), as a storage depot (yolk sac), and as a marker (blood plasma). No difference was observed in body weight, liver, heart, or yolk sac weight of chicks ( $P > 0.05$ ). The brain weight as percent of body weight was higher in vitamin E-injected chicks compared to noninjected chicks ( $P < 0.05$ ). In ovo feeding of vitamin E increased the brain total lipids and vitamin E compared to control chicks ( $P < 0.05$ ). In ovo feeding of 20 IU vitamin E led to a significant increase in yolk sac vitamin E

content ( $P < 0.05$ ). No difference was found between the total lipid or vitamin E content of liver, heart, or blood plasma of in ovo vitamin E-injected compared with noninjected chicks ( $P > 0.05$ ). Polyunsaturated fatty acid concentrations were not affected by in ovo injection of vitamin E. Hatchability of fertile eggs was 90% for vitamin E injected and noninjected eggs. The results of this experiment demonstrate that in ovo feeding of vitamin E may enhance brain tissue lipids and the antioxidant status of hatched chicks.

**Key Words:** in ovo feeding, vitamin E, polyunsaturated fatty acid

**157 Vitamin E and selenium supplementation in laying hens.** A. A. Aljamal\*, M. K. Masa'deh, and S. E. Scheideler, University of Nebraska, Lincoln.

The objective of this study was to assess the effect of dietary Vit E and selenium (Se) level and source on egg production parameters. A total of 432 White Bovan hens were fed the experimental diets for 25 weeks from 25 to 50 wk of age. Three levels of Vit E (0, 50, 100 IU/kg diet), 3 levels supplemental Se (0, 0.25, 0.50 ppm), and 2 sources of Se (SelPlex, Na Selenite) were combined in a factorial design and added to a corn-soybean meal basal diet. Feed intake and egg production were measured daily. Egg weights were done weekly on 1 days egg production. Specific gravity, Haugh unit, aged and fresh albumen and yolk pH were measured biweekly. Hens were weighed every 4 weeks. Four eggs from each treatment were taken 3 times throughout the experiment to determine  $\alpha$ -tocopherol content in yolks. Feed intake increased linearly at higher Se levels. Hens fed Selenite had significantly greater feed intake than those fed SelPlex ( $P < 0.05$ ). Supplementation with 50 IU/kg produced greater feed intake ( $P < 0.05$ ) than the other 2 levels of Vit E. When supplementing the hens either with 50 or 100 IU/kg Vit E, egg production was maximized. Supplementing 0.5 ppm Se in the diet regardless of the Se source, gave the highest egg production ( $P < 0.05$ ). Egg weight linearly increased with increasing the level of Vit E in the diet ( $P < 0.05$ ). Source of Se had no effect on egg specific gravity, but higher levels of Se (0.5 ppm) resulted in the highest specific gravity ( $P < 0.05$ ). A significantly higher Haugh unit was found in eggs from hens supplemented with SelPlex ( $P < 0.05$ ). Fresh yolk pH also increased linearly with increasing Se level in the diet ( $P < 0.05$ ). Whereas fresh albumen pH significantly decreased when using SelPlex in the hens' diet ( $P < 0.05$ ). The  $\alpha$ -tocopherol in yolks increased linearly by increasing Vit E in diet ( $P < 0.05$ ). In summary, when including the highest level of Vit E (100 IU/kg) in the diet of laying hens, the quality of eggs is enhanced significantly. Egg production, feed intake, and specific gravity are significantly increased with increasing level of Se in the hens' diet.

**Key Words:** laying hens, SelPlex, egg production

**158 Inadequate vitamin A during development increases bur-sacocyte apoptosis in chicks.** K. A. Livingston\* and K. C. Klasing, University of California, Davis.

Vitamin A has been shown to facilitate peripheral B-cell maturation, but its role during B-cell development is unclear. We used a 2-generation

model where HyLine W36 hens were fed diets that contained either 2,100, 3,000, or 3,900 IU/kg of vitamin A. Chicks hatched from eggs with 0.95 µg retinol/g egg yolk were fed 1,050 IU/kg of vitamin A, those from eggs with 1.29 µg retinol/g yolk were fed diets that contained 1,500 IU/kg of vitamin A, and those hatched from eggs with 1.66 µg retinol/g yolk were fed 1,950 IU/kg of vitamin A. At 7, 14, and 21 d of age the bursa of Fabricius was collected and relative mRNA expression for activation-induced cytidine deaminase (AID) and Bu-1 was measured. AID and Bu-1 expression was significantly depressed in chicks with inadequate vitamin A at 7 d of age ( $P < 0.02$ ). Next bursocytes were isolated and stained with annexin V to determine the amount of apoptosis. When compared to bursocytes isolated from adequately fed chicks, bursocytes from chicks fed inadequate vitamin A had significantly higher amount of apoptosis at 7 and 11 d of age ( $P < 0.02$ ); however, neither total IgM nor IgG were different among dietary treatments. In conclusion, inadequate vitamin A during bursocyte development increases apoptosis, which leads to a decrease in AID expression.

**Key Words:** activation-induced cytidine deaminase, apoptosis, vitamin A

**159 Deposition of and performance responses to Zn from 3 organic sources fed to broiler chickens in the presence of cotton seed hull diets containing gossypol.** M. D. Sims\*<sup>1</sup> and M. J. de Veth<sup>2</sup>, <sup>1</sup>Virginia Diversified Research Corp., Harrisonburg, VA, <sup>2</sup>Balchem Corp., New Hampton, NY.

A 42 d, 48 pen study was conducted to determine Zn deposition and response of broilers fed diets supplemented with different Zn sources in the presence of gossypol, a trace mineral antagonist found in cottonseed hulls (CSH). On this study were 3 organic Zn groups: Keyshure Zn<sup>®</sup> (KeyZn), Availa-Zn 40<sup>®</sup> (AvZn) and Mintrex<sup>®</sup> (MinZn); 2 inorganic Zn (from ZnSO<sub>4</sub>) groups: inorganic Zn in both a CSH diet (CSH+Zn) and non-CSH diet (CON+Zn); and a CSH group with no added Zn (CSH-Zn). Nutritionally similar (cr. protein = 20%; ME = 1,400 kcal/lb; cr. Fat = 9.9%) corn/soy based diets were used in all groups. Diets of the 3 organic Zn, CSH-Zn and CSH+Zn groups included 10% CSH. Straight-run, Cobb × Ross, 1-day-old broilers (n = 1,200) were placed 25/pen at 0d. Broilers were weighed (BW) on 0, 28, and 42 d and feed intake documented through 28 and 42d. Femurs were harvested at 28 and 42d for determination of bone Zn levels (BZL). BW at 42 d of KeyZn (1.90 kg) and CON+Zn (1.93 kg) were not different ( $P > 0.05$ ) while both were heavier ( $P \leq 0.05$ ) than MinZn (1.76 Kg) and AvZn (1.80 Kg). BW at 42 d for CSH-Zn (1.65 kg) and CSH+Zn (1.68 kg) were the lightest ( $P \leq 0.05$ ) in this study. Mortality adjusted feed conversions (AFCR) at 42 d for CON+Zn (1.66 kg/kg) and KeyZn (1.69 kg/kg) were similar ( $P > 0.05$ ) while better ( $P \leq 0.05$ ) than all other groups with CSH-Zn (1.93 kg/kg) inferior ( $P \leq 0.05$ ) to all groups. BZL at 28 d showed: CON+Zn (176 ppm) having highest ( $P \leq 0.05$ ); CSH+Zn (159 ppm) and AvZn (165 ppm) similar ( $P > 0.05$ ); MinZn (143 ppm) lower ( $P \leq 0.05$ ) than CSH+Zn and AvZn; and KeyZn (155 ppm) similar ( $P > 0.05$ ) to AvZn, CSH+Zn and MinZn. BZL at 42 d showed: CSH-Zn (99.94 ppm) as lowest ( $P \leq 0.05$ ) on study; and CON+Zn (121 ppm), CSH+Zn (111 ppm), KeyZn (116 ppm), MinZn (113 ppm) and AvZn (113 ppm) similar ( $P > 0.05$ ). Data show that broilers fed organic Zn in CSH diets had greater 28 d bone Zn levels and heavier 42-d body weights than broilers fed inorganic Zn in CSH diets.

**Key Words:** broilers, organic trace minerals, zinc

**160 The effect of dietary supplementation on egg vitamin content.** M. L. Johnson\* and D. R. Korver, University of Alberta, Edmonton, AB, Canada.

Nutrients are deposited into eggs by hens to allow growth of the embryo should the egg be fertilized. Eggs produced for consumption are usually not fertilized, but may contain a significant proportion of the recommended daily intake of various vitamins for humans. The egg content of several vitamins can be manipulated with relative ease. A laying hen vitamin premix was developed with the intention of increasing the vitamin content of eggs relative to a control premix. The control and experimental diets contained the following levels of supplemental vitamins: A, 11,600 or 23,200 IU/kg; E, 36 or 91 IU/kg; menadione, 1.8 or 11.8 mg/kg; folic acid, 1.4 or 4.4 mg/kg; B<sub>12</sub>, 16 or 116 mg/kg; riboflavin, 8 or 48 mg/kg; pantothenic acid, 16 or 76 mg/kg; thiamine, 2.4 or 11.4 mg/kg; and biotin, 200 or 450 mg/kg, respectively. Vitamin D (3,760 IU/kg), niacin (80 mg/kg) and pyridoxine (4.0 mg/kg) levels were the same in both diets. Each diet was fed to a commercial flock of laying hens. Feed samples and eggs were collected from both flocks at 6 weeks of supplementation and analyzed for levels of the following vitamins: A, E, K, B<sub>12</sub>, folacin, riboflavin, pantothenic acid, and thiamin. Egg vitamin concentrations were analyzed using ANOVA using the General Linear Models procedure of SAS. Differences were considered significant at  $P < 0.05$ . Average vitamin contents (µg/60 g egg unless otherwise noted) of the control eggs were: vitamins A, 464 IU/egg; E, 2.19 IU/egg; B<sub>12</sub>, 0.72; folic acid, 28.31; riboflavin, 204; thiamin, 239; and pantothenic acid, 842. We found increased egg concentrations of vitamins A (34.65%), E (135.67%), B<sub>12</sub> (28.1%), thiamin (65.4%), folic acid (59.5%), riboflavin (36.3%), and pantothenic acid (111.4%) relative to the control eggs, whereas vitamin K concentrations were not increased. The enriched eggs could be claimed to be an excellent source of vitamins E, B<sub>12</sub> and thiamin; and a good source of vitamin A, folic acid, riboflavin, and pantothenic acid according to the Food and Drug regulations of the Canadian Food Inspection Agency.

**Key Words:** laying hens, egg enrichment, vitamins

**161 A dose titration comparison of Mintrex<sup>®</sup> Zn versus ZnSO<sub>4</sub> on performance in broilers with high dietary Cu supplementation.** J. Zhao\*, R. B. Shirley, T. R. Hampton, J. D. Richards, R. J. Harrell, J. J. Dibner, P. Winkelbauer, C. D. Knight, M. Vazquez-Anon, and A. F. Giesen, Novus International Inc, St. Charles, MO.

High dietary Cu is used in commercial broiler diets as a growth promoter and may antagonize Zn utilization. The objective of this study was to compare the dose response of ZnSO<sub>4</sub> and Mintrex<sup>®</sup> Zn on growth performance and tibia Zn in broilers supplemented with 250 ppm dietary Cu. A total of 576 ROSS 308 male chicks were allotted to 8 experimental treatments with 6 replicate cages per treatment and 12 birds per cage. All birds were fed a semi-purified Zn deficient basal diet (5.5 ppm) for the first week, and then were fed the experimental Zn diets for 2 weeks. The dietary treatments were: ZnSO<sub>4</sub> or Mintrex<sup>®</sup> Zn added to the basal diet at levels of 30, 45, 60, and 75 ppm. Weight gain, feed intake, and tibia Zn increased with higher Zn (dose,  $P < 0.001$ ), and feed conversion decreased with increased Zn (dose,  $P < 0.004$ ). Compared to ZnSO<sub>4</sub>, birds fed Mintrex<sup>®</sup> were heavier, had higher feed intake and lower feed conversion (source,  $P < 0.01$ ) and the benefits of Mintrex<sup>®</sup> were more profound at lower Zn supplementation (dose × source,  $P < 0.02$ ). Final body weights were 406 and 468 g at 30 ppm, and 488 and 519 g at 45 ppm for ZnSO<sub>4</sub> and Mintrex<sup>®</sup>, respectively (dose × source,  $P < 0.02$ ).

Feed intakes were 455 and 528 at 30 ppm, and 550 and 572 g at 45 ppm for ZnSO<sub>4</sub> and Mintrex<sup>®</sup>, respectively (dose × source,  $P < 0.002$ ). No differences were observed on tibia Zn or mortality between Zn sources ( $P > 0.05$ ). Birds fed Mintrex<sup>®</sup> had improved performance compared to birds fed ZnSO<sub>4</sub> with 250 ppm CuSO<sub>4</sub>. The benefits of Mintrex<sup>®</sup> were more apparent at lower dietary Zn levels and less Mintrex<sup>®</sup> than ZnSO<sub>4</sub> is required to achieve similar performance.

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**Key Words:** copper, Mintrex Zn, broiler

**162 Benefits of an organic trace mineral on performance with dietary Cu antagonism in broilers.** J. Zhao\*, R. B. Shirley, T. R. Hampton, J. D. Richards, R. J. Harrell, J. J. Dibner, C. D. Knight, and M. Vazquez-Anon, *Novus International, Inc., St. Charles, MO*.

The objective of this study was to investigate the potential antagonism of high dietary Cu between 2 sources of Zn on performance and tibia Zn levels in broilers. A total of 288 ROSS 308 male chicks were divided into 4 experimental treatments with 6 replicate cages per treatment and 12 birds per cage. All birds were fed a common semi-purified Zn deficient diet (5.5 ppm) for the first week and then were offered their respective experimental Zn diets for 14 days. The trial was a 2 × 2 factorial design with 2 levels of Cu (10 vs. 250 ppm CuSO<sub>4</sub>) and 2 Zn sources at 30 ppm (ZnSO<sub>4</sub> vs. Mintrex<sup>®</sup>). Significant 2-way interactions of Cu level and Zn source were observed on body weight, weight gain and performance index ( $P < 0.05$ ). Weight gain was decreased 14% with 250ppm Cu supplementation in ZnSO<sub>4</sub> groups (382 vs. 328 ± 7 g), but not in Mintrex<sup>®</sup> groups (404 vs. 390 ± 7 g). Similar results were observed on final body weight: where high dietary Cu reduced final body weight in ZnSO<sub>4</sub> groups (465 vs. 407 ± 8 g) but not in Mintrex<sup>®</sup> groups (481 vs. 467 ± 8 g). Feed intake was increased 12% with Mintrex<sup>®</sup> ( $P = 0.001$ ) and decreased 11% with 250 ppm Cu supplementation ( $P = 0.005$ ). No interaction was observed between Cu level and Zn source on feed intake ( $P = 0.33$ ). Feed conversion, mortality, and tibia Zn were not affected with dietary treatments ( $P > 0.05$ ). In summary, Mintrex<sup>®</sup> improved weight gain and feed intake when compared to ZnSO<sub>4</sub> in broilers and the magnitude of the response over ZnSO<sub>4</sub> was higher when Cu was supplemented at 250ppm. High Cu is an effective antagonism on Zn utilization, and Mintrex<sup>®</sup> Zn is more effective than ZnSO<sub>4</sub> at overcoming high Cu supplementation.

Mintrex<sup>®</sup> is a trademark of Novus International, Inc. and is registered in the United States and other countries.

**Key Words:** zinc, copper, broiler

**163 Mintrex<sup>®</sup> organic trace minerals are more bioavailable and support the antioxidant response more than other trace mineral forms.** J. D. Richards\*, C. A. Atwell, P. Winkelbauer, C. W. Wueling, M. E. Wehmeyer, and J. J. Dibner, *Novus International, Inc., St. Charles, MO*.

Zinc, copper and manganese play a wide variety of biochemical roles in the cells and tissues of an animal. One of their functions is to reduce oxidative stress, partly by acting as cofactors to antioxidant enzymes such as superoxide dismutase. High oxidative stress induces damage

to lipids, proteins, and nucleic acids, and can lead to high rates of cell death. Trace minerals are generally supplemented as inorganic trace mineral (ITM) salts such as sulfates and oxides. However, trace mineral chelates, or organic trace minerals (OTM), can be more bioavailable and thus more functional than ITMs. We tested the relative bioavailability of several trace mineral forms, as well as the ability of these minerals to reduce oxidative stress in a 29 day broiler experiment. The experiment had 4 treatments (negative control, or the control supplemented with an additional 30 ppm Zn, 20 ppm Mn and 5 ppm Cu as ITM, amino acid complexes (AAC), or Mintrex Organic Trace Minerals). There were 12 replicates per treatment with 13 Ross 308 males per cage. Birds were vaccinated for coccidiosis on day 10. There were no differences between supplemental treatments with respect to body weight, gain, feed conversion, or feed intake at day 29, although all were superior to the control birds in performance. Tibias were measured for Zn and Mn on days 7, 14, 22, 24, and 29. Bone Mn levels fell significantly over time across treatments. Across time all supplemented treatments exhibited numerically or significantly greater tibia manganese and tibia zinc than control. Birds fed Mintrex exhibited significantly or numerically higher tibia Mn and Zn than all other treatments. As an indicator of oxidative stress, lipid hydroperoxide (LPO) levels in plasma were measured on day 29. There was no difference in plasma LPO levels in control, ITM or AAC birds. Birds fed diets containing Mintrex exhibited significantly lower LPO levels than all other treatments, indicating lower oxidative stress in these birds. Mintrex<sup>®</sup> is a trademark of Novus International, Inc., and is registered in the United States and other countries

**Key Words:** Mintrex, bioavailability, oxidative stress

**164 Se contents of eggs from broiler breeders fed Se from selenite or Zn-L-Se-methionine.** R. N. Reis<sup>1</sup>, S. L. Vieira\*<sup>1</sup>, P. C. Nascimento<sup>2</sup>, D. M. Freitas<sup>1</sup>, and R. Barros<sup>1</sup>, <sup>1</sup>UFRGS, Porto Alegre, RS, Brazil, <sup>2</sup>UFMS, Santa Maria, RS, Brazil.

This study evaluated sources and levels of Se supplemented into broiler breeder diets and the effects on Se concentration in the white + yolk fractions of eggs. Fifty Cobb 500 hens 22 wk of age were weighed and selected prior to placement. Each bird was individually placed in a wire laying hen cage, 0.33 cm wide × 46 cm deep × 0.40 cm high. Hens were fed a basal diet w/o Se supplementation to 25 wk and then were given 5 treatments with 10 replications each were composed of sodium selenite (inorganic) and Zn-L-Se-methionine (organic; Availa<sup>®</sup> Se, Zinpro Corporation). Both were supplemented on a corn-soybean meal basal diet as follows: T1) 0.15% inorganic; T2) 0.30% inorganic; T3) 0.15% organic; T4) 0.30% organic; T5) 0.15% inorganic and 0.15% organic. Two birds of each treatment were maintained aside in individual cages and in the same house to replace mortality. Egg production and egg weight were daily recorded whereas specific gravity was done twice a week toward the end of the study. Egg white + yolk fractions were stored frozen (-18°C) as a pool of 2 hens for two 4-week periods. Egg contents were mixed after the end of each period. Samples were analyzed for Se content using graphite furnace atomic absorption spectrometry. A one-way ANOVA was conducted on the egg production and Se contents and means were separated using Tukey at 5%. In the first period egg production was reduced for T2 and w/o difference in the second period. Egg weight and specific gravity were not different in any period. Se content of eggs was higher when hens were fed 0.30% organic Se compared to the other treatments in both periods, but supplementing 0.30% Se from both sources led to a similar content in the second period. It is concluded that Se contents in egg white + yolk resemble the levels

added to the feeds, but deposition from Zn-L-Se methionine was more effective than sodium selenite.

**Key Words:** broiler breeder, selenium, egg

**165 Impact of vitamins and minerals on breeder nutrition.** L. F. Araujo\*<sup>1,2</sup>, C. S. S. Araujo<sup>1</sup>, D. Dumwalt<sup>1</sup>, A. Corzo<sup>1</sup>, C. D. MacDaniel<sup>1</sup>, and M. T. Kidd<sup>1</sup>, <sup>1</sup>Mississippi State University, Starkville, <sup>2</sup>University of Sao Paulo, Pirassununga, SP, Brazil.

The effect of vitamins and minerals supplementation was studied in broiler breeders from 27 to 37 wk of age. Bird performance was assessed in that period and egg weight, incubational egg weight loss and hatch weight were measured at 34 wk of age. Ross 708 breeders received a control diet (vitamin and mineral premix devoid of Se) or diets containing supplemental vitamin B (vitamin B<sub>12</sub>, 60 µg/kg; D-biotin, 500 µg/kg; folic acid, 4 mg/kg; niacin, 80 mg/kg; D-pantothenic acid, 25 mg/kg; vitamin B<sub>6</sub>, 10 mg/kg; riboflavin, 25 mg/kg), vitamin D (1 kg of HyD/ton), and vitamin E 120 IU/kg, the combination of the 3 vitamins, Se (0.3 mg/kg), Zn (30 mg/kg), Mn (40 mg/kg) from organic sources, the combination of the 3 minerals and an additional diet containing combination of all vitamins and minerals. During the laying period from wk 27 to 37, egg production was lower for broiler breeders fed with control diet and supplemental combinations of vitamins B, D, E, compared with the other treatments. Breeders fed with organic manganese provided higher egg weight and incubational egg weight loss at 34 wk of age. However, progeny from breeders fed with vitamins B and D showed lower hatch weight at 34 wk. This suggests that supplemental vitamins and minerals in broiler breeder diets effects offspring performance.

**Key Words:** eggs production, incubational egg weight loss, hatch weight

**166 The effect of diet formulation and manufacturing technique on pellet processing variables and quality.** N. P. Buchanan\*, K. G. S. Lilly, C. K. Gehring, and J. S. Moritz, *West Virginia University, Morgantown.*

The majority of commercial broilers and turkeys are fed pelleted feed. Least-cost diet formulation and pellet mill operating technique vary widely. As a result, pellet quality is often inconsistent. Past research has associated pellet quality changes to feed formulation and manufacturing technique. However, the interaction between the 2 factors is rarely explored. The objective of the current study was to evaluate the effects of altering a least-cost diet formulation and altering manufacturing technique on pellet processing variables and quality. Past research has shown an improvement in pellet quality with higher levels of protein and moisture. Therefore, increased levels of crude protein and moisture were added to a least-cost (LC) broiler starter and grower formulation in order to comprise a research-based (RB) formulation. The LC and RB formulations were pelleted using 2 manufacturing techniques, a thin die with a fast production rate (TnF) or a thick die with a slow production rate (Tks). During manufacture of starter diets, RB formulation improved Pellet Durability Index (PDI) and Modified Pellet Durability Index (MPDI) while decreasing Pellet Mill Relative Electrical Energy Usage (PREE) ( $P = 0.0044$ ,  $0.0005$ , and  $0.0031$ , respectively) compared to LC formulation. The Tks technique increased PDI and MPDI while decreasing fines production ( $P = 0.0001$ ) compared to the TnF

technique. However, PREE and production rate increased ( $P = 0.0001$  and  $0.0001$ ) for both the starter and grower diets. During manufacture of grower diets, both RB formulation and Tks technique resulted in decreased fines production ( $P = 0.0003$ ) compared to LC formulation and TnF technique. A significant interaction observed for PDI and MPDI of grower diets indicated that RB formulation improves pellet quality and is even more beneficial if a mill uses a TnF technique ( $P = 0.0013$  and  $P = 0.0025$ , respectively). These results demonstrate that diet formulation and manufacturing technique are, in fact, linked and must be considered when attempting to optimize pellet quality.

**Key Words:** feed manufacture, pellet quality, diet formulation

**167 The effect of diet formulation, manufacturing technique, and antibiotic inclusion on broiler growth and development.** N. P. Buchanan\*, K. G. S. Lilly, A. L. Rack, K. R. Beaman, and J. S. Moritz, *West Virginia University, Morgantown.*

Feeding pellets results in improved weight gain and feed conversion compared to feeding mash. Past research has shown that optimizing diet formulation and manufacturing technique improves pellet quality. However, high pellet quality must equate to improved broiler performance in order to justify increased economic input. Moreover, high pellet quality has been linked to an increased incidence of necrotic enteritis in broiler chickens and may necessitate the use of antibiotics. The objective of the current study was twofold; 1) to assess broiler performance based on changes in pellet quality obtained by altering diet formulation and manufacturing technique and 2) to assess broiler performance using pelleted diets including and excluding antibiotics. Male broiler chicks ( $n = 1,280$ ) were obtained from a commercial facility at hatch. Commercial nutrient recommendations based on digestible amino acids were used to formulate starter (3–21 d) and grower (21–42 d) diets. All broilers were reared on built-up litter. Experimental treatments were arranged in a  $2 \times 2 \times 2$  factorial design consisting of 2 diet formulations [least-cost (LC) or research-based (RB)], 2 manufacturing techniques [thin die with fast production rate (TnF) or thick die with slow production rate (Tks)], and 2 antibiotic inclusions [including antibiotics or excluding antibiotics]. Starter diets were fed in crumbled form and grower diets were fed in pelleted form. Antibiotic inclusion had no effect on broiler performance ( $P > 0.05$ ). Feeding RB formulation improved live weight gain and fat pad yield compared to feeding LC formulation ( $P = 0.0002$  and  $0.0001$ , respectively). A significant interaction was observed for carcass weight and breast yield ( $P = 0.0132$  and  $0.0194$ , respectively). A RB formulation was found to be most beneficial when TnF technique was utilized. These data demonstrate that, in order to maximize broiler performance, diet formulation and manufacturing technique must be considered.

**Key Words:** feed manufacture, pellet quality, broilers

**168 The effects of fiber, moisture and protein on pellet manufacture variables.** K. G. S. Lilly\*, N. P. Buchanan, S. E. Cutlip, and J. S. Moritz, *West Virginia University, Morgantown.*

Pelleted feed increases weight gain and feed efficiency in comparison to mash feed. However, improvement in broiler performance is reliant upon pellet quality. Past research has shown that pellet durability is improved with increased inclusions of fiber, moisture and protein. The objectives of this study were to determine the main effects and interactions of graded

levels of fiber, moisture and protein on pellet manufacture variables. Treatments were arranged in a  $3 \times 3 \times 3$  factorial design consisting of 3 levels of added fiber (0, 2 and 4% oat hulls), added moisture (0, 2 and 4% tap water) and added protein (0, 2 and 4% soybean meal). Fiber, moisture and/or protein were added to a corn/soybean based basal diet that was formulated to Cobb specifications. Feed was manufactured at the West Virginia University pilot feed mill utilizing a randomized complete block design over a 4-week period. Steam conditioning temperature was held at  $80 \pm 2^\circ\text{C}$ . Steam pressure was held constant at 262kPa. Fiber decreased modified pellet durability index (MPDI), bulk density and production rate ( $P = 0.0001, 0.0001, \text{ and } 0.0524$ , respectively) and increased total fines ( $P = 0.0234$ ). Detrimental pellet manufacture effects of fiber were likely associated with particle size. Moisture increased MPDI and decreased bulk density and production rate ( $P = 0.0030, 0.0001, \text{ and } 0.0001$ , respectively). Protein increased MPDI ( $P = 0.0440$ ). Ingredient interactions (fiber|moisture|protein) were not significant ( $P > 0.05$ ). Results suggest that further research is warranted using increased levels of moisture and protein in practical diet formulations.

**Key Words:** pellet quality, feed manufacture, diet formulation

**169 Effects of diet preconditioning on digestive system morphology in roosters fed increasing levels of guar meal.** O. Gutierrez\*, A. Haq, and C. A. Bailey, *Texas A&M University, College Station.*

Several studies report adaptive morphological responses in the digestive system of gallinaceous birds fed high-fiber diets over an extended period of time. This often results in increased utilization of diets low in nutrient density. The purpose of the current study was to determine whether morphological adaptations could occur as a result of feeding relatively high levels of guar meal (GM) to adult Leghorn roosters over a 3-week period. Guar meal is a high fiber by-product of guar gum processing and contains approximately 18% residual gum, which is comprised of a  $\beta$ -1 $\rightarrow$ 4-linked D-mannopyranose chain with  $\alpha$ -1 $\rightarrow$ 6-linked D-galactopyranose branches. A total of 28 roosters were fed 1 of 4 diets containing differing amounts (0, 6, 12, and 24%) of GM for a period of 3 weeks. Following this preconditioning period, all birds were euthanized and evaluated for changes in villus height and incidence of intestinal mucosal damage as determined by light microscopy. Changes in relative organ weights (ventriculus, liver, heart, pancreas, spleen, and small intestine), cecum length, body weight, and feed consumption were also measured. Significant increases in cecum length, villus height and severity of intestinal mucosal injury were observed in birds consuming the 24% GM diet. Additionally, increased pancreas and liver weight and decreased heart and body weight was noted for this group. Birds consuming the 6% GM diet exhibited intestinal lesion scores and relative heart weights intermediate to those of the control and 24% GM groups. No significant differences were noted for any other parameters. These results indicate that a diet preconditioning period of 3 weeks is sufficient to induce morphological adaptations of the digestive system of chickens consuming a 24% GM diet. However, the effect of these adaptations on nutrient utilization is unknown due to factors such as the increase in intestinal mucosal damage associated with the 24% GM diet.

**Key Words:** diet preconditioning, digestive morphology, guar meal

## Pathology

**170 Effect of passage through laying hens on organ invasiveness and phenotypic heterogeneity of *Salmonella* Enteritidis.** R. K. Gast\*, J. Guard-Bouldin, R. Guraya, and P. S. Holt, *USDA-ARS, Egg Safety and Quality Research Unit, Athens, GA.*

Horizontal transmission within and between flocks is an important aspect of the epidemiology of *Salmonella* Enteritidis (SE) in poultry. Previously, a series of passages through infected laying hens increased the frequency at which an SE isolate was deposited inside eggs. The present study evaluated the effect of in vivo passage of an SE isolate on its ability to invade to internal tissues and its expression of a phenotypic property (biofilm production) associated with invasiveness and egg contamination. In each of 3 trials, a group of laying hens was infected orally with a PT13a strain of SE (prepared from a separate stock culture each time). After internal organ samples were removed for culturing at 7 days postinoculation, an SE isolate from the upper oviduct of an extensively infected hen was used to infect a second group of hens in each trial. In trial 1, the frequency of SE isolation from organs declined from 40 to 12% between the 2 rounds of infection, but the frequency of biofilm production by SE colonies obtained from round 2 organ samples (98%) was higher than for the original inoculum culture (59%). In trial 2, no colonies from either the inoculum strain or round 2 organ isolates were biofilm-positive, and the frequency of SE isolation from organs increased from 27 to 42% between rounds 1 and 2. In trial 3, the frequency of SE isolation from organs was similar in the 2 rounds

of infection (61 and 58%), but the frequency of biofilm production by round 2 organ isolates (58%) was lower than for the original inoculum strain (88%). Passage of SE through infected chickens did not always select for a higher ability to invade internal organs in the present study. Moreover, in vivo passage did not consistently select for either increased or decreased phenotypic diversity within the overall SE population. The characteristics of the original inoculum population, the selective pressure exerted in the tissues of infected chickens, and the exact proportions of relevant phenotypic subpopulations actually transferred to subsequently infected birds may combine to determine the outcome.

**Key Words:** *Salmonella* Enteritidis, in vivo passage

**171 Development and evaluation of candidate recombinant *Salmonella*-vectored *Salmonella* vaccines.** R. E. Wolfenden\*<sup>1</sup>, S. L. Layton<sup>1</sup>, A. D. Wolfenden<sup>1</sup>, A. Khatiwara<sup>1</sup>, G. Gaona-Ramírez<sup>1</sup>, N. R. Pumford<sup>1</sup>, K. Cole<sup>2</sup>, Y. M. Kwon<sup>1</sup>, G. Tellez<sup>1</sup>, and B. M. Hargis<sup>1</sup>, <sup>1</sup>*University of Arkansas, Fayetteville*, <sup>2</sup>*The Ohio State University, Columbus.*

Attenuated *Salmonella* Enteritidis ( $\Delta$ SE) recombinant vaccine vectors incorporating a *Salmonella* flagellar protein (*fliC*) subunit, a hydrophobic putative cell-mediated epitope, ( $\Delta$ SE/*fliC*) for LamB expression, with or