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The Effects of Environment, Feed Form and Dietary Caloric Density on Broiler Performance; and Effect of Variable CatP Ratio and Phytase on Growth performance and Mineral Deposition in Corn-Soy Diets fed to Straight-run Broilers

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The Effects of Modest Improvement in Pellet Quality on Tom Turkey and Straight-run Broiler Performance, with Focus on Experimental Design.

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ABSTRACT

THE EFFECTS OF MODEST IMPROVEMENT IN PELLET QUALITY ON TOM TURKEY AND BROILER PERFORMANCE, WITH FOCUS ON EXPERIMENTAL DESIGN.

BY BRIAN G. GLOVER

Improving the crumble/pellet percentage of feed has been argued to be difficult to obtain in the commercial industry due to the necessity of feed mills producing adequate feed volume within a time constraint. Poultry research often utilizes small numbers of birds per pen or experimental unit that may affect the estimation of variance components, potentially producing pen performance metrics that are less valuable for industry guidance. In Experiment 1, diets were manufactured to maintain nutrient availability and vary only in crumble/pellet percentage (standard = 40% pellets, improved = 70% pellets). The two dietary treatments were then fed to Hybrid Converter male turkeys from d 1-126. Growth performance variables were measured and carcass characteristics (breast wt. and yield) were determined. Average pen weight increased by 0.17 kg (P = 0.02) and tended to decrease feed conversion ratio by 11-points (P = 0.07) for toms fed improved quality pellets. Experiment 2, was designed to determine the effects of pen size and crumble/pellet percentage on commercial broiler performance using a 2 (feed quality) x 2 (pen size) factorial treatment arrangement in a randomized complete block design. Feed manufacture was manipulated to maintain nutrient availability constant with treatments differing only in crumble/pellet percentages (standard = 50% pellets, improved = 70% pellets). Growth performance was analyzed at the end of each growth phase (starter d 1-10, grower d 11-21, finisher d 22-38). Carcasses characteristics of hot breast weight and yield were determined on d 38. No interactions were observed for the d1-38 growth period (P > 0.05). Broilers consuming improved crumble/pellet percentage had a tendency towards decreased feed intake (P = 0.07) and feed conversion ratio by 3 points (P = 0.1), but maintained a similar weight gain (P = 0.3). Large pens tended to decrease live weight gain (P = 0.06). Improved (crumble/pellet) percentage increased pen coefficient of variation for within pen ending weight (P = 0.05), likely due to competitive feeding behavior. These experiments suggest that a modest improvement to pellet quality improves both tom turkey and broiler performance, and a small pen model may produce sufficient results for broiler chicken research.

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CHAPTER 2

1. American Society For Testing And Materials – ASTM
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12. General Linear Model – GLM
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14. Least Significant Difference – LSD
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CHAPTER 3

1. American Society For Testing And Materials – ASTM
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4. Feed Conversion Ratio – FCR
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7. Mixer-Added Fat – MAF
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9. Modified Pellet Durability Index – MPDI
10. Ending Body Weight – EBW
11. Analysis Of Variance – ANOVA
12. General Linear Model – GLM
13. Statistical Analysis System – SAS

CHAPTER 1: LITERATURE REVIEW

Commercial Broiler and Turkey Production in West Virginia

West Virginia produced 94 million broilers, resulting in 376 million pounds of meat, which had a production value of 188 million dollars in 2012. West Virginia, in 2013, increased production to 96.8 million broilers, 387 million pounds of meat, at a production value of 234 million dollars. Broiler production within West Virginia has made increases in all areas and is continuing to increase every year. Broiler data represent annual estimates taken from a period beginning on December 1 and continuing through November 30. West Virginia raised 3.3 million turkeys, produced 89.1 million pounds of meat, resulting in a production value of 64.2 million dollars in 2012. There were similar statics observed in 2013 with 3.1 million turkeys raised, 80.6 million pounds of meat produced, all at a production value of 53.6 million dollars. Turkey statistics were based on turkeys that were placed on September 1 through August 31. This statistical analysis ranked West Virginia 19th in broiler production and 13th in turkey production in total U.S. comparison [1].

FEED MANUFACTURE AND FEED FORM

Pelleting Procedure

Feed is the major cost associated with a commercial poultry grower's budget. This is due to the fact that feed represents 60-70% of the total production cost for a commercial poultry grower, and the price of ingredients accounts for the major quantity of the total feed cost. Pelleting feed has been known to be a more costly form of processing; but pelleting a diet has been shown to increase live weight gain (**LWG**), increase feed intake (**FI**), and decrease feed conversion ratio (**FCR**), and decrease feed wastage [2-9]. The feed manufacture process consists of combining raw materials through batching, mixing, grinding, steam conditioning, pelleting, cooling, and packaging [10]. All of these elements singularly or in combination can affect bird performance and health.

The process of pelleting has been defined as the agglomeration of smaller particles into larger particles through a mechanical process combining moisture (through steam), heat, and pressure [2-11]. Cereal grains (corn, wheat, barley, etc...), which can be part of a poultry diet formulation, are typically ground before being mixed allowing for improved blending and decreasing mixing problems [3,12]. The process of grinding is also known as particle size reduction [10]. Once the ingredients are ground and mixed they are then conditioned with steam at an average temperature of 80-90˚C, and extruded through a pellet die. The hot pellet is next conveyed through a cooling deck, once through the cool deck the pellets can either be packaged or pass through a roller mill to reduce size to a crumble and then be packaged [10,13]. The final product is then transported to poultry barns and augured into feed pans for broiler or tom turkey consumption.

Pellet Quality

Pellet quality is the capability a pellet has to preserve integrity after manufacture and through mechanical stressors associated assisted with transportation and handling [13-14]. The physical quality of pellets can be determined through pellet durability index (**PDI**), modified pellet durability index (**MPDI**), particle size, and percentage of pellets to fines. The PDI and MPDI are found by sifting a 500 gram sample through an American Society for Testing and Materials (**ASTM**) sieve based on pellet die diameter, placing it into a Pfost tumbling box for 10 minutes, removing the sample and sieving it again, then finally calculating the final weighed sample. Particle size is determined by placing a 100 gram representative sample into a Ro-Tap machine for 10 minutes; the sample is then removed and each sieve was weighed and recorded.

The percentage of pellets to fines ratio is determined through sifting a representative sample through the appropriate ASTM sieve to receive the proper percentage of pellets, and then through a second ASTM sieve to receive the appropriate percentage of fines. The feed remaining on the first sieve is considered pellets; the sample of feed that passes through the first sieve is then sifted through the second sieve. The feed that remains on the second sieve is considered crumbles, while the remaining feed sample that passes through the second sieve is considered fines. The weight of the pellets, crumbles, and fines is then used to calculate the percentage of pellet to fine ratio by using the total weight of the representative sample [14-15]. These data provide a comprehensive view of pellet quality.

PELLET QUALITY AND MEAT BIRD PERFORMANCE

Previous studies confirm that feeding whole or intact pellets to meat birds can improve growth performance metrics such as decreasing FCR and increasing LWG. Proudfoot and Hulan [16] found that presenting a higher percentage of fines to turkeys demonstrated a negative effect on FCR and body weight gain [16]. These results are similar to that of a study done by Lilly et al [2] that found for every 10-percentage-point increase in whole pellets there was a 0.4-point improvement in FCR and breast weight, while increasing FI [2]. Plavnik et al [17] noticed that pelleted feed resulted in a moderate improvement to FCR and an increased growth response in both turkeys and broiler chicks regardless of age [17]. Pelleting diets may be a more expensive pelleting technique, but the improved bird growth performance has been viewed to out-weigh manufacturing cost. Lilly et al. [2] also examined the economic returns based on feed costs and bird performance. These authors found that broilers fed a high pellet quality (90:10 pellet:fine) diet achieved a low FCR and high carcass weight, indicating production savings relative to a ground pellet diet of $0.05 to $0.03/kg of carcass weight [2]. Through these and other previous research papers it is clear that growth performance will improve from feeding a pelleted diet, with a low percentage of fines.

TURKEYS AND THE DIFFERENCE FROM BROILERS

Turkeys and broilers are both produced for human consumption. Tom turkeys are typically reared longer than broilers, due to turkeys taking longer to mature. Turkeys generally go to market between 15 and 25 weeks of age (105 d to 175 d). These turkeys typically weigh around 35-40 pounds at 20 weeks of age. Broilers reach maturity much sooner, and are typically reared from 5 to 8 weeks (35 d to 55 d). Broilers are not placed on pellets until the finisher phase, whereas turkeys can be placed on pellets during the grower and finisher phases. Performance differences associated with feeding pellets have been noticed to be numerically greater for turkeys than broilers, possibly due to the increased grow out time. A study conducted by Wamsley and Moritz [18] determined that feeding a diet of high quality pellets (average of 78.64% pellets) fed from d 42-118 produced toms that were 0.29 kg (0.64 lb) per bird heavier with 9 points lower FCR, as compared to toms fed a diet of ground pellets. Regression analyses predicted that if toms fed a ground pelleted diet finished at the same d 118 ending weight as turkeys fed a diet of high quality pellets the FCR advantages of the high quality pellet diet would be 12 points [18]. Improvement of FCR by 12 points (a point is considered a 0.01 difference) is of greater magnitude compared to pelleting research conducted on broilers. For example, the previous broiler study conducted by Lilly et al. [2] found a 4 point improvement to FCR.

COMMERCIAL FEED MILLS

A survey of local commercial feed mill production was taken by Dr. Moritz in 2007 [18]. This survey compared the manufacturing techniques: conditioning time and temperature, production rate (ton/week), die size, and the typical PDI manufactured in three local commercial feed mills. The first mill demonstrated a conditioning time and temperature of 35 seconds at 90.5˚C; 16,400 ton/week; a 7 x 3 mm of die used; and an average PDI of 75%. The second mill demonstrated a conditioning time and temperature of 20 seconds at 82.2˚C; 1,000 ton/week; an 11 x 2 mm of die used; and an average PDI of 70%. The final mill surveyed demonstrated a conditioning time and temperature of 4 seconds at 68.3˚C; 1,000 ton/week; a 13 x 1 mm of die used; and an average PDI of 95%. This survey of surrounding commercial feed manufacturing techniques demonstrates that there is no standard manufacturing technique when it comes to feed manufacture [18].

BIRDS PER EXPERIMENTAL MODEL AND PEN SIZE

Broiler performance research often utilizes small numbers of birds per pen or experimental unit that may affect the estimation of variance components, potentially producing pen performance metrics that are less valuable for industry guidance. University research typically rears birds in a more controlled environment than that of a commercial setting. These controlled environments may produce data that is less applicable to the commercial industry. Researchers often utilize experimental units based on research barn resources and budget constraints. Through the use of power curves an investigator may decrease research cost and increase probability of correctly assessing treatment comparisons. Power curves aid in predictions of proportion for experiments yielding a designated level of significance as the differences between two means increases [19]. Shim and Pesti [20] found that the larger the sample size the smaller the sampling error; however they also found that the sample size only has to be large enough to produce reasonable accuracy and having excessive sample size increases cost and time [20]. Cravener et al [21] stated that a commercial poultry house presents social interactions that may be different from pens housing only 20 to 42 birds [21]. Shim and Pesti [20] found that more replications generally produce improved results in comparison to more birds per pen [20]. Social interactions or tendencies among an increased number of birds may produce increased variations among individual bird weights.

SOCIAL TENDENCIES OF BIRDS

Most researchers and commercial growers have noticed that poultry exhibit behavioral tendencies when placed into a group. The formation of "pecking orders" among birds is usually determined through stronger birds being more dominant over weaker birds. The level of competition among group members is usually dictated by the ease of access to resources because of dominance relationships [22-30]. Resources located in one exclusive area may allow for dominant individuals to control access to those resources forcing subordinates (weaker birds) to wait [22-30]. Leone and Estévez [22] observed increased aggression in larger group sizes when birds had to compete for limited access to resources, and that a greater number of birds were excluded from feeders at any given time during a restricted feeding phase [22]. These data suggest that group hierarchies may exist, but are more prominent when resources are restricted.

When conducting poultry research it is important for scientists to consider many facets that can affect performance: pellet quality, experimental model specific to pen size, and social hierarchies. By considering these factors, research can better assess growth performance and ultimately increase applicability to the commercial industry.

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CHAPTER 2: MANUSCRIPT PREPARED FOR JOURNAL OF APPLIED POULTRY RESEARCH: EFFECTS OF MODEST IMPROVEMENTS IN PELLET QUALITY AND EXPERIMENT PEN SIZE ON BROILER CHICKEN PERFORMANCE

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Primary Audience: Researchers, Nutritionists, Feed Mill Managers

SUMMARY: Improving the crumble/pellet percentage of feed has been argued to be difficult to obtain in the commercial industry due to the necessity of feed mills producing adequate feed volume within a time constraint. Broiler performance research often utilizes small numbers of birds per pen or experimental unit that may affect the estimation of variance components, potentially producing pen performance metrics that are less valuable for industry guidance. The objective of this study was to compare the performance of straight run Hubbard x Cobb broiler chickens receiving a standard crumble/pellet percentage (50%) vs a modestly improved crumble/pellet percentage (70%), in either large pen (46 birds) or small pen (23 birds) experimental units. All diets were batched, mixed, steam conditioned to approximately 82˚C, extruded through a 4.8 x 38.1 mm pellet die, and crumbled at the West Virginia University pilot feed mill. Crumble/pellet percentage differences were obtained by grinding a portion of the complete feed then remixing. Treatments were replicated 10 times and fed for 1-38 d using a 2 x 2 factorial arrangement in a randomized complete block design to measure growth performance. Bird density and feeder space access was 0.06 m^2/bird and 1.2 cm/bird, respectfully for both experimental units. Crumble/pellet percentage and pen size main effects did not interact for any growth performance metric. Broilers consuming improved crumble/pellet percentage had a tendency towards decreased feed intake (P=0.07) and feed conversion ratio by 3 points (P=0.1), but maintained a similar weight gain (P=0.3). Large pens decreased live weight gain (P=0.03). Improved crumble/pellet percentage increased pen coefficient of variation for ending weight (P=0.05), likely due to competitive feeding behavior. These data suggest that modest improvements in crumble/pellet percentage may provide performance benefits, and feed quality variation effects on growth performance can be satisfactorily evaluated utilizing a small pen experimental unit.

Keywords: crumble, pellet, broiler, pen size, feed conversion ratio

DESCRIPTION OF THE PROBLEM

Pelleting feed has been shown to increase feed intake (**FI**), increase live weight gain (**LWG**), and decrease feed conversion ratio (**FCR**) [1], thus justifyng the expense of pelleting. Broiler growth response to feed has importance to commercial integrators since feed and feed manufacture constitute 60 to 70% of production cost. Additional benefits of pelleting include the potential to decrease pathogens in feed and improve feed flow [1-8]. Past research has described that maintaining equivalent nutrient availability is important in pelleting research. Lilly and coauthors [9] studied variations of pellets and fines on broiler chickens, while maintaining similar nutrient availability, and accounting for bird sex variation. The authors found that increased pellet to fine ratios increased FI and LWG and had a more minor effect on decreasing FCR [9]. This type of research provides integrated poultry operations justification for investing in techniques that improve pellet quality. However, research must be conducted in a manner that best mimics industry conditions and reduces experimental error in order for results to properly guide the industry. Many research institutions utilize small pens of broiler chickens as experimental units that may affect the estimation of variance components and consequently the application of said research to an industry setting. Shim and Pesti [10] examined the statistical and economic implications of different combinations of birds per replicate, and replicates per treatment for poultry research through a Microsoft Excel workbook [10]. These authors demonstrated through a power analysis that more replications, rather than an increase in birds per pen, generated improved results [10]. Although an increase in replications may improve research results it may be less indicative of industry standards, where there are large numbers of birds competing for resources. A study done by Leone and Estévez [11] observed that a larger bird group size demonstrated increased aggression when birds had to compete for limited access to feed during a restricted access phase. This observation may be especially important in feed quality research. Based on past research and the goal of providing applicable data to the industry, the objective of this study was to compare the performance of straight run Hubbard x Cobb broiler chickens receiving a standard crumble/pellet percentage (50%) vs a modestly improved crumble/pellet percentage (70%), in experimental units of either a large pen (46 birds) or small pen (23 birds) with equal bird density (0.06 m^2/bird).

MATERIALS AND METHODS

Feed Manufacture

All feed was manufactured at the West Virginia University pilot feed mill [12]. All diets were formulated to meet nutrient needs of the bird based on Agristat standards [14] and were corn and soybean meal based (Table 1). Samples were taken throughout the feed manufacturing process and analyzed for percentages of crude protein (Kjeldahl anlysis), crude fat (ether extract), calcium, ash and moisture (dry matter), then non-phytate phosphorus was calculated (Table 1). Diets were manufactured at approximately 82˚C, using a 38.1x 4.8 mm die with an average production rate of 1.02 tonne/h relative to the recommended mill capacity (0.91 tonne/h), and crumbled to a small particle, large particle or maintained as a pellet depending on growth phase (Table 2). All dietary treatments (70% crumble/pellet = Improved vs. 50% crumble/pellet = standard) were manufactured using similar techniques, to maintain nutrient availability, and feed form variation was produced by grinding a portion of the pelleted feed and remixing. The percentages of pellets, crumbles, and fines were determined by sifting a representative sample (50lb bag) through a number 5 and 14 U.S. sieve (Table 2). The two dietary treatments and resulting feed form characteristics are described in Table 2.

Growth Performance

Forty six or 23 straight run Hubbard x Cobb 1-d-old chicks from a commercial hatchery [15] were randomly assigned to large (1.2 x. 2.4m) or small (0.69 x 2.4m) pens respectively at a density of 0.06 m^2/bird. A total of 1,300 broilers and 40 pens were utilized in the experiment. Floor pens containing fresh shavings were utilized within a cross-ventilated negative-pressure house. Feed and water were provided for ad libitum consumption. Each pen contained nipple drinkers (approximately 1 nipple to 12 birds) and feed pans that were adapted to hoppers. The temperature, lighting, and humidity schedules modeled that of a commercial integrator. One feed pan/hopper was placed in each small pen and two feed pan/hoppers were placed in each large pen. Feed pan space mimicked that of industry (0.06 m^2/bird) through placement of a laminated wood restrictor over top of the feed pan [16]. Feeder space was consistent with Choretime recommendations for small broilers [16]. Individual broiler weights were obtained at the end of each growth phase (d 1-10, d 11-21, and d 22-38) in order to measure growth performance variables [FI, LWG, FCR (adjusted for mortality), Table 3]. On d 38 either two or four male birds (small or large pens respectively) were selected ± 100g of the mean bird body weight per pen for analysis of hot breast weight and yield. Birds were cared for according to West Virginia University Animal Care and Use Committee Guidelines.

Statistical Analysis

Performance variables were analyzed using a 2 (feed quality) x 2 (pen size) factorial arrangement of treatments in a randomized complete block design. The experimental unit was a pen of broilers. Prior to analysis of variance, Levene's test was performed to check homosedasticity, using the main effects and interaction means in three separate analyses. If variance was found to be heterogenous, then Friedman's Chi-Square test was utilized. The main effects of feed quality and pen size as well as their interaction were determined, and Fisher's

LSD test was used for multiple comparisons. The statistical analysis was performed through the GLM or FREQ procedure of the Statistical Analysis System (SAS) [17]. Alpha was designated as 0.05, and letter superscripts demonstrate differences among means. Alpha values between 0.1 and 0.05 were considered a trend towards a significant treatment effect. Although, feed phase data was collected and analyzed, only the overall period data has been presented and discussed.

RESULTS AND DISCUSSION

Manufacturing parameters and feed quality descriptors are presented in Table 2. Nutrient availability was maintained similar among both dietary treatments by manufacturing diets at the same time using consistent manufacturing techniques then generating crumble/pellet percentage differences through grinding and mixing. Percentage differences among treatments were developed in part to continue the work of Lilly et al [1]. Lilly [1] compared the effects of four different pellet-to-fine dietary treatments (90:10 high pellet quality, 60:40 medium pellet quality, 30:70 low pellet quality, and 0:100 ground pellet quality) on Cobb x Cobb broiler performance. They found that each 10-percentage-point increase in pellets; increased FI by 100-g, improved FCR by 0.4-points, and increased breast weight by 4-g [1]. In the current study, the improved pellet percentage treatment showed a trend to decrease FI ($P = 0.07$), maintained similar weight gain ($P = 0.3$), and demonstrated a trend towards decreased FCR by 3-points ($P = 0.1$, Table 3). Intake differences between the two studies may be associated with variation in genetic strain and/or the decreased feeder space access of the current study. Regardless, these data show that a modest improvement in pellet quality may provide performance benefits. The coefficient of variation (**CV**) for bodyweight (Table 3) shows a significant effect for feed quality where an improved crumble/pellet percentage produced a higher within pen variation in body weight ($P = 0.05$). This analysis was supported by Levene's test that found the variance to be heterogenous for live weight gain due to feed quality (P=0.006), demonstrating higher variability for the improved pellet percentage treatment. Based on these data we speculate that the within pen coefficient of variation for body weight may have been affected in part by the feeder space access permitting the more dominant birds fed the improved pellet percentage treatment to consume the majority of crumbles/pellets, leaving fines for the less dominant birds. Resources located in one exclusive area may allow for dominant individuals to control access to those resources forcing subordinates (weaker birds) to wait [11, 18-26]. These data are similar to that shown by Shim and Pesti [10], where the authors demonstrated through a power analysis that more replications, rather than an increase in birds per pen, generated improved results [10]. These behavioral tendencies anecdotally were observed as a "follow the leader" effect where one bird committing to one activity would in turn cause other birds to partake in the same activity; such as consuming more feed from one hopper than another within a large pen. These results are similar to those observed in a behavioral study completed by Leone and Estévez [11]. Leone and Estévez observed more aggression in a larger bird group size when birds had to compete for limited access to feed during a restricted access phase [11]. Previous research demonstrates that phenotypic variance among experimental models increases when pushed to optimum or desired performance [26-28]. We can speculate that although pelleting reduces ingredient segregation [1-8], possible feed form segregation effects, due to the improved crumble/pellet percentage (70%), may have influenced performance variables. A small pen size (23 birds) demonstrated increased LWG (P = 0.03). This observation may also be associated with behavioral tendencies that created more stress in large pens. Table 3 shows that main effects did not interact for any performance metric, suggesting that small pens of broilers are a sufficient experimental unit to assess feed quality variation.

CONCLUSIONS AND APPLICATIONS

1. Modest improvements in pellet quality (50% crumbles/pellets to 70% crumbles/pellets) may improve broiler performance (FI and FCR).
2. The within pen ending weight CV increased with increased feed quality likely due to dominant broilers monopolizing feeder space and consuming the majority of pellets.
3. Feed quality and pen size did not interact, demonstrating that small pens of broilers are a sufficient experimental unit to assess feed quality variation.

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Table 1. Diet formulations[1] and nutrient specifications

Item	Starter diet (1 to 10 d)	Grower diet (11 to 21 d)	Finisher diet (22 to 38 d)
Ingredient %			
Corn	58.86	61.62	68.17
Soybean Meal (48%)	31.18	26.31	20.23
Meat and Bone Meal (50%)	5.00	5.00	5.00
Animal and Vegetable Blend Fat	3.49	3.61	3.42
Dicalcium Phosphate	1.54	1.31	1.29
Limestone	0.74	0.66	0.65
Salt	0.30	0.35	0.32
DL Methionine	0.32	0.31	0.22
Poultry Premix[4]	0.25	0.25	0.25
Lysine	0.21	0.18	0.17
Threonine	0.09	0.28	0.26
Chloromax 50[5]	0.03	-	0.03
BMD 60[6]	-	0.08	-
Coban 90[7]	-	0.05	-
Calculated Nutrients			
ME, kcal/kg	1386.0	1409.0	1434.0
Crude Protein	22.40	20.60	18.09
Methionine, %	0.88	0.83	0.69
Lysine, %	1.19	1.05	0.90
Calcium, %	1.15	1.06	1.04
Available Phosphorus, %	0.60	0.55	0.54
Analyzed Nutrients[8]			
Moisture	16.83	14.90	12.84
Crude Protein	20.52	18.89	17.66
Crude Fat	5.87	6.09	5.98
Ash	5.65	5.37	4.84
Calcium[9]	1.30	1.08	1.14
Npp[10]	0.56	0.48	0.48

[1-3]Agristat Recommendations [15]

[4]Supplied the following per kilogram of diet: manganese, 0.02%; zinc, 0.02%; iron, 0.01%; copper, 0.0025%; iodine, 0.0003%; selenium, 0.00003%; folic acid, 0.69 mg; choline, 386 mg; riboflavin, 6.61 mg; biotin, 0.03 mg; vitamin B6, 1.38 mg; niacin, 27.56 mg; pantothenic acid, 6.61 mg; thiamine, 2.20 mg; menadione, 0.83 mg; vitamin B12, 0.01 mg; vitamin E, 16.53 IU; vitamin D3, 2,133 ICU; vitamin A, 7,716 IU.

[5]Chloromax 50 = Chlorotetracycline (50g/ton)

[6]Bacitracin methylene disalicylate, 50 g/lb (50 g/ton inclusion, Alpharma, Fort Lee, NJ), for increased rate of BW gain and improved FE.

[7]Active drug ingredient monensin sodium, 60 g/lb (90 g/ton inclusion, Elanco Animal Health, Indianapolis, IN), as an aid in the prevention of coccidiosis caused by *Eimeria necarix*, *Eimeria tenella*, *Eimeria acervulina*, *Eimeria brunette*, *Eimeria mivati*, and *Eimeria maxima*.

[8]Analysis was performed by Eurofins Scientific, Des Moines, IA.

[9]inductively coupled plasma mass spectometry (ICP analysis)

[10]Non-phytate phosphorus = total phosphorus – (0.282 X phytic acid) x 100

Table 2. Manufacturing variables and pellet quality for growth periods

Item	Starter diet (1 to 10 d)	Grower diet (11 to 21 d)	Finisher diet (22 to 38 d)
Die Size, mm x mm	38.1 x 4.8	38.1 x 4.8	38.1 x 4.8
Production Rate, tonne/h (tons/h)	1.02	1.16	1.31
Pellet Durability Index[1], %	84.4	86.4	86.6
Modified Pellet Durability Index[2], %	78.6	81.5	81.2
NHP[3], %	80.1	79.2	76.0
Treatment	**Standard vs Improved**	**Standard vs Improved**	**Standard vs Improved**
Pellet[5], %	0 vs. 0	12 vs. 32	54 vs. 69
Crumble[6], %	51 vs. 71	47 vs. 52	21 vs. 17
Fine[7], %	49 vs. 29	41 vs. 16	25 vs. 14
Bulk Density Pellets[8] (kg/m^3)	674 vs. 578	732 vs. 622	753 vs. 727

[1] Pellet durability index was determined by placing 500 g of sifted pellets into a Pfost tumbler. Samples were tumbled for 10min at 50 rpm. The sample was then sifted again and weighed. Pellet durability index was calculated as the percentage of sifted pellets retained after tumbling (descriptive data).

[2] Modified pellet durability index was measured similarly to the previous description, with the exception that five 13-mm hexagonal nuts were added to the 500-g sample before tumbling (descriptive data).

[3] New Holman Pellet Test was determined by placing a 100 g of sifted pellets into the NHP. Samples were run for 30 seconds. The sample was then weighed and pellet durability was calculated as a percentage (descriptive data).

[5]Feed retained on a no. 6 ASTM screen (4.0mm) was described as a pellet (descriptive data).

[6]Feed retained on a no. 14 ASTM screen (1.4mm) was described as a crumble (descriptive data).

[7]Feed that passed through the no. 14 ASTM screen was described as fines (descriptive data).

[8]Bulk density is measured in kg/m3 and was calculated from a 22.7-kg sample of feed from each treatment replicate obtained from a complete feed sample. A box measuring 30.5 × 30.5 × 30.5 cm was then tared. Next, the feed sample was poured into the box reaching maximum capacity and the top was leveled off. The weight of the amount of feed that exactly filled the box was used to determine the bulk density (descriptive data).

Table 3. Effects of Feed Form and Pen Size on D 1-38 Broiler Performance and Carcass Quality

Item	FI[1] per Bird (kg)	LWG[2] (kg)	FCR[3] (kg/kg)	CV[4] Among Bird Weight Within Pen	Average Bird Breast Weight (kg)	Average Bird Breast Yield (g/kg)
Treatment						
Standard Quality/Small Pen	3.88	2.37	1.73	9.45	0.490	201.11
Standard Quality/Large Pen	3.92	2.36	1.74	10.84	0.492	204.47
Improved Quality/Small Pen	3.76	2.37	1.70	11.40	0.493	200.93
Improved Quality/Large Pen	3.78	2.32	1.71	12.22	0.484	200.96
ANOVA P value	0.2039	0.1391	0.3662	0.1328	0.8978	0.8238
SEM[5]	0.0600	0.0190	0.0157	0.8206	0.0093	3.1558
Marginal Means Based On Feed Quality						
Standard Quality	3.90	2.36	1.74	10.14	0.491	202.79
Improved Quality	3.78	2.35	1.71	11.81	0.490	200.95
Marginal Means Based On Pen Size						
Small Pen	3.82	2.37	1.72	10.42	0.492	201.03
Large Pen	3.85	2.34	1.73	11.53	0.488	202.72
Main Effect and Interaction P-values						
Feed Quality[6]	**0.0659**	0.3378	**0.1042**	**0.0515**	0.8239	0.5717
Pen Size[7]	0.6771	**0.0570**[8]	0.4192	0.1867	0.6785	0.6041
Feed Quality x Pen Size	0.9190	0.3081	0.8711	0.7379	0.5855	0.6108

[1]FI = Feed Intake
[2]LWG = Live Weight Gain
[3]FCR = Feed Conversion Ratio
[4]CV = Coefficient of Variation
[5]SEM = Standard Error of the Mean
[6]Feed Quality = Standard Quality (50% Pellets), Improved Quality (70% Pellets)
[7]Pen Size = Small Pen (0.69 x 2.44 m), or Large Pen (1.2 x 2.44 m)
[8]The variance was found to be heterogenous for live weight gain due to feed quality (P=0.006), therefore data were re-analyzed using Proc FREQ Friedman's Chi-Square Test, and the pen size main effect for live weight gain was found to be significant (P=0.0253).

CHAPTER 3: MANUSCRIPT PREPARED FOR JOURNAL OF APPLIED POULTRY RESEARCH: THE EFFECTS OF MODEST IMPROVEMENT TO PELLET QUALITY ON TOM TURKEY PERFORMANCE

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Primary Audience: Researchers, Nutritionists, Feed Mill Managers

SUMMARY: Feed and feed manufacture consists of 60-70% of turkey production cost. Past research has demonstrated that benefits of pelleting per se ultimately provide an economic return on investment. However, less is understood concerning returns on modest improvements to feed of poor physical quality. The objective of this study was to compare the performance of tom turkeys that receive feed of standard physical quality at the feed pan to tom turkeys receiving an improved pellet percentage at the feed pan. A common starter diet was batched, mixed, steam conditioned at 79^{o}C, extruded through a 44.5 by 4.8 mm pellet die, and crumbled at the West Virginia University pilot feed mill. Physical feed quality differences of the starter diet were created by manipulating the roller mill gap during the crumbling process. The physical quality of the starter diets was defined as retained percentage of sieved feed and particle size. Feed retained on a no. 5 ASTM screen (4.0mm) was described as a pellet, feed retained on a no. 14 ASTM screen (1.4mm) was described as a crumble, and feed that passed through the no. 14 ASTM screen was described as fines. The feed for the remaining growth phases (2 growers, and 2 finishers) was manufactured at a commercial feed mill. The standard pellet quality diet for the grower and finisher phases were ground to contain an average percentage of pellets (40%) vs. that of the improved pellet quality diet (70%). Diets were fed to 8 replicate pens of 80 Hybrid Converter male poults using a randomized complete block design. Average pen weight significantly increased for toms fed improved quality pellets by 0.17 kg (P = 0.02) and tended to decrease feed conversion ratio by 11-points (P = 0.07) compared to toms fed standard quality pellets. These data suggest that improvements in crumble/pellet percentage may provide growth performance benefits.

Keywords: pellet, turkey, feed form, particle size, crumble

DESCRIPTION OF THE PROBLEM

Previous research has demonstrated that benefits of pelleting a diet may ultimately provide an economic return on investment. These benefits include: increased live weight gain (**LWG**), decreased feed conversion ratio (**FCR**), decreased pathogens in feed, decreased ingredient selection, and improved feed flow [1-9]. Performance differences have been numerically greater for turkeys than broilers, possibly due to the increased grow out time and consistent exposure to pelleted feed. Commercial feed mills typically maintain a high through-put of feed pelleting to keep up with bird feeding requirements. Consequently feed quality is poor due to decreased residence time of conditional mash in the pellet die. One solution to resolve poor pellet quality is through the incorporation of a pellet binder such as calcium lignosulfonate (**CaLS**) into a diet formulation. Corey and coauthors [10] showed that the inclusion of CaLS binder (0.5%) increased both the pellet and modified pellet durability index ($P < 0.05$) [10]. These authors also observed that CaLS decreased pellet mill motor amperage and pellet temperature after die extrusion ($P < 0.01$) [10]. These findings show potential to improve pellet quality and maintain through-put demands. Much of past research that has focused on pellet quality incorporates treatment extremes such as a 90:10 pellet to fine percentage in comparison to a 0:100 pellet to fine percentage [1]. High pellet quality such as 90:10 pellet to fine percentage has been argued to be impossible to obtain in the commercial industry due to throughput demands, but also due to the magnitude of transportation and auguring stress that pellets endure. A need exists to explore the effect of modest improvement in pellet quality obtained through techniques practical for the commercial industry. The objective of this study was to assess the effect of improving pellet quality from 40% pellets to 70% pellets through use of CaLS and decreased pellet production rate on 1-126 d tom turkey performance.

MATERIALS AND METHODS

Feed Manufacture

The starter diets for this experiment were manufactured at the West Virginia University pilot feed mill [11] using CaLS as a pellet binder at a 0.5% inclusion. The grower and finisher diets were manufactured by a commercial feed mill. All diets were formulated to meet nutrient needs of the bird based on commercial standards and were corn and soybean meal based (Table 1). The manufacturing technique for the starter diets were accomplished by creating four 907.4-kg basal batches. Fat inclusion consisted of 4% pre-pellet mixer-added fat (**MAF**) and 3.5% fat added post pellet. Each batch was pelleted using a 40HP California pellet mill [11] equipped with a thick pellet die (4.8 × 45mm) at a conditioning temperature of 82˚C. A representative sample was collected from the pellet cool deck for pellet durability index (**PDI**) and modified pellet durability index (**MPDI**) (Table 1) [13]. Grower and finisher diets were manufactured using a 400HP California Pellet Mill [11] at approximately 82˚C, with an average production rate of 40 tonne/hour relative to the maximum production rate (60 tonne/hour), necessitating a 30% drop in production rate. All dietary treatments (70% crumble/pellet = Improved vs. 40% crumble/pellet = standard) were manufactured maintaining nutrient variability by grinding a portion of the improved treatment in order to produce the standard treatment. The two dietary treatments and resulting feed form characteristics are described in Table 2. Diet nutrient analysis included percent non-phytate phosphorus (**nPP**), calculated by taking the total phytate times 0.282 and then subtracting that value from the total phosphorus [12] and protein, fat, and calcium percentage [14].

Growth performance

Eighty Hybrid Converter male 1-d-old poults were randomly assigned to pens (6 x 5m) at a density of 0.39 m^2/bird, at the West Virginia University turkey facility located in Wardensville, WV [15]. A total of 1,280 male turkeys and 16 pens were utilized in the experiment. Floor pens containing fresh shavings were utilized within a tunnel-ventilated house. Feed and water were provided for ad libitum consumption. The temperature, lighting, and humidity schedules mimicked that of a commercial integrator. Individual weigh scales were placed within each pen to record weekly bird weights. Individual bird weigh days were designated at the end of each growth phase: starter (d 1-42), grower (d 42-91), and finisher (d 91-126) in order to measure growth performance variables [FI, LWG, FCR (adjusted for mortality), Table 3]. The starter feed was hand fed to each pen, and the grower and finisher periods utilized an automated feed conveyance and weigh system. On day 126, tom turkeys were weighed by pen and transported to a commercial processing facility. A total of 50 toms were randomly selected per treatment and utilized for descriptive carcass evaluation (Table 4).

Statistical Analysis

A pen of turkeys represented the experimental unit. Treatments were analyzed as a randomized complete block design, with birds fed one of two dietary treatments (standard pellet quality or improved pellet quality). A one-way ANOVA test was performed to compare the means of each treatment. Statistical analysis and data tables were produced through the GLM procedure of SAS [16]. Alpha was set at a p-value less than or equal to 0.05, and letter superscripts were utilized to symbolize differences among treatment means.

RESULTS AND DISCUSSION

Descriptive manufacturing parameters along with feed quality descriptors are presented in Table 2. Nutrient availability was maintained similar among both dietary treatments by manufacturing diets using consistent manufacturing techniques then generating crumble/pellet percentage differences through grinding a portion of the feed (40% crumble/pellet = standard, 70% crumble/pellet = improved). The pilot mill utilized 0.5% CaLS and the commercial feed mill manufactured the improved pellet treatment through a 30% reduction to production rate and the inclusion of CaLS at 0.5%. Previous research has shown that the inclusion of a pellet binder (CaLS) improves pellet quality [10]. Pelleting differences consisted of an average crumble/pellet difference of 30%, 1,571.6 microns particle size, and pellet durability on average differed by 65% (Table 2). Percentage differences were developed in part to continue the work of previous research done by Wamsley [19]. Wamsley [19] through a regression analysis predicted that if toms fed a ground pellet diet finished at the same weight (d 118) as those fed a high quality pellet diet, then FCR advantages of high quality pellet would be 12 points [19]. These authors also reported that toms fed a high quality pellet from 42-118 d grew 0.29 kg heavier than birds fed a ground pellet diet [19]. In the current study, the improved crumble/pellet percentage (70%) was defined as the average of the starter, grower, and finisher calculated percentage of pellets. This demonstrated a trend for an 11 point improvement in FCR (P = 0.07), along with a significant improvement to tom turkey gain of 0.17 kg (P = 0.02, Table 3). Research focusing on pelleting effects on turkey performance are sparse; however a previous study done by Lilly et al [1] demonstrated that each 10-percentage-point increase in pellets; increased FI by 100-g, improved FCR by 0.4-points, and increased breast weight by 4-g in Cobb 500 broilers [1,17]. This is similar to the results reported in a study conducted by Proudfoot and Hulan [18]; which demonstrated that pelleted finisher diets had a significant improvement on both 98-day female turkey body weight and overall FCR, concluding that the higher levels of fines had a significant detrimental effect on FCR [18]. In the current study, no descriptive carcass data demonstrated that feeding an improved crumble/pellet percentage numerically increased breast weight compared to birds fed a standard crumble/pellet percentage (Table 4). These data and past research continue to support that the use of a pellet binder and reduced pellet production rate can improve pellet quality, and feeding these improved pellet percentages can improve growth performance in meat birds.

CONCLUSIONS AND APPLICATIONS

1. A commercial feed mill was able to produce a 70% pellet to turkeys using a 0.5% CaLS diet formulation and a 30% reduction in normal pellet production rate.
2. Feeding improved quality pellets 70% pellets compared to 40% pellets improved tom turkey gain by 0.17 kg (P =0.02) and tended to decrease FCR by 11 points (P = 0.07).

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13. American Society for Agricultural Engineers. 1983. Methods for determining and expressing fineness of feed materials by sieving. Page 325 in American Society of Agricultural Engineers Standard S 319. Am. Soc. Agric. Eng. Yearbook Standards, Am. Soc. Am. Eng., St. Joseph, MI. Pellet durability index was determined by sifting 500 g of pellets from a treatment through a No. 6 American Society for Testing and Materials (ASTM) screen before being deposited into a Pfost tumbler. The sifted pellets were then tumbled in the container, dimensions 5 × 12 × 12 in., with a 2 × 9 in. plate fixed diagonally along the 12 × 12 in. side, for approximately 10 min at 50 rpm. The sample was then sifted again through the No. 6 (ASTM) mm screen, weighed, and the percentage of pellets was calculated by dividing the weight of pellets after tumbling by the weight of pellets before tumbling and then multiplying that value by 100. Modified pellet durability index was similarly measured, with the exception of the addition of five, 13-mm hexagonal bolts to the 500 g of sample in the tumbler. Both analyses are meant to simulate the deleterious effects of transferring and handling the pellets.
14. Eurofins Scientific, Des Moines, IA.
15. Turkey grow-out facility, Wardensville, WV.
16. SAS Institute. 2000. The SAS System for Windows 2000. Release 8.1. SAS Inst. Inc., Cary, NC.
17. Cobb-Vantress, Siloam Springs, AR. 2008.
18. Proudfoot, F. G., and H. W. Hulan. 1982. Feed texture effects on the performance of turkey broilers. Poult. Sci.61:327–330.
19. Wamsley, K.G.S. 2012. Strategies to maximize feed quality and poultry performance. Dissertation published by West Virginia University.

Table 1. Diet formulations[1] and Nutrient Specifications

Item	Starter diet (1 to 42 d)
Ingredient %	
Corn	35.60
Soybean Meal (48%)	41.95
Poultry Meal	10.00
Animal and Vegetable Blend Fat	7.50
Dicalcium Phosphate (18.5%)	1.80
Limestone	1.20
Salt	0.105
Sodium Bicarbonate	0.075
DL Methionine	0.365
Lysine	0.215
Threonine	0.055
VPGC Turkey Starter	0.15
Choline Chloride (60%)	0.15
Copper Sulfate (25.2%)	0.05
AXTRA PHY 10000 L	0.005
ROVABIO EXCEL LC2	0.011
Diamond V	0.125
Prem Micro-Aid Premix	0.10
Ameribond 2X[2]	0.50
Coban[3] 60	0.04
BMD[4] 50	0.05
Calculated Nutrients	
ME, kcal/lb	1474.0
Methionine, %	0.80
Lysine, %	1.85
Calcium, %	1.49
Non-Phytate Phosphorus, %	0.76
Analyzed Nutrients	
Crude Protein (%)	28.71
Crude Fat (%)	9.69
Calcium (%)	1.57
Non-Phytate Phosphorus (%)	0.72

[1]Agristat Recommendations [15]
[2]CaLS Binder at 0.5% inclusion
[3]Bacitracin methylene disalicylate, 50 g/lb (50 g/ton inclusion, Alpharma, Fort Lee, NJ), for increased rate of BW gain and improved FE.
[4]Active drug ingredient monensin sodium, 60 g/lb (90 g/ton inclusion, Elanco Animal Health, Indianapolis, IN), as an aid in the prevention of coccidiosis caused by *Eimeria necarix*, *Eimeria tenella*, *Eimeria acervulina*, *Eimeria brunette*, *Eimeria mivati*, and *Eimeria maxima*.

Table 2: Descriptive feed quality of diets fed to tom turkeys from d 1-126.

Item	Particle Size[1] (microns)	Percent Pellets[3] (%)
Diet[4]		
Prestart	1,196	0.40
Starter (SQ[5])	1,907	20.5
Starter (IQ[6])	2,521	62.6
Grower 1(SQ)	2,923	40.1
Grower 1(IQ)	4,515	79.7
Grower 2(SQ)	2,787	37.1
Grower 2(IQ)	4,226	67.0
Finisher 1(SQ)	2,088	36.0
Finisher 1(IQ)	4,479	67.2
Finisher 2(SQ)	2,669	39.2
Finisher 2(IQ)	4,164	68.4

[1] Particle size was determined with a Ro-Tap particle size analyzer model RX-29 type 110V 60H2, WS Tyler, Mentor, OH. One hundred grams of each crumbled diet was placed in a dust-tight enclosed series of stacked (No. 4, 6, . . .) American Society for Testing and Materials (ASTM) screens affixed to the Ro-Tap particle size analyzer and shaken for 10 min. The screens were then separated and weighed. Particle size was calculated by subtracting the weight of the screen from the final weight of screen and sample after shaking. The mean geometric particle size and log normal geometric standard deviation were calculated as described by McEllhiney, 1994. Multiple samples were assayed and averaged.

[2] Pellet durability index was determined by placing 500 g of sifted pellets into a Pfost tumbler. Samples were tumbled for 10min at 50 rpm. The sample was then sifted again and weighed. Pellet durability index was calculated as the percentage of sifted pellets retained after tumbling (descriptive data).

[3] Percent pellets was defined as the percentage of pellets from a representative feed sample (50lb bag) that did not pass through a No. 5 ASTM screen (descriptive data).

[4] Starter and Prestarter diets were manufactured at the West Virginia University Pilot Feed mill. Grower and Finisher diets were manufactured by a local commercial feed mill (descriptive data).

[5] SQ = Standard Quality

[6] IQ = Improved Quality

Table 3: Effect of feed quality (standard vs. improved) on tom turkey performance from d 1-126.

Item	FI per Pen[1] (kg)	Individual Tom Weight Gain (kg)	FCR[2](kg:kg)	Mortality (%)
Standard Quality	3,237.32	18.03	2.42	7.083
Improved Quality	3,235.61	18.20	2.31	10.625
ANOVA P-value	0.9921	0.0173	0.0728	0.576
SEM[3]	26.93	0.1670	0.0291	1.983

[1]FI = Feed Intake
[2]FCR = Feed Conversion Ratio
[3]Standard Error of the Mean (n=8)

Table 4: Descriptive processing plant data for d 1-126 tom turkeys.

Item	Average Canner[1] Weight (kg)	Average Breast Weight (kg)	Average Breast Yield (%)
Standard Quality	15.61	3.52	22.524
Improved Quality	15.80	3.61	22.846

[1]Canner Weight = eviscerated carcasses without giblets, necks, or feet
[2]FCR = Feed Conversion Ratio

Curriculum Vitae

Brian G. Glover, Master's Candidate

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Enthusiastic and works well within a team, but also proficient working as an individual. Not foreign to hard-work and thrives under pressure.

EDUCATION

Degree earned: Associate of Arts, Animal and Nutritional Science, Potomac State College; 2012

Degree earned: Bachelors of Science, Animal and Nutritional Science, West Virginia University; May 2013
Undergraduate GPA: 3.03

Expected Degree: Master of Science, Animal and Food Science, West Virginia University; May 2015
Thesis title: "The Effects of Modest Improvement in Pellet Quality on Tom Turkey and Broiler Performance, with Focus on Experimental Design."
Expected Graduate GPA: 3.15

PUBLICATIONS

First Author Publications:

Peer-reviewed manuscripts

B.G. Glover, A.M. Evans, and J.S. Moritz. In association with VPGC. The effects of modest improvement to pellet quality on tom turkey performance. Journal of Applied Poultry Research. (In Preparation)

B.G. Glover and J.S. Moritz. Effects Of Modest Improvements In Pellet Quality And Experiment Pen Size On Broiler Chicken Performance. Journal of Applied Poultry Research. (In Preparation)

Abstracts

B.G. Glover and J.S. Moritz. 2015. Effects of modest improvements in pellet quality and experiment pen size on broiler chicken performance. Poultry Sci. (Accepted)

B.G. Glover, A.M. Evans, and J.S. Moritz. 2014. The effects of modest improvement to pellet quality on tom turkey performance. Poultry Sci. Vol. 95 (Suppl. 1): 65.

Co-author Publications:

Peer-reviewed manuscripts

A.M. Evans, **B.G. Glover**, and J.S. Moritz. Effects of enzyme supplementation on nutrient digestibility and growth performance of chicks fed diets containing meat and bone meal. Journal of Applied Poultry Research. (In Preparation)

RESEARCH EXPERIENCE

National Meeting Paper Presentations

- 2015 Poultry Science Association (Louisville, KY; Graduate Student)
  "Effects Of Modest Improvements In Pellet Quality And Experiment Pen Size On Broiler Chicken Performance."(In Preparation)
- 2014 Poultry Science Association (Corpus Christi, TX; Graduate Student)
  "The effects of modest improvement to pellet quality on tom turkey performance."

National Meeting Poster Presentations

- 2015 Mid-Atlantic Nutrition Conference (Timonium, MD; Graduate Student)
  "Effects Of Modest Improvements In Pellet Quality And Experiment Pen Size On Broiler Chicken Performance."

Other Research Experience

- Led study examining the effects of feed form on tom turkey growth performance (Spring 2013)
- Led preliminary study examining the effects of feed form and pen size on broiler performance (Summer 2014)
- Led follow-up study on examining feed form effects and pen size on broiler performance (Spring 2015)
- Assisted study utilizing algae biomass in Cobb 500 broiler diets and its effect on live bird performance, ileal digestibility, and amino acid digestibility (Summer 2013)
- Assisted study utilizing poultry litter biochar (PLB) in Cobb 500 broiler diets and its effects on mineral sparing (Fall 2012)
- Assisted other studies funded by Verenium, DSm, Huvepharma, Aviagen, NuTech, Alltech

TEACHING EXPERIENCE

- Teaching Assistant for Poultry Production (ANPR 367)
- Teaching Assistant for Poultry Judging (Role includes lecturing occasionally in class) (ANPR 338)

EDUCATION HONORS/AWARDS

Graduated from Pendleton County High School in 2009:

- Beta Club Member (2008-2009)
- National Honor Society Member (2008-2009)
- Boys' Basketball Team Member (2005-2009)
- Golf Team Member (2008)

Scholarships/Grants Received:

- Promise Scholarship (2009-2010)
- Potomac State College Achievement Scholarship (2009-2010)
- Governors Honors Achievement (2009-2010)

OTHER EXPERIENCE

West Virginia Department of Highways **2013**

- Temporary/summer employment
- Main flagger for both primary and secondary road crews
- Animal removal from highway
- Assisted with road repair
- Assisted with pavement of roads
- Assisted with removal of storm debris and road flooding

SKILLS

- Proficient in Window's Microsoft Programs
- Internet Literate
- Poultry Handling, Judging, and Husbandry
- Feed Manufacture and Diet Formulation
- Cecectomy Surgery
- Tibia and Ileum Extraction
- Experience with statistical programs SAS and JMP

Animal specific courses taken:

-Intro to Animal Science 150
-Principles to Animal Science 251
-Issues-Animal Science 480
-Professional Field Experience 491
-Professions in Agriculture 112
-Animal Nutrition 260
-Companion Animal Science 275
- Adv Evaluation- Animal Products
- Beef Production 341,343
- Poultry Production 367, 369
- Intro to Animal Physiology 301
- Poultry Judging 301

Graduate Courses:

- Introduction to Biochemistry 410
- Nutrition/Disease Prevention 614
- Statistical Methods 511, 512
- Nutritional Biochemistry 512
- Grants/Grantsmanship 593
- Teaching Practicum 690
- Graduate Seminar 696
- General Plant Pathology 401