Effects of nutrient levels on pen-raised ring-necked pheasant performance and feather growth parameters.

by

Christopher James Delfelder

B.S., Kansas State University, 2013

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry

College of Agriculture

KANSAS STATE UNIVERSITY

Manhattan, Kansas

2021

Approved by:

Major Professor

R. Scott Beyer

Abstract

As more upland gamebird habitat is cleared for residential housing and commercial agriculture operations, the industry for restocking and hunting commercially produced ring-necked pheasants has grown substantially. While most commercial poultry production involving broilers and turkeys are evaluated by feed consumption and body growth parameters such as meat yield, the commercial pheasant production industry puts more value on a leaner bird with good feather quality. Feather quality may consist of the overall color of feathers and consistency of feather growth, as well as length of tail feathers in male pheasants raised for release.

Three research experiments were conducted to evaluate the effects of different nutrient levels and their effects on general body parameters as well as how those values affected certain feather growth characteristics. The first experiment was conducted to evaluate the effects of graded levels of protein on male pheasant chick performance and tail feather length in the 3- to 6-week and 6- to 9-week growth periods. The results of this experiment indicated that pheasant chick performance was affected based on starter ration protein levels ($P<0.05$) but the tail feathers of the male pheasant chicks were not affected by the addition or subtraction of protein into the diet ($P>0.10$). The next trial was conducted to evaluate the effects of graded protein and lysine levels in the starter phase on female pheasant chicks performance from 0 to 4 weeks of age and then subsequently measured for compensatory growth during the 4- to 8-week growth period. The data shows that hen pheasant chick performance was affected by starter ration protein and lysine levels during the first 4 weeks of growth ($P<0.05$) but body weight and feed conversion ratio were not significantly affected during the second feed period ($P>0.10$). The final experiment measured graded levels of methionine in the diets and their effects on growth performance parameters as well as feather quality of male ring-necked pheasants at 24 weeks of age. The growth parameter data showed that the males fed higher levels of methionine exhibited a greater effect on body growth characteristics as well as positive growth on feather quality at a young age.

In conclusion, certain body growth parameters and feather quality characteristics in ring-necked pheasants can be greatly affected by different nutrient levels in the diet. Through proper management of these differences, birds raised in different climates and seasons can be managed with proper phase feeding and feed costs may be significantly decreased.

Key words: ring-necked pheasant, reduced protein, feather quality, supplemental amino acids, compensatory growth

Table of Contents

List of Tables

Acknowledgements

There are many people to thank for the success of this project. I would like to thank my wonderful wife and my parents for always believing in me a pushing me to finish this degree no matter what it took. My professor, Dr. Beyer, for helping me design the facilities that made these experiments possible as well as all the time spent helping me with every aspect of my research projects. The numerous fellow graduate students in both the Department of Grain Science and Animal Sciences and Industry. From handling wild roosters, to helping me mix feed and run statistics, I would have not been able to accomplish any of this without them.

A special thanks to Robert Resser and all the students at the Poultry Research Unit for all the time helping me build pens and feed and weigh my birds. Thank you for all the hard work you accomplished to help me with my research.

Dedication

I dedicate this thesis to my amazing wife, Laura. Thank you for always sticking by my side and forcing me to persevere every time I wanted to give up.

Also, to my son Calvin. Hopefully one day you will read this and understand that hard work and perseverance will always propel you forward in life.

Chapter 1

Literature Review

Introduction

The ring-necked pheasant (*Phasianus Colchicus,* hereafter pheasant) was imported from China in the 1880s to provide a supplemental game source to immigrants arriving to the American West Coast. Since then, the pheasant has widely adapted to many states and successfully established flourishing populations in many of the central midwestern states. Although diminishing habitat due to urban expansion and other commercial agriculture has decreased pheasant numbers across the United States (US), there is still a healthy population for wing shooting enthusiasts. However, to enhance pheasant populations for hunters, gamebird producers raise pheasants for release in hunting clubs and state wildlife agency stocking programs all across the U.S.

The modern pheasant is prized for its bright, colorful plumage and quick, powerful flight style. A successful gamebird producer must produce a bird that is not only a strong, robust flyer but also is aesthetically pleasing to the hunter. Obtaining quality plumage on a highly cannibalistic, territorial bird, like the pheasant, can be a daunting task if appropriate management practices are not instituted. However, research on broiler breeders and other commercial poultry has demonstrated that appropriate nutrition can improve feather quality as well.

Since the original nutrition studies by Norris et. al., (1936), Scott et. al. (1949) and Scott et. al., (1954), there have been few studies published on nutritional standards for pheasants and studies on the effects of nutrition on pheasant feather quality is limited.

The effects that commercial feedstuffs have on feather development is generally not important economically by the commercial poultry industry. However, appropriate feathering in commercial poultry production is a crucial part of successfully growing a quality finished bird. Without proper feathering the birds may face additional hardships throughout the growing process due to an increased amount of energy expenditure for thermal regulation, which may decrease body weight. In addition to the performance challenges, poor feathering may also lead to condemnations of the carcass due to poor skin quality.

Dietary Factors Affecting Performance of Commercial Poultry

Many nutritional factors can affect the performance of commercially raised poultry. The effects of supplemental amino acid additions to diets with reduced crude protein content has been widely studied over the last few decades. Researchers formulate these diets in search of ways to decrease feed costs without sacrificing performance. Boling and Furman (1997) reported no significant differences in turkey poults fed reduced protein diets supplemented with sucrose and glutamic acid, (added at the expense of sucrose), when added to the treatment rations containing additional formulated essential amino acids and $NaHCO_3$. The research team theorized that the digestible amino acid requirements of the turkey poult may be determined by utilizing amino acid titrations from the low-protein diets with necessary amino acid supplementation. Research has demonstrated the total sulfur amino acid requirement for feed conversion efficiency and breast meat yield in broiler chicks was achieved by feeding supplemental dietary DL Methionine to a corn/soy basal ration. Supplemental methionine added at an 18% increase to the basal ration, formulated to reach a dietary sulfur amino acid level of 0.75% of the diet, resulted in improved feed conversion efficiency and weight gain (Schutte and Pack, 1995). Another study by Kalinowski et. al., (2003) confirmed these findings while researching the requirements of methionine and cysteine in fast- and slow-feathering broiler males from 3-6 weeks of age. It was formulated that, at a level of 0.46%, dietary methionine, added to the corn/soy basal ration, would produce positive linear effects to body weight, body weight gain and feed conversion. In multiple separate experiments, Bregendahl et. al., (2002) concluded that chicks fed low-protein diets (19 and 20% CP) grew slower, had a lower feed efficiency ratio and retained less nitrogen than chicks fed higher crude protein, despite supplemental crystalline asparagine and glutamine. Research has also shown that with the addition of valine and glycine to low crude protein diets, broilers in the starter period were reported having no adverse effects on body performance (Ospina-Rojas, 2014). However, researchers did discover that, during the growing period, male broiler chicks would need additional supplementation of isoleucine and arginine as well as glycine and valine to avoid compromised growth parameters.

Dietary Factors Affecting Body Performance of Gamebirds

There have been few research investigations focused on reporting the effects of nutrition on the performance characteristics of gamebird species such as pheasant and quail. The majority of research trials completed using pheasants have used commercial turkey rations as the basal ration or by using commercial lines of Japanese (Coturnix) quail to test diets and management practices. Scott and Reynolds (1949) tested this theory by utilizing a commercial turkey ration that was proven successful in producing quality turkey poults and making small systematic changes to the formula to distinguish what ingredients in the diet affected uniform growth and feathering in ring-necked pheasants. They implemented these changes over the course of 3 separate experiments. After finding the greatest performing base ration in experiment 1 (wheat middlings and pulverized oats), experiment 3 involved adding magnesium sulfate and experiment 4 added various animal proteins to verify their effects on pheasant chick performance. The results of Scott and Reynolds experiment 3 indicated that the addition of magnesium sulfate promoted feathering and decreased the occurrence of feather picking without sacrificing body growth. Experiment 4 resulted in no significant effects when supplemental glycine or animal proteins were added to the basal diet which were calculated at 1.7 and 29.1%, respectively. Scott and Reynolds (1949) concluded that except for the protein requirements, which resemble those for the turkey poult, the remaining nutritional requirements of the pheasant resemble that of the domestic chicken. Years later, Scott et al., (1962) would once again produce results pertaining to the protein and methionine requirements of pheasant chicks. Supplemental methionine was added at various levels to diets consisting of 23, 26, and 30% CP. The results indicated that at a minimum level of 0.05% inclusion, supplemental methionine added to the 26% CP ration produced similar results to the diets formulated for higher protein levels. The birds fed the 26% CP diet were similar in body weight and had the same level of feather quality as the pheasant chicks fed higher protein levels. In a similar set of trials by Woodard et. al., (1977) the researchers reported that pheasant chicks fed diets containing at least 24% CP achieved the best growth up to 8 weeks of age, at which point Woodard reported that the CP levels of the diets may be reduced to 20% until the birds are at least 16 weeks of age. Fuentes (1981) completed 3 trials to determine the effect of CP and methionine levels on pheasant chicks and adult laying hen pheasants in their first and second year of production. The first experiment consisted of 14 diets with calculated protein values of 24, 26, and 28% and containing 0.36, 0.40, 0.44, 0.48 and 0.51%, respectively, graded methionine for each level of CP. The results of experiment 1 observed that pheasant chick body weights were significantly influenced by methionine levels for all subsequent protein levels tested. At 4 weeks of age, a diet containing 26% CP with levels of methionine calculated to 0.463% was satisfactory to produce birds conditioned for release. In experiment 2 and 3 performed by Fuentes (1981) 9 experimental diets consisting of 14, 16, and 18% CP and methionine levels of 0.25, 0.29 and 0.33%, respectively for each protein level was fed to adult laying hen pheasants in their 1st and 2nd year of laying. It was concluded that that hen-day egg production was not affected by protein or methionine levels but an effect was reported for egg size where hens fed the 18% CP diet had significantly larger eggs than the hens fed 14 or 16% CP. Two experiments were conducted by Aboul-Ela et. al., (1992) to evaluate the reproductive performance of mature Bobwhite quail fed increasing levels of dietary protein. The results concluded that a significant increase in egg production was achieved in the flight-type birds in experiment 1 when the protein content of the diet was increased from 12 to 15%, but no further increase in egg production was observed at CP levels higher than 15%. The flight-type quail also saw a major increase in egg weight when fed the 18-24% CP levels. In the meat-type quail line, experiment 2 increased the protein levels from 12 to 21%, considerably increasing egg weight, but had no effect on hatchability of the eggs. It was reported by Ohlsson and Smith (2001) that pheasant chicks fed a lowered-protein diet (20.5% CP) developed less body mass and shorter tarsus lengths during the first 3-week growth period when compared to pheasant chicks fed a standard turkey starter (27% CP). However, as the birds matured, it was discovered that the birds fed the lower-protein ration from the beginning utilized accelerated growth to become equal in body mass to their higher protein fed counterparts. This study did point out that even though the low-protein birds were able to utilize compensatory growth to obtain equal body mass, the tarsus lengths of the reduced protein birds remained significantly shorter than those of the 27% CP birds. A study was conducted in England by Sage et. al., (2002) where 6 pens of juvenile pheasants were fed a high-protein diet for 10 weeks beginning at 6 weeks of age and the remaining 4 pens of birds were fed the high CP diet for 4 weeks beginning at 6 weeks of age and then a diet consisting purely of wheat grain. The results concluded that the birds removed from the high-protein diet at 10 weeks of age had significantly less body mass than the birds allowed to feed on the high protein diet for the full 10-week feeding period. More recently, using white, meat-type pheasants, Roberson (2005) concluded that after 12 weeks of age, white pheasant chicks (a type bred for meat production) could be fed a finisher ration with 17% CP and still achieve appropriate body weights compared to chicks fed a 22% CP grower ration to 20 weeks of age. This 23% reduction in CP levels would significantly decrease the feed costs of raising meat-type pheasants in a commercial setting without sacrificing weight.

Dietary Factors Affecting Feather Growth

Crude protein levels and utilization of crucial amino acids in poultry diets play a strong role in feather growth and uniformity. Many published studies have linked proper amino acid utilization to feather growth in commercial poultry flocks. Starting back as early as the 1940's, researchers were discovering the crucial role that nutrition played in feather development. In a paper published by Fuller and Wilcke (1942), the investigators discovered that a basal ration consisting mostly of oat groats was insufficient at producing normal pigmentation and structure of the feathers of New Hampshire and Barred Plymouth Rock chicks. However, once the basal ration was supplemented with a variation of untreated oat hulls or wheat bran, it was observed that the feathers of the chicks being fed this diet were normal in structure and pigmentation. Anderson and Warnick (1962) fed chicks multiple diets that were deficient in essential amino acids. The growth rate and feather development of the chicks was reduced when the ration was lacking in histidine, lysine, threonine, methionine and cysteine. More recently, a study performed by Moran (1981) reported an improvement in feed conversion with the addition of methionine into starter rations supplemented with cysteine, but saw no effect on the weight of the feathers or an effect on feather weight as a percentage of overall body weight. The effect of crude protein and lysine on feather growth was observed by Urdaneta-Rincon and Leeson (2004) when diets containing 170, 210, 250 or 290 g of CP/kg with varying levels of lysine were fed to day-old broiler chicks. The rations with lysine levels ranging from 0.86 to 1.46% affixed to the different CP levels revealed no effect on feathers as a percentage of total body weight or overall feather weight. However, when feather development was compared within individual CP levels, feather growth showed development when CP increased from 170 to 250 g/kg, but no further improvements were observed in the rations containing greater than 250 g/kg of crude protein. Wylie et al., (2003) reported the effects on dietary protein and amino acid concentrations on body weight and feather growth in turkey poults. Feather growth was significantly impacted by dietary CP compared to muscle growth in the more modern line of turkeys compared to the traditional species, wherein the higher CP percentage promoted feather growth in the breast, back and wing feathers, but surprisingly not in the tail feathers. It was also observed that feather growth was increased more by the addition of arginine and methionine in the diet than the addition of tyrosine and valine. A study involving Pekin ducks performed by Zeng et. al., (2015) demonstrated the effect dietary methionine had on feather growth and body performance parameters. It was discovered that a minimum level of 0.30% methionine level had a negative effect on averaged daily gain, breast meat yield and feather coverage. Primary wing feather length, feather coverage, breast meat weight and breast meat yield all showed significant improvement with an increase in methionine content. It was concluded that for ducks 15-35 days of age, methionine requirements of 0.468%, 0.408% or 0.484% were sufficient to provide optimal results of body weight, breast meat yield and feather coverage, respectively. Lima et al., (2016) studied the effects of lysine levels on 1-day old Japanese (Coturnix) quail performance and feathering. The quail were supplied diets consisting of levels of digestible lysine set at 8.8, 9.8, 10.8, 11.8 and 12.8 g/kg, and it was concluded that a positive, linear effect would be obtained with increasing lysine levels in the diet. Lima proved that an increase in performance between the end of the growing phase and beginning of the laying phase could be achieved using a digestible lysine level of approximately 11.85 g/kg.

Chapter 2

The Effects of Dietary Protein Level on Performance and Tail Feather Length of Male Ring-Necked Pheasant Chicks from 3-9 Weeks of Age.

Abstract

Pen raised ring-necked pheasants must be well feathered and healthy for release programs. A research trial was conducted to evaluate the effects of graded levels of protein on the performance and tail feather length of male pheasant chicks in the 3 to 6-week and 6 to 9-week growth periods. Groups of pheasants were fed diets with three protein levels of 24%, 26%, and 28%, after the first 3 weeks of growth on a commercial 28% protein starter. The crude protein content of all 3 diets were reduced by 4% in the second phase (20%, 22% and 24%, respectively), for the final 3 weeks of the 6-week trial. Body weight gain and feed consumption were determined weekly for 6 weeks. Tail feather lengths were measured weekly for the first 3 weeks and then once more at the end of the 6-week trial. Data were analyzed as a complete randomized design using the GLIMMIX procedure of SAS (9.4). No significant differences ($P \leq 0.05$) in feed intake, tail feather length or overall growth of the tail feathers were observed. A significant difference ($P \leq 0.05$) in body weight was observed for the first 3 weeks of the trial between the 24% and 28% protein diets but not between the 26% vs 28% or the 24% vs 26% protein diets. The difference in body weight was observed in the second phase with the 28% protein treatment chicks staying significantly heavier than the birds receiving the other two diets during the second 3-weeks of the trial. No significant difference ($P<.05$) in feed conversion was detected for the first 3 weeks of the trial. However, during the second 3-week period, the feed conversion ratio of the 28% fed treatment birds was lower than the ratio of the other two treatment diets. The results indicated that the performance of pheasant chicks was affected based on starter ration protein levels, but the tail feathers of the male pheasant chick were not affected by the levels of protein in the diet. More research is needed to determine whether there may be

potential for feeding programs that utilize slower growth with potential compensatory gain at an older age, so that growers holding birds for longer periods may reduce feed costs.

Key words: ring-necked pheasant, reduced protein, feather quality, growth performance, tail feathers

Introduction

As the human population increases, the need for more commercial crop production area increases as well. Unfortunately for populations of wild native gamebirds, this results in loss of vital habitat needed to produce a growing population. Although Kansas wild gamebird numbers have stayed relatively stable over the last 10 years (Dahlgren 2010, Prendergast 2020), gamebird producers across the midwestern US have taken on responsibility for providing a sustainable population of pheasant (*Phasianus Colchicus*) for the upland gamebird hunting industry. The gamebirds on these farms are raised specifically for the purpose of being released by hunting lodges and resorts across the Midwest. Therefore, it is crucial that the pheasants released from these hunting operations not only be in peak physical condition but are aesthetically pleasing as well. Limited information is known about the nutritional needs of pheasants. Traditionally, the nutritional standards of a commercial pheasant ration are based on what is known pertaining to commercial turkey diets. Boling and Firman (1997) found that a low protein diet containing the appropriate amounts of amino acid supplementation resulted in comparable growth in turkey poults compared to a standard 28% protein starter ration. Woodard et al., (1977) concluded that starter rations for pheasants should contain at least 24% protein. This level can be reduced to 20% after about 8 weeks of age. After 16 weeks of age, the pheasants can be fed diets with no more than 10% to 12% protein. Compensatory growth has been found to balance out the average body weight across treatments in pheasant chicks fed low-protein diets during the first 5 weeks of growth (Ohlsson and Smith, 2001). Utilizing the nutritional concepts from their earlier studies, Ohlsson et. al., (2002) evaluated the effect of early nutritional conditions on sexual ornament expression in pheasant males. It was concluded that males receiving a ration with 27% CP during the first 3 weeks of life grew wattles that were larger and more vibrant when sexually mature than pheasant chicks fed the low-CP ration of 20.5%. In the 4 weeks following this initial feeding period, adjustments of protein levels in the diets had no significant effect on the size or coloration of the pheasant wattles. The results of Ohlsson et. al., (2002) continued to support the hypothesis that early nutritional conditions have a significant effect on the growth of pheasant chicks throughout maturity.

A study was designed to utilize the concepts of early ration manipulation to discover the crude protein requirements of young pheasant chicks. The objectives set out to determine whether early manipulation of crude protein levels in young male pheasants would influence tail feather growth and subsequent overall length once birds reached 9 weeks of age. The research was performed to test a hypothesis that these effects would not be significant enough to deter a producer from using lower-protein diets in the early stages of chick growth to reduce overall cost without sacrificing performance.

Materials and Methods

Poultry Husbandry and Experimental Setup

The experiment was conducted during September and October, 2018, at the Thomas B. Avery Poultry Research Unit at Kansas State University, Manhattan, Kansas, US. The Institutional Animal Care and Use Committee of Kansas State University approved all procedures involving poultry according to official IACUC protocols (no. 4046). To re-create industry standards for housing pheasant chicks, multiple local Kansas gamebird producers were contacted, and each producer’s management style evaluated for efficacy. After comparing multiple management styles from producers across the state, a list of management practices for types of feeders and waterers to be used, light schedule and intensity, cannibalism control and schedule of exterior release into flight pens was developed. It was decided that this regimen of husbandry and management practices would best replicate a commercial industry style brooding and raising program for ring-necked pheasants.

For the first 3 weeks, chicks were whole house brooded and fed a commercial pheasant starter ration. After this initial feeding period, 414 birds were separated into groups of 23 birds per pen, of relative equal weight, with 18 pens total being tested. During phase 1 of this feeding, trial chicks continued to be whole house brooded and given 24-hr continuous light. Ambient temperature was maintained during the day, while night-time temperatures were maintained at 24 degrees Celsius with supplemental heat. Each floor pen had an interior section for younger birds, roughly 4.57m x 3.05m and an exterior "exercise" pen. The exterior pen, roughly 7.62m x 3.05m and accessible through a 1.0 x 0.5m door, which was completely enclosed with 2.54cm polyethylene netting allowing the birds to maintain access to outdoor environmental conditions. Birds were allowed access outdoors at 6 weeks of age. The exterior pen included a natural dirt floor with local forage (*Abutilon theophrasti, Amaranthus palmeri, Ambrosia trifida*) and grasses (*Digitaria sanguinalis, Setaria viridis*) to simulate commercial ground cover. A Plasson bell waterer and two Shenandoah feeders with 11.34kg capacity were placed inside the interior pen, as well as 8cm of dried pine shavings for bedding. Per industry management standards, pheasants were captured at 6weeks of age and fitted with Kuhl® Pin-Less Peeper® (Kuhl Corp. Flemington, NJ). These anti-pecking devices were used to minimize the risk of cannibalism and subsequent chick loss from mortality. At this point in the trial, chicks were housed at an ambient temperature inside the research facility and subjected to a light regimen that corresponded with the natural daylight patterns of the season. A lighting schedule of approximately 16hr light and

8hr dark was utilized. Cannibalism and daily mortality were monitored and chicks with “broken” or “missing” anti-pecking devices were caught weekly and refitted with new devices to maintain flock welfare.

Dietary Treatments

Throughout the extent of the trial, birds had *ad libitum* access to feed and water. Dietary rations were calculated following recommendations from Leeson and Summers (2005) and National Research Council guidelines (NRC, 1994). Pheasant chicks were initially fed a commercial starter ration containing 28% CP for the first 3 weeks of growth. For weeks 3-6 of growth, the chicks were fed 1 of 3 research diets consisting of 24%, 26% and 28% CP (Table 1); the 28% CP diet was considered to be the control ration. After week 6, each ration’s CP content was decreased by 4% for the final 3 weeks of the trial resulting in diets with 20%, 22% and 24% crude protein. All complete rations were isocaloric and fed in mash form for the extent of both 3-week feeding periods. Mash diets were manufactured in a Sudenga Model M750 single ribbon horizontal mixer and mixed for 10 minutes.

Body Performance Measurements

Pens of male pheasant chicks were evaluated for body growth differences by using standard production factors such as average body weight (BW), body weight gain (BWG) and mortality. Pheasant chicks and their respective feed storage containers were weighed at 3, 6, and 9 weeks of age. This data was used to calculate feed intake and feed conversion ratio for each individual feeding period as well for the total duration of the experiment from 3-9 weeks of age.

Feather Data Collection

Measurements of tail feather growth were calculated from an average of 5 male chicks per pen. Tail feather lengths were measured by placing a metric ruler at the base of the tail and measuring the length of the longest rectrices to the nearest centimeter. During the first 3-week feeding period, tail feather measurements were taken once per week and at the end of the subsequent 3-week feeding period. Total feather growth over the 6-week feeding period was calculated using the feather measurements from both feeding periods.

Statistical Analyses

Treatments were arranged in a completely randomized design with pens of pheasant chicks being considered as the experimental unit. Generalized linear mixed models (Proc GLIMMIX, SAS 9.4) were used to assess differences in treatment means in all measurements between groups. Statements of significance using least squares means were calculated by contrast and considered significant at $P \leq 0.05$.

Results

Body and Feather Growth Parameters

Throughout the extent of the 6-week trial there were no significant differences detected between rate of feed intake, average tail feather length, or total average tail feather growth (P=0.128, 0.855, 0.772, Table 2 and Table 3). There was no effect on mortality by treatment. Beginning on day 21 of the trial (6 weeks of age) there was a considerable difference in BWG per pen (Table 2) from the 28% crude protein diet (mean=4.90kg, SE=0.11, P=0.023) compared to the 24% CP diet (mean=4.58kg , SE=0.11). But no major differences in BWG were detected in the 28% vs 26% CP diets (P=0.257) or the 26% vs 24% CP rations (P=0.431, Table 2). Throughout the extent of the 6-week trial, the chicks with access to the highest level of CP in the diet (28%CP-24%CP), continued to have the highest level of BWG (mean=5.69kg, SE=0.13, P=0.001; Table 2). There was no significant effect on FCR (Table 2) until the 2nd 3-week period (P=0.553), where, birds fed the 28% starter had the lowest FCR (Table 2) of all three treatments (mean=2.73, SE=0.076). However, this FCR was not considered significantly different from the 26% CP diet (mean=2.87, SE=0.076, P=0.170) but was significantly different to the 24% CP diet (mean=3.00, SE=0.076, P=0.007; Table 2).

Discussion

The results of this experiment show that diets that consist of lower crude protein levels slow growth in many poultry species during early stages of life. However, for pheasant chicks that will be held in grow-out pens throughout the length of the hunting season, this reduced rate of growth may make economic sense if the performance of the mature adult pheasant will not been compromised. Producers of pen-raised pheasants should determine a feeding regimen dependent on cost of feed ingredients in their area and the environmental conditions at the time. More research is needed to narrow down the parameters of a balanced, low-protein diet with supplemental amino acids to establish a proper feeding strategy that potentially reduces cost without affecting performance.

Acknowledgements

The authors would like to thank the staff at the Kansas State University Poultry and Gamebird Research Unit for their assistance during data collection and housing of the birds associated with this trial. The authors would also like to thank MacFarlane Pheasants, Inc. for their gracious donation of the pheasant chicks.

Table 1: Composition (%) and calculated nutrient content of experimental diets.

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Corn	62.00	58.80	52.40	46.10	39.98
SBM 48%	30.30	36.10	41.50	46.80	51.91
Alfalfa Meal	2.30	-	-	-	-
Monocalium Phosphate (21%)	2.28	2.26	2.22	2.19	2.16
Limestone	1.91	1.98	1.96	1.94	1.91
Choice White Grease	-	0.01	1.11	2.15	3.12
Salt	0.4	0.41	0.41	0.41	0.41
Methionine	0.14	0.14	0.14	0.16	0.25
Lysine	0.13	0.09	0.01	-	-
Vitamin/Mineral Premix[1]	0.25	0.25	0.25	0.25	0.25
Calculated Analysis					
ME, kcal/kg	2900	2900	2900	2900	2900
CP, %	20.00	22.00	24.00	26.00	28.00
Total Lys, %	1.20	1.30	1.37	1.49	1.63
Total Met, %	0.46	0.48	0.51	0.55	0.65
Total Met and Cys, %	0.78	0.84	0.90	0.96	1.10
Calcium, %	1.20	1.20	1.20	1.20	1.20
Av. Phosphorus, %	0.60	0.60	0.60	0.60	0.60
Sodium, %	0.18	0.18	0.18	0.18	0.18

[1]Supplied/kg feed: vitamin A, 6,601 IU; cholecalciferol, 1,980 IU; niacin, 55 mg; α-tocopherol, 33 mg; pantothenic acid, 11 mg; riboflavin, 6.6 mg; pyridoxine, 4 mg; menadione, 2 mg; thiamine, 2 mg; folic acid, 1.1 mg; biotin, 0.13 mg; and vitamin B12, 0.02 mg, Zn from zinc sulfate, 120 mg; Mn from manganese oxide, 120 mg; Fe from iron sulfate, 80 mg; Cu from copper sulfate, 10 mg; I from calcium iodate, 2.5 mg; Co from cobalt chloride, 1.0 mg; Se from sodium selenite, 0.2 ppm.

Table 2: Body performance characteristics for ring-necked pheasant chicks from 3-9 weeks of age.

Treatment	Body Weight Gain (kg/pen)	Feed Intake (kg/pen)	Feed Conversion Ratio
		3-6 weeks	
24% CP	4.58^{b}	11.74	2.57
26% CP	4.72^{ab}	12.25	2.60
28% CP	4.90^{a}	12.45	2.54
p-value	0.0336	0.1048	0.5534
Linear	0.0105	0.0420	0.6323
		6-9 weeks	
20% CP	4.92^{b}	14.72	3.00^{a}
22% CP	5.12^{b}	14.68	2.87^{ab}
24% CP	5.69^{a}	15.51	2.73^{b}
p-value	0.0028	0.1733	0.0089
Linear	0.0010	0.1146	0.0025
		3-9 weeks	
24%-20%	9.50^{b}	26.46	2.79^{a}
26%-22%	9.84^{b}	26.93	2.74^{ab}
28%-24%	10.60^{a}	27.96	2.64^{b}
p-value	0.0021	0.1277	0.0114
Linear	0.0007	0.0503	0.0035

1 a,b Means followed by different letters in the same column are significantly different ($p<0.05$).

Table 3: Feather growth characteristics for ring-necked pheasant chicks from 3-9 weeks of age.

Treatment	Total Feather Length (cm)	Total Feather Growth (cm)
24%-20%	13.60	8.17
26%-22%	13.32	7.69
28%-24%	12.88	7.25
p-value	0.8548	0.7716
Linear	0.5850	0.4790

1 a,b Means followed by different letters in the same column are significantly different ($p<0.05$).

Chapter 3

The Effects of Dietary Protein and Lysine Levels on Performance Characteristics of Female Ring-Necked Pheasant Chicks from 0-8 Weeks of Age.

Abstract

Ring-necked pheasants held for breeding stock or raised for release must be provided appropriate nutrition for survival out in the wild. A trial was conducted to evaluate the effects of graded protein and lysine levels in the starter phase on female pheasant chick performance from 0-4 weeks of age and then subsequently measured for compensatory growth during the 4- to 8-week growth period. Pens of pheasants were fed diets with 26% or 28% protein and 3 levels of dietary lysine (1.5%, 1.6%, 1.7%) for each of the protein levels for the first 4 weeks. At the end of the first 4-week period, all birds were weighed and put on a commercial 24% CP chick starter. End weights for the second 4-week period were recorded and any compensatory growth was measured. Birds were placed in Petersime batteries with 8 chicks per pen and 6 replications per treatment for the first 4-week feeding period. For the following 4-week feeding period, the pheasant hens were moved to open floor pens with an outside exercise pen. Throughout the trial, birds were allowed *ad libitum* access to feed and water. Mortality, BWG, FI and FCR were determined for both the 4-week and 8-week feeding periods. Treatments were arranged in a completely randomized design and data were analyzed using the GLIMMIX procedure of SAS (9.4). Statements of significance were compared using least squares means by contrast and considered notable at $P \leq 0.05$. During the 4-week and 8-week starter periods, no substantial difference in FI, BWG, or mortality was observed. At 4 weeks of age the 28% CP diet with 1.6% lysine had a considerably lower FCR then the 26% and 28% CP diets with 1.5% lysine levels. No major differences in FCR were detected at 8 weeks of age. At 4 weeks of age a considerable difference in total average BW was observed between the 26% CP (1.5% lysine) diet and the 28% CP diets with 1.6% and 1.7% lysine levels, as well as the 26% CP diet with 1.7% lysine levels. However, this difference in BW was not observed in the second phase, where all pens of birds showed similar BW by 8 weeks. The results indicated that female pheasant chick performance was affected based on starter ration protein and lysine levels during the first 4 weeks of growth but BW and FCR were not significantly affected during the second feed period. Pheasants raised commercially for release programs may be able to utilize compensatory growth patterns to decrease feed costs during long-term holding periods. More research is needed to determine if these growth patterns continue until the birds reach market age.

Key words: ring-necked pheasant, reduced protein, lysine levels, growth performance, compensatory growth

Introduction

The commercial gamebird industry has grown exponentially over the years and thus has an expanding need for increased research into the nutritional effects formulated poultry feeds have on the growth and performance of gamebirds. Few studies in the last decade have researched these effects (specifically protein and amino acid levels), with most of the results for gamebird nutrition research taking place in the 1970s and ‘80s.

Most of what is known about pheasant nutrition has been realized by utilizing diets formulated originally for commercial turkey production (Scott and Reynolds, 1949). An experiment conducted by Warnick and Anderson (1973) tested semi-purified diets containing 28% CP on Broad Breasted Bronze turkey poults and discovered that lysine levels of 1.68% met the minimum requirements for enhanced growth. It was noted that reductions of single amino acids in the diet slightly reduced performance. Only when levels of 9 or all 10 essential amino acids were reduced to minimum levels, was growth performance greatly reduced. Following the trend of Warnick and Anderson, a series of 4 research studies performed by Tuttle and Balloun (1974) tested the effects of dietary lysine and crude protein levels in commercial Broad Breasted White turkey poults. During the first 4 weeks of age, it was determined that male poults required 28% to 30% protein with at least a minimum 1.65% supplemental lysine in the diet. From 4-8 weeks of age, the CP level of 24% to 26% was discovered to be sufficient for growth with 1.35% and 1.21% supplemental lysine added to the ration. These results confirmed that when expressed as a percentage of protein, lysine requirements from day 0 through 8 weeks of age remained similar, but after 8 weeks the requirements for lysine could be reduced to 1.12% of the overall diet. More recently, Firman (2004) assessed digestible lysine requirements in Nicolas White male turkeys. Firman's experiment resulted in determining that during the period of 7-18 days and 23-37 days the minimum requirement for digestible lysine could be 1.31% and 1.19%.

Although few studies directly related to specific pheasant nutrition exist, nutritionists and producers may utilize requirements of other Galliforme species to help determine the dietary needs of the pheasant chick. Multiple studies using Bobwhite quail have been conducted to help determine appropriate nutritional standards that could be utilized in formulating pheasant diets. For example, an experiment performed by Andrews et. al, (1973) assessed dietary crude protein levels in Bobwhite quail chicks up to 9 weeks of age. The results showed that in the initial 6 weeks of age, protein levels of 28% were sufficient to produce maximum body weight gains. After this initial 6-week period, it was concluded that 20% CP was adequate for maximum growth performance. Andrews (1973) also concluded that quail chicks fed higher levels of protein during the 6- to 9-week period, after being fed low levels of protein during the initial 6 weeks, could not overcome reduced body weights produced from the starter feeding period. Relatively fair growth was observed with quail chicks fed 20% CP for the entire 9-week feeding trial, although body weight values were considered significantly lower than values considered at the "maximum" growth level. An experiment performed by Serafin (1977) tested the nutrient levels in Bobwhite quail diets and examined the influence of protein levels in purified diets. Serafin used the results to determine sulfur amino acid (SAA) levels for the growing chick. It was reported that 26% protein was sufficient for rapid growth as long as the ration contained supplemental methionine and for optimal feed utilization. No more than 1.0% sulfur containing amino acids was necessary in the finished purified ration. Serafin also tested practical non-purified rations and discovered that at these same protein and SAA levels (26% and 1.0%) young Bobwhite quail chicks showed similar responses in bordy growth and feed utilization. Utilizing results from previous research for Bobwhite quail and ring-necked pheasants (Baldini 1953, Scott 1963) Blake et. al, (2013) reported on the effects of crude protein levels in the diets of young Hungarian partridges. The high CP regimen fed over the course of the first 9 weeks of age, (30%-26%-22%CP) provided no significant increase in body weight in the partridge chicks at any point in the trial, but did increase the overall cost of production due to the significant increases in feed consumption and FCR ratio during the 4- to 8-week feeding period. As suggested by Blake et. al, (2013), using a lower CP regimen (26%-22%-18%) over the course of the first 9 weeks of life was proven to meet the minimum requirement levels, and fed over time, produce quality feed consumption, FCR and feather scores without a major increase in ration costs. These studies have given us the parameters needed to establish similar research experiments designed to unlock the requirements for optimal growth in ring-necked pheasant chicks.

The objective was to determine the nutritional effects of lowered CP levels with supplemental dietary lysine and their effects on early chick growth performance. Female pheasant chick performance was monitored, from 0 to 4 weeks of age, to evaluate the effects of CP and lysine levels and the chicks were later measured for compensatory body growth during the 4- to 8-week feeding period. It is hypothesized by the researchers that the higher protein levels and increased levels of dietary lysine will yield higher performance parameters than the diets containing lower levels of CP and lysine.

Materials and Methods

Poultry Husbandry and Experimental Setup

The Institutional Animal Care and Use Committee of Kansas State University approved all procedures involving poultry according to official IACUC protocols (no. 4046). All experiments were maintained and completed at the Kansas State University Poultry and Gamebird Research Unit, Manhattan, Kansas, US. Utilizing 36 pens, 288 female Kansas Blueback ring-necked pheasant chicks were placed into Petersime batteries. Chicks were placed 8 to a pen for the first 4-week feeding period and 6 pens were randomly selected for each of the 6 treatments. Inside an environmentally controlled room, utilizing a 24-hour continuous lighting program, the battery brooder units contained an open-trough style feeder as well as a gravity fed watering jar. Birds had *ad libitum* access to feed and water. Each pen inside the brooder unit measured 15 x 35 x 18cm. After 4 weeks of age, all pens of birds were weighed and then pens of like-treatment birds were combined into groups and re-allotted by weight into 18 floor pens to start the second 4-week feeding period. Each floor pen measured 3.05 x 4.57m with a 7.62 x 3.05m exterior exercise pen attached to the outside and accessible through a 1.0 x 0.5m door. Polyethylene netting, with 2.54cm holes, enclosed the outdoor exercise pens to allow the birds access to outdoor environmental conditions. To simulate commercial ground cover, outdoor pens were allowed to overgrow with local forage (*Abutilon theophrasti, Amaranthus palmeri, Ambrosia trifida*) and grasses (*Digitaria sanguinalis, Setaria viridis).* The inside of the building was kept at ambient temperature and set on a 24 hr light schedule for the first 3 days of placement of the birds. Once acclimated, hens were given a modified light regime of 16hr light and 8hr dark. Birds were monitored daily for signs of cannibalism and subsequent mortality.

Dietary Treatments

National Research Council guidelines (NRC, 1994) were used to formulate all hen chick diets. Chicks in each treatment were assigned 1 of 6 treatment diets containing different dietary protein levels (26% vs 28%) with 3 different levels of graded lysine for each protein level (1.5%, 1.6%, 1.7%), on an as-fed basis (Table 4). Diets were formulated to be isocaloric. After the initial 4-week starter period, pheasant chicks were fed a commercial chick starter (24% CP) and weighed at the end of the second 4-week feeding period so any compensatory growth could be measured.

Body Performance Measurements

Individual pheasants were analyzed for body growth differences by using commercial poultry production parameters such as average body weight (BW), feed conversion rate (FCR), feed intake (FI), body weight gain (BWG) and mortality. Pheasant chicks and their respective feed storage containers were weighed at 4 weeks of age and FI and FCR was calculated for the first 4 week period. At 8 weeks of age, these calculations and measurements were repeated.

Statistical Analyses

Pens of chicks fed various diets were arranged in a completely randomized design with a whole pen of hen chicks considered as the experimental unit. Generalized linear mixed models (Proc GLIMMIX, SAS 9.4) were used to evaluate differences in treatment means between feed groups. Statements of significance were compared using least squares means by contrast. Linear and quadratic comparisons were considered notable at $P \leq 0.05$.

Results

Body Growth Parameters

No significant differences in FI (P=0.67), BWG (P=0.25) or mortality (P=0.50) were observed during the 4-week starter or the subsequent 8-week grower feed periods. It was observed that the 4-week old pheasant chicks fed the 28% CP diet with the 1.74% lysine level had a substantially lower FCR (mean=1.897 mg/kg, SE= 0.054, P=0.0004) than either CP level formulated with the lowest level of lysine (26%CP/1.5% Lys: mean=2.15 mg/kg, 28%CP/1.64% Lys: mean=2.08 mg/kg, SE=0.054, P=0.0004, Table 5). After the full 8-week feeding trial was completed, the pheasant chicks showed no major differences in FCR (P=0.82, Table 6). Hen chick average BW was affected significantly (P=0.002) at 4 weeks of age (Table 5). The pheasant chicks fed the 26% CP diet (1.5% lysine) were considerably lighter in BW (mean=145.59g, SE= 5.485, P=0.002) compared to the 26%CP diet (1.7% lysine), (mean=165.46g, SE= 5.485) and the 28% CP diets containing 1.74% (mean=167.07G, SE= 5.485) and 1.84% lysine (mean=166.72G, SE= 5.485) concentrations (Table 5). However, at the end of the 8-week trial, the chicks showed no considerable differences in BW (P=0.25) with all pens displaying similar body weights (Table 6).

Discussion

Protein and amino acid levels in early chick diets play a crucial role in the early success of ring-necked pheasant chicks (Woodard 1977, Fuentes 1981, Cain 1984). This research study revealed that starter ration protein and lysine levels were most influential in the first 4 weeks of growth for the hen pheasant chick. Average BW and FCR were considerably affected during the first 4 week feed period but not during the second 4-week feed period. It is hypothesized that the chicks utilized compensatory growth during the second feed period to reach the performance levels of hen chicks fed the higher nutrient levels. A similar trend was revealed in a trial conducted by Warner and Darda (1982) where pheasant chicks were fed two protein levels (18% and 28%). The young pheasants in this trial grew significantly quicker for the first 4 weeks post-hatching when fed the higher-protein diets. After the initial feeding period was completed, the chicks fed the 18% CP diet gained body weight just as quickly and efficiently as the chicks on the higher-protein diet. A more recent study by Sage et. al, (2002) contradicted these findings by discovering that pheasants raised in outdoor pens on a high-protein diet, from 6-16 weeks of age, weighed more when compared to birds only fed the high-protein diets from 6-10 weeks of age and a diet of wheat seeds for the remaining 6 weeks. However, it was speculated that the heavier body weights of the older birds were caused by increased fat accumulation rather than muscle mass, which was shown to be insignificantly different between the two treatment groups.

Very little data specifies the best lysine requirements for starting pheasant chicks. The lysine level ranges (1.5%-1.7%) were based on recommendations by Leeson and Summers (2005) and the NRC (1994). In an unpublished trial conducted by Millar and Smith (1971), the authors fed diets with similar lysine and protein levels as the current trial, but different results were found. At 1.45% lysine and 26% CP in the diet, Millar determined there to be no significant differences between body weights when comparing this treatment and the chicks being fed 26%CP feed with higher lysine levels (2.00% lysine).

Gamebird producers may be able to reduce feed costs by capitalizing on compensatory growth patterns created by feeding lower-protein diets with additional supplemental amino acids, such as lysine and methionine. The long-term holding periods between initial hatch and release to the field could provide ample time to allow pheasant chicks to increase growth performance parameters naturally over a longer period. More research is needed to determine if these growth patterns continue until the birds reach market age.

Acknowledgements

The authors would like to thank the staff at the Kansas State University Poultry and Gamebird Research Unit for their assistance during data collection and housing of the birds associated with this trial. The authors would also like to thank Blue Hill Gamebirds and Hatchery, LLC for their gracious donation of the pheasant chicks.

Table 4: Composition (%) and calculated nutrient content of experimental diets.

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Corn	45.90	46.30	46.20	39.70	40.10	40.40
SBM 48%	47.00	46.50	46.60	52.20	51.80	51.40
Monocalium Phosphate (21%)	2.19	2.19	2.19	2.16	2.16	2.16
Limestone	1.94	1.94	1.94	1.91	1.91	1.92
Choice White Grease	2.27	2.10	1.94	3.28	3.12	2.95
Salt	0.41	0.41	0.41	0.41	0.31	0.41
Methionine	-	0.11	0.21	0.04	0.15	0.25
Lysine	-	0.11	0.22	-	0.11	0.22
Vitamin/Mineral Premix[1]	0.25	0.25	0.25	0.25	0.25	0.25
Calculated Analysis						
ME, kcal/kg	2900	2900	2900	2900	2900	2900
CP, %	26.0	26.0	26.0	28.0	28.0	28.0
Total Lys, %	1.50	1.60	1.70	1.64	1.74	1.84
Total Met, %	0.39	0.50	0.60	0.46	0.56	0.66
Total Met and Cys, %	0.81	0.91	1.10	0.90	1.00	1.10
Calcium, %	1.20	1.20	1.20	1.20	1.20	1.20
Av. Phosphorus, %	0.60	0.60	0.60	0.60	0.60	0.60
Sodium, %	0.18	0.18	0.18	0.18	0.18	0.18

[1]Supplied/kg feed: vitamin A, 6,601 IU; cholecalciferol, 1,980 IU; niacin, 55 mg; α-tocopherol, 33 mg; pantothenic acid, 11 mg; riboflavin, 6.6 mg; pyridoxine, 4 mg; menadione, 2 mg; thiamine, 2 mg; folic acid, 1.1 mg; biotin, 0.13 mg; and vitamin B12, 0.02 mg, Zn from zinc sulfate, 120 mg; Mn from manganese oxide, 120 mg; Fe from iron sulfate, 80 mg; Cu from copper sulfate, 10 mg; I from calcium iodate, 2.5 mg; Co from cobalt chloride, 1.0 mg; Se from sodium selenite, 0.2 ppm.

Table 5: Body performance characteristics for female ring-necked pheasant chicks from 0-4 weeks of age.

Treatment	Average Body Weight (g/bird)	Body Weight Gain (g/pen)	Feed Intake (g/pen)	Feed Conversion Ratio	Mort %
26% CP					
1.50% Lys	145.59[b]	1000.41	2157.83	2.154[a]	0.021
1.60% Lys	159.89[ab]	1110.53	2165.00	1.950[bc]	0.042
1.70% Lys	165.46[a]	1134.61	2277.83	2.011[abc]	0.063
28% CP					
1.64% Lys	153.60[ab]	1013.17	2098.83	2.083[ab]	0.104
1.74% Lys	167.07[a]	1118.62	2118.17	1.897[c]	0.125
1.84% Lys	166.72[a]	1140.43	2192.17	1.940[bc]	0.083
p-value	0.002	0.250	0.672	0.0004	0.505
linear trtA	0.001	0.085	0.293	0.013	0.483
linear trtB	0.023	0.095	0.411	0.013	0.725
quadraticA	-	-	-	0.008	-
quadraticB	-	-	-	0.023	-

1 a,b,c Means followed by different letters in the same column are significantly different ($p<0.05$).

Table 6: Body performance characteristics for female ring-necked pheasant chicks from 4-8 weeks of age.

Treatment	Average Body Weight (g/bird)	Body Weight Gain (kg/pen)	Feed Intake (kg/pen)	Feed Conversion Ratio	Mort %
26% CP					
1.50% Lys	395.30	0.2488	5.017	2.764	0.267
1.60% Lys	404.00	0.2438	5.950	2.854	0.133
1.70% Lys	428.00	0.2567	6.589	2.752	0.067
28% CP					
1.64% Lys	400.70	0.2555	4.917	2.657	0.300
1.74% Lys	410.00	0.2492	6.364	2.645	0.033
1.84% Lys	408.00	0.2359	6.111	2.785	0.067
p-value	0.250	0.632	0.695	0.824	0.571

1 a,b,c Means followed by different letters in the same column are significantly different ($p<0.05$).

Chapter 4

The Effects of Graded Methionine Levels on Pen-Raised Ring-Necked Pheasant Performance and Feather-Growth Parameters.

Abstract

Ring-necked pheasants (hereafter pheasants) raised for release on game farms must have proper nutrition to assure birds and their feathers, are conditioned for flight. We used a randomized-designed trial to evaluate the effects of methionine levels on body and tail feather growth in commercial pheasants raised to 23 weeks of age. Pheasants in treatment groups were fed 1 of 3 diets containing 0.63 mg/kg, 0.70 mg/kg and 0.78 mg/kg of graded methionine for the first 8 weeks and then all were given a standard grower diet (0.70 mg/kg) for the remainder of the trial. Throughout the trial, birds were allowed *ad libitum* access to feed and water. Mortality, average body weight, body weight gain, feed intake and feed conversion ratio were determined at both the 4-week and 8-week feeding periods. Individual feather measurements were collected at the end of the first feeding period and end of the trial. Treatments were arranged in a completely randomized design and data was analyzed using the GLIMMIX procedure of SAS (9.4). Generalized linear mixed models were used to assess differences in treatments and controls. At 4 weeks there was a large difference in average body weight between pheasants exposed to the 0.63 mg/kg and the 0.78 mg/kg methionine diets, with the 0.63 mg/kg diet yielding significantly higher body mass ($P \leq 0.05$). Pheasants fed the 0.63 mg/kg diet had considerably longer tail feathers at 4 weeks of age than the birds consuming the 0.78 mg/kg diet ($P \leq 0.05$). There were no other effects on body performance or feather quality throughout the extent of the trial. Our study suggests that tail feather length and body weight may be positively affected by dietary methionine level at an early age, but these effects are likely to diminish as pheasants age to maturity.

Key words: ring-necked pheasant, methionine levels, feather growth, growth performance, compensatory growth

Introduction

As native upland gamebird habitat is lost to residential housing and agriculture (Hiller, 2009 and USDA, 2018), opportunities for hunters have diminished. The industry for commercial ring-necked pheasant (*Phasianus colchicus,* hereafter 'pheasant') production has grown substantially. Since their successful introductions from China in the late 1800's pheasants have been reared commercially across the U.S. to be released on game-hunting reserves and harvested for sport. Gamebirds have also been reared as part of state and federal release programs to help improve native breeding populations of pheasants, although these efforts were largely ineffective at increasing population numbers without supplemental habitat restoration (Anderson 1964, Hill and Robertson 1988, Leif 1994, Musil and Connelly 2009). The knowledge regarding the effects of pheasant nutrition on growth characteristics in captive facilities has largely been learned by research and applied management of large-scale production poultry applications. Most industrial poultry operations involve broilers (*Gallus gallus domesticus*) and turkeys (*Meleagris gallopavo*) and production goals are focused on increasing marketable results such as meat yield or egg production, however, the pheasant production industry values leaner birds with an emphasis on exterior body growth characteristics such as feather quality. An aesthetically appealing bird (e.g., large, colorful) that flies like a native ring-necked pheasant, is crucial in operating a successful hunt club or reserve. These factors drive marketability and sales in all pen-raised pheasant operations.

Although research regarding optimal nutritional needs in commercial poultry operations is well established, we have a limited understanding of how nutrient-specific parameters affect measures of quality in captive-raised pheasants. Wylie et al., (2003) measured the effect of nutrition on commercial white turkeys and discovered that certain amino acids played a major role in the feather coverage of male turkey poults. Additionally, deficiencies of niacin and zinc in basal diets produced both poor feather coverage and severe leg abnormalities in young pheasant chicks (Scott et al., 1959). Good feather-quality characteristics (e.g., percentage of feather coverage and color schemes, durability during transport) can be correlated to measures of individual nutrition. Currently, there are no studies quantifying the effect of nutrition on pheasant feather quality – an important profitability parameter in captive-raised pheasant operations (Carroll, et. al., 1997).

The research objectives were to assess nutritional effects on body performance and feather quality parameters of captive pheasants. Both standard body performance data and indices of feather growth and feather coverage data were used in a completely randomized design to assess the effect various levels of methionine concentration have on quality of captive-raised pheasants. It is hypothesized by the researchers that the data will demonstrate that dietary methionine levels will have a significant effect on body performance traits and feather quality in pheasant chicks.

Materials and Methods

Poultry Husbandry and Experimental Setup

All experimental procedures involving poultry use were approved by the Kansas State University Institutional Animal Care and Use Committee (IACUC no. 4046). A total of 374 male Kansas Blueback ring-necked pheasant chicks were used and randomly assigned to 3 separate Petersime® battery brooder units housed at the Kansas State University Poultry and Gamebird Research farm, Manhattan, Kansas, USA. Battery brooder units were positioned within an environmentally controlled room utilizing a 24-hour continuous lighting program. Fifty-four individual pens were designated with 7 pheasant chicks allotted by total pen body weight into each pen. Each pen was ~15.0 x 35.0 x 18.0cm with an open-trough feeder and water jar with gravity filled reservoir. After 4 weeks, all remaining birds were combined in groups by treatment, re-allotted by weight, and placed in one of 18 floor pens to begin phase 2 of the trial. Floor pens were 3.05 x 4.57m with a 7.62 x 3.05m exterior exercise pen attached to each floor pen. Each exterior exercise pen was completely enclosed with 2.54cm polyethylene netting allowing the birds to maintain access to outdoor environmental conditions and included a natural dirt floor with local forage (*Abutilon theophrasti, Amaranthus palmeri, Ambrosia trifida*) and grasses (*Digitaria sanguinalis, Setaria viridis*) to simulate commercial ground cover. Birds were kept inside the enclosed building at ambient temperature and 24-hr light until 6 weeks of age and then allowed access to the outside exercise pen through a 1.0 x 0.5m door. As per industry standards, at 6-weeks of age, all pheasants were captured, fitted with Kuhl® Pin-Less Peeper® (Kuhl Corp. Flemington, NJ) anti-pecking devices to minimalize risk of cannibalism, and exposed to a modified light regime to coincide with the natural daylight patterns (16hr light and 8 hr dark). Pheasants were held in the floor pens until full age of maturity (23 weeks) where feed and water were maintained *ad libitum* throughout the 23-week holding process. Birds were monitored daily for mortalities and cannibalism issues and birds with "lost" or "broken" anti-pecking devices were caught weekly and refitted with devices to maintain welfare of the flock.

Dietary Treatments

Each of the treatment diets were informed by National Research Council guidelines (NRC, 1994). Chicks in each treatment were given *ad libitum* access to water and assigned 1 of 3 treatment diets containing different levels of graded methionine (0.63mg/kg, 0.70mg/kg and 0.78 mg/kg) on an as-fed basis (Table 7). Diets were formulated to be isocaloric and contained the same levels of graded protein.

Body Performance Measurements

Individual pheasants were analyzed for body growth differences by using commercial poultry production parameters such as body weight gain (BWG), feed intake (FI), feed conversion rate (FCR) and mortality. Pheasant chicks and their respective feed storage containers were weighed at 4 weeks of age and calculated FI and FCR for the first 4-week period. Measurement practices were repeated at 8 weeks of age. At 8 weeks, all birds were taken off experimental feed and allowed *ad libitum* access to a common 24% crude protein poultry grower feed across all pens until they reached age of maturity at 23 weeks of age. While collecting birds to acquire feather data (see below), pheasants were weighed at 21 weeks of age.

Feather Data Collection

Multiple measures of feather quality were collected at different times throughout the study. At 8 weeks, 8 birds with unbroken tail feathers were randomly collected and their individual tail feathers measured (cm) by placing a standard ruler at the base of the tail and measuring to the tip of the longest rectrice. Birds with broken tail feathers were not measured at this time. Feather lengths from another set of randomly tested birds were collected at 23 weeks and used to measure total feather growth over the 15-week compensatory growth period. Two different feather coverage criteria were analyzed over the course of the trial. At 8 weeks, an unbiased observer assessed the amount of brown adult plumage on breasts of 8 birds per pen using a coverage-score system created specifically for this trial. Individuals were ranked on a coverage-score scale from 1 to 5 (1= no brown plumage, 3 = light brown plumage, 5 = >75% of dark brown plumage) within each pen. At 21 and 23 weeks, 8 birds per pen were evaluated for feather coverage around the head (1 = few green feathers and lacking complete white ring, 3 = complete coverage of green feathers and complete white ring) and the mean score was used as a value to represent the entire pen. At 23 weeks, tail feathers were collected to test for weight (g) and breaking strength. The two longest rectrices from 8 randomly selected test birds per pen were removed by twisting 180 degrees to break contact with the feather's keratin sheath and placed in a sealed bag inside a freezer prior to testing. Each feather was weighed individually using a Mettler Toledo Model450 balance weighing to the nearest 0.01g.

Statistical Analyses

Generalized linear mixed models (Proc GLIMMIX, SAS 9.4) were used to assess mean differences in all measures between treatment groups. Statements of significance were compared using least squares means by contrast and considered significant at $P \leq 0.05$.

Results

Body Growth Parameters

No effects on mortality were observed in association with treatment at any point during the trial (P=0.95). Feed intake, feed conversion and average body weight gain were not appreciably different (P<0.05) at 4 weeks (Table 8). However, chicks fed the lowest level of methionine (0.63mg/kg) had a tendency for less BWG (mean=852.77g, SE=53.03) than chicks in other treatments (0.70 mg/kg, mean=924.90g, SE=51.53; 0.78 mg/kg, mean=930.42g, SE=51.53; P=0.51, Table 8). The research team observed a considerable difference (P<0.05) in average chick body weight with the lowest level of methionine (0.63mg/kg) producing the lightest chicks. Average body weights equaled 158g compared to 172g and 173g for the 0.70mg/kg and 0.78mg/kg diets (Table 8). No meaningful effects (P<0.05) on FI, FCR, and BWG were observed between 4-

and 8-week growth based on treatments (Table 9). There was a linear effect on average body weight per bird ($P<0.05$) between 4- and 8-week periods (Table 9). The lower methionine level (0.63mg/kg) had a linear relationship with the average body weight per bird though the difference in body weights were not considered significant ($P=0.12$). Between the 8 and 24-week growth period there was no substantial effects ($P<0.05$) of treatment on FI, FC, and BWG (Table 9). Additionally, there was no observation on effect of treatment on average body weights at 23 weeks of age (Table 9). Although 23-week old pheasants fed the 0.63mg/kg diet were slightly heavier after the 16-week compensatory growth period, this effect was not significant ($P<0.05$).

Feather Quality

There was an effect of treatment on feather length at the end of the 4-week feed period (Table 10). At the end of the first measuring period, birds fed the 0.78mg/kg methionine diet had significantly longer tail feathers (mean = 8.76, SE = 0.27) than the birds fed the 0.63mg/kg methionine diet (mean = 7.96, SE = 0.27; $P<0.05$). This difference however, was no longer seen in the lengths of feathers during the remainder of the trial. There was no significant difference observed between tail feather growth during the 4- to 8-week or 8- to 21-week growth periods ($P<0.05$). There were no substantial differences ($P<0.05$) in brown plumage feather scoring across all treatments at 8-weeks of age and no major effects ($P<0.05$) on head feather scoring were discovered during the trial (Table 10).

Discussion

The study found multiple feather quality and physical performance parameters were affected by methionine in the pheasant chick diets. Early chick growth in most poultry species is crucial for the overall success of the bird throughout the rearing period. Improper amino acid levels have been proven to greatly inhibit growth and performance in most commercial poultry operations. (Lima et al., 2016, Schutte and Pack, 1995, Scott et al., 1959) These insufficiencies not only affect performance but cause increases in cost per bird by increasing feed expenses and expenditures associated with supplemental nutrition. Furthermore, pheasants with decreased feather strength can experience a higher chance of broken/disturbed feathers, which may contribute to a loss of marketability of that bird for release.

Considerations for the effect's nutrition has on performance in male versus female pheasants must be acknowledged in further research. Specific formulated diets can affect body performance of males and female pheasant chicks differently, and pheasant producers should adjust their feed rations to specifically enhance bird growth based on age and sex of the birds being raised. These considerations should also include decisions made by managers on regulating the cost of nutritional changes.

In this trial it was determined that chick growth and tail feather performance during the first 4 weeks was affected by methionine levels. However, once the birds reached maturity these differences were no longer detected. This idea of potential supplemental growth may give producers the capability of decreasing the methionine content in the diet during the starter period and therefore decrease feed costs. More in-depth research is needed to further narrow down the parameters of amino acid composition in pheasant diets to determine what levels can deliver an appropriate balance of feed cost and performance.

Acknowledgements

The authors would like to thank the staff at the Kansas State University Poultry and Gamebird Research Unit for their assistance during data collection and housing of the birds associated with this trial. The authors would also like to thank MacFarlane Pheasants, Inc. for their gracious donation of the pheasant chicks.

Table 7: Composition (%) and calculated nutrient content of experimental diets.

Ingredients	Diet 1	Diet 2	Diet 3
Soybean Meal	47.30	47.30	47.30
Sorghum	45.00	45.00	45.00
Soy Oil	2.380	2.360	2.320
Monocalium Phosphate (21%)	2.360	2.350	2.360
Limestone	1.840	1.840	1.840
Salt	0.420	0.420	0.420
Vitamin/Mineral Premix[1]	0.250	0.250	0.250
Methionine	0.239	0.315	0.391
L-Threonine	0.080	0.080	0.080
Calculated Analysis			
ME, kcal/kg	1318	1318	1318
CP, %	27.00	27.00	27.00
Total Lys, %	1.50	1.50	1.50
Total Arg, %	1.90	1.90	1.90
Total Met, %	0.63	0.70	0.78
Total Met and Cys, %	1.05	1.13	1.20
Total Try, %	0.73	0.73	0.73
Total Thr, %	1.10	1.10	1.10
Calcium, %	1.20	1.20	1.20
Av. Phosphorus, %	0.60	0.60	0.60
Sodium, %	0.18	0.18	0.18

[1]Supplied/kg feed: vitamin A, 6,601 IU; cholecalciferol, 1,980 IU; niacin, 55 mg; α-tocopherol, 33 mg; pantothenic acid, 11 mg; riboflavin, 6.6 mg; pyridoxine, 4 mg; menadione, 2 mg; thiamine, 2 mg; folic acid, 1.1 mg; biotin, 0.13 mg; and vitamin B12, 0.02 mg, Zn from zinc sulfate, 120 mg; Mn from manganese oxide, 120 mg; Fe from iron sulfate, 80 mg; Cu from copper sulfate, 10 mg; I from calcium iodate, 2.5 mg; Co from cobalt chloride, 1.0 mg; Se from sodium selenite, 0.2 ppm.

Table 8: Body performance characteristics for ring-necked pheasant chicks from day 0-28.

Methionine mg/kg	Body Weight (g/bird)	Body Weight Gain (g/pen)	Feed Intake (g/pen)	Feed Conversion Ratio	Mort %
0.63	158.29^{b}	852.77	1575.24	1.8751	0.1598
0.70	172.70^{ab}	924.90	1641.44	1.7924	0.1747
0.78	173.65^{a}	930.42	1670.39	1.8044	0.1748
p-value	0.0126	0.5111	0.7142	0.0709	0.9507

1 a,b Means followed by different letters in the same column are significantly different (p<0.05).

Table 9: Body performance characteristics for ring-necked pheasant chicks from day 56-161.

	Days of age							
	56				112	161		
Methionine mg/kg	Body Weight (kg/bird)	Body Weight Gain (kg/pen)	Feed Intake (kg/pen)	Feed Conversion Ratio	Feed Intake (kg/pen)	Body Weight of males (kg/bird)	Body Weight of females (kg/bird)	Body Weight of pen (kg/bird)
0.63	0.43	3.08	8.61	2.84	52.84	1.15	0.81	1.12
0.70	0.45	3.39	9.20	2.72	64.70	1.13	0.78	1.01
0.78	0.46	3.10	8.44	2.75	58.18	1.14	0.83	1.09
p-value	0.1153	0.6604	0.6432	0.4315	0.3445	0.6239	0.6002	0.5183
linear	0.0426	-	-	-	-	-	-	-

1 a,b Means followed by different letters in the same column are significantly different (p<0.05).

Table 10: Feather growth characteristics of ring-necked pheasant chicks from day 28-161.

	Days of Age							
	28	56		147		56	147	161
Methionine mg/kg	Total Tail Length (cm)	Total Tail Length (cm)	Total Growth (cm)	Total Tail Length (cm)	Total Growth (cm)	Breast Feather Score	Head Feather Score	Head Feather Score
0.63	7.96[b]	11.14	3.18	50.79	39.65	3.54	1.92	2.14
0.70	8.61[ab]	11.61	3.00	50.29	38.66	3.84	1.90	2.23
0.78	8.76[a]	11.36	2.60	50.34	38.98	3.67	2.24	2.24
p-value	0.0204	0.3048	0.3010	0.7343	0.2732	0.5156	0.2267	0.8571
linear	0.0081	-	-	-	-	-	-	-

1 a,b Means followed by different letters in the same column are significantly different ($p<0.05$)

References

Aboul-Ela, S., H. R. Wilson, and R. H. Harms. 1992. The Effects of Dietary Protein Level on the Reproductive Performance of Bobwhite Hens. Poult. Sci. 71:1196-1200. doi.org/10.3382/ps.0711196.

Anderson, W. L. 1964. Survival and reproduction of pheasants released in southern Illinois. Journal of Wildlife Management 28:254–264.

Andrews, T. L., R. H. Harms, and H. R. Wilson. 1973. Protein requirement of the bobwhite chick. Poult. Sci. 52:2199–2201. doi.org/10.3382/ps.0522199.

Baldini, J. T., R. E. Roberts, and C. M. Kirkpatrick. 1953. Low protein rations for the bobwhite quail. Poult. Sci. 32:945–949. doi.org/10.3382/ps.0320945.

Blake, J.P., J.B. Hess, and W.D. Berry. 2013. Effect of two protein regimens and two lighting intensities on performance of the Hungarian Partridge (*Perdix perdix*). J. of Appl Poult Res. 22: 365-369. doi.org/ 10.3382/japr.2013-00755.

Boling, S.D., J. D. Firman. 1997. A low-protein diet for turkey poults. Poult. Sci. 76:1298–1301. doi.org/10.1093/ps/76.9.1298.

Bregendahl, K., J. L. Sell, and D. R. Zimmerman 2002. Effect of Low Protein Diets on Growth Performance and Body Composition of Broiler Chicks. Poult. Sci. 81:1156-1167. doi: 10.1093/ps/81.8.1156.

Cain, J.R., J.M. Weber, T.A. Lockamy, and C.R. Creger, 1984. Grower diets and bird density effects on growth and cannibalism in ring-necked pheasants. Poult Sci. 63: 450-457.

Carroll, J. P., P. A. Robertson, and R. A. H. Draycott. 1997. Flight characteristics, hunter selection and morphometrics of reared pheasants (Phasianus colchicus) in England. Gibier Faune Sauvage 14:601–614.

Dahlgren, D. 2010. Quail, Pheasant and Turkey Brood Survey. Kansas Department of Wildife, Parks and Tourism Performance Reports. Retrieved from https://ksoutdoors.com/Services/Research-Publications/Wildlife-Research-Surveys/Upland-Bird.

Firman, J. 2004. Digestible lysine requirements of male turkeys in their first six weeks. Int. Jrnl. Poult. Sci. 3 (6): 373-377.

Fuentes, M. 1981. Protein and Methionine Requirements for Starting and Laying Ring-necked Pheasants. Ph.D. dissertation. Michigan State University, East Lansing, Mich.

Hill, D., and P. A. Robertson. 1988. Breeding success of wild and hand-reared ring-necked pheasants. Journal of Wildlife Management 52:446–450.

Hiller, T. L., L. A. Powell, T. D. McCoy, and J. J. Lusk. 2009. Long-term agricultural land-use trends in Nebraska, 1866–2007. Great Plains Research 19:225–237.

Leif, A. P. 1994. Survival and reproduction of wild and pen-reared ring-necked pheasant hens. Journal of Wildlife Management 58:501–506.

Leeson, S. and J.D. Summers. 2005. Commercial Poultry Nutrition. 3rd Ed, Publ. University Books, Guelph, Ontario Canada. (2005).

Lima, H. J. D., S.L.T. Barreto, J.L. Donzele, G.S. Souza, R.L. Almeida, I.F.F. Tinoco, L.F.T. Albino. 2016. Digestible lysine requirement for growing Japanese quails. Journal of Applied Poultry Research. 25:483-491. doi.org/10.3382/japr/pfw030.

Millar, R. I. and L.T. Smith. 1971. Evaluation of Varying Methionine and Lysine Levels in a 26 Percent Protein Starter Diet for Ringneck Pheasants. Poult. Sci. 50: 1606. doi.org/10.3382/ps.0501542.

Musil, D. D., and J. W. Connelly. 2009. Survival and reproduction of pen-reared vs. translocated wild pheasants (Phasianus colchicus). Wildlife Biology 15:80–88.

Norris, L. C., L. J. Elmore, and R. C. Ringrose. 1936. The Protein Requirement of Ring-necked Pheasant Chicks. Poult. Sci. 15:454-459. doi.org/10.3382/ps.0150454.

NRC (1994) Nutrient Requirements of Poultry, 9th rev. edn (Washington, DC, National Academic Press).

Prendergast, J. 2020. Quail, Pheasant and Turkey Brood Survey. Kansas Department of Wildlife, Parks and Tourism Performance Reports. Retrieved from https://ksoutdoors.com/Services/Research-Publications/Wildlife-Research-Surveys/Upland-Bird.

Ohlsson, T., and H. G. Smith. 2001. Early nutrition causes persistant effects on pheasant morphology. Phys. Biochem. Zool. 74:212–218.

Ohlsson, T.; H. G. Smith, L. Rberg, and D. Hasselquist. 2002. Pheasant sexual ornaments reflect nutritional conditions during early growth. Proceedings of the Royal Society B: Biological Sciences. 269:21-27. doi.org/10.1098/rspb.2001.1848.

Sage, R. B., A. Putaala, and M. I. A. Woodburn. 2002. Comparing Growth and Condition in Post Release Juvenile Common Pheasants on Different Diets. Poultry Sci. 81:1199-1202. doi.org/10.1093/ps/81.8.1199

Schutte, J. B. and M. Pack. 1995. Sulfur amino acid requirement of broiler chicks from fourteen to thirty-eight days of age. 1. Performance and Carcass Yield. Poultry Sci. 74: 480-487. doi.org/10.3382/ps.0740480.

Scott, M. L. and R. E. Reynolds, 1949. Studies on the nutrition of pheasant chicks. Poult. Sci. 28:392-397. doi.org/10.3382/ps.0280392.

Scott, M. L., E. R. Holm, and R. E. Reynolds, 1954. Studies on pheasant nutrition. 3. Effect of antibiotics, arsenicals, and thyroactive compounds upon growth and feathering in pheasant chicks. Poult. Sci. 33:1261- 1265. doi.org/10.3382/ps.0331261.

Scott, M. L., E.R. Holm, and R.E. Reynolds. 1959. Studies on the niacin, riboflavin, choline, manganese and zinc requirements of young ring-necked pheasants for growth, feathering and prevention of leg disorders. Poultry Sci. 38:1344–1350. doi.org/10.3382/ps.0381344

Scott, M. L., E. R. Holm, and R. E. Reynolds. 1963. Studies on the protein and methionine requirements of young bobwhite quail and ring-necked pheasants. Poult. Sci. 42:676–680. doi.org/10.3382/ps.0420676.

Serafin, J. A. 1977. Studies on the protein and sulfur amino acid requirements of young bobwhite quail. Poult. Sci. 56: 577-585. doi.org/10.3382/ps.0560577

Tuttle, W.L., and S.L. Balloun. 1974. Lysine requirements of starting and growing turkeys. Poult. Sci. 53:1698-1704. doi.org/10.3382/ps.0531698.

U.S. Department of Agriculture. 2018. Summary Report: 2015 National Resources Inventory, Natural Resources Conservation Service, Washington, DC, and Center for Survey Statistics and Methodology, Iowa State University, Ames, Iowa.

Warner, R.E., D.M. Darda, D.H. Baker. 1981. Effects of dietary protein levels and environmental temperature stress on growth of young ring-necked pheasants. Poult. Sci. 61:673- 676. doi.org/10.3382/ps.0610673.

Warnick, R.E., and J. O. Anderson. 1973. Essential amino acid levels for starting turkey poults. Poult. Sci. 52: 445-452. doi.org/10.3382/ps.0520445.

Woodard, A. E., P. Vohra, and R. L. Snyder. 1977. Effect of protein levels in the diet on the growth of pheasants. Poult. Sci. 56:1492. doi.org/10.3382/ps.0561492.

Wylie, L.M., G.W. Robertson and P.M. Hocking. 2003. Effects of dietary protein concentration and specific amino acids on body weight, body composition and feather growth in young turkeys. British Poultry Science, 44:1, 75-87, doi: 10.1080/0007166031000085346.