

2011

Optimizing the feeding time for low crude protein, amino acid-supplemented diets for broilers

Stephen T. Treese

Louisiana State University and Agricultural and Mechanical College

Follow this and additional works at: https://digitalcommons.lsu.edu/gradschool_theses



Part of the [Animal Sciences Commons](#)

Recommended Citation

Treese, Stephen T., "Optimizing the feeding time for low crude protein, amino acid-supplemented diets for broilers" (2011). *LSU Master's Theses*. 730.

https://digitalcommons.lsu.edu/gradschool_theses/730

This Thesis is brought to you for free and open access by the Graduate School at LSU Digital Commons. It has been accepted for inclusion in LSU Master's Theses by an authorized graduate school editor of LSU Digital Commons. For more information, please contact gradetd@lsu.edu.

**OPTIMIZING THE FEEDING TIME FOR LOW CRUDE PROTEIN,
AMINO ACID-SUPPLEMENTED DIETS FOR BROILERS**

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The Interdepartmental Program in the School of Animal Sciences

by
Stephen T. Treese
B.S., Louisiana State University, 2009
August, 2011

ACKNOWLEDGMENTS

I would like to thank Dr. Southern for giving me the opportunity to join his research program and passing on a wider array of knowledge than I ever expected. I would also like to show my gratitude to Dr. Bidner and Dr. Williams not only for serving on my committee, but also for increasing confidence in myself and believing in my capabilities to reach my goals long before I did.

I would like to thank Jason Schmidt for his advice, assistance, and friendship over my entire LSU education. Allowing me to assist in his graduate research while I was an undergraduate helped set the road in front of me. During stressful times, he and his family have been the most continuous source of trust and support I've had in this city.

I want to show thanks to my parents and family for their support of my endeavors. Regardless of whether they agreed with my decisions, they respected me enough to allow me the independence to pursue them as I wished.

I want to thank Mindy Haslauer for being the one friend I could always call on for coffee whenever the stress of the day required my mind to release itself from the situation. My gratitude to Sam and Lyn Bailey cannot be underestimated as your encouragement to reach my goals helped lead me to where I am today.

Lastly, but not least, I would like to thank the graduate students for their assistance and making all the hard times more enjoyable than was ever called for by the situation. I also want to show my gratitude to Syrena. Despite our differences and feuds, her guidance was invaluable. I would also like to thank April, Jose, and Victor for their assistance and guidance over the past two years. To the other graduate students in animal sciences, thank you for more positive memories than I ever had during my undergraduate education.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	ii
LIST OF TABLES.....	iv
ABSTRACT.....	v
CHAPTER	
1 INTRODUCTION.....	1
2 REVIEW OF LITERATURE	2
INTRODUCTION.....	2
DIETARY MODIFICATIONS OF DIETS WITH REDUCED CRUDE PROTEIN.....	3
DELAYING THE FEEDING OF DIETS WITH REDUCED CRUDE PROTEIN.....	5
TRANSITION TO FEED AND INTESTINAL DEVELOPMENT	6
PHASE FEEDING AND CARRYOVER EFFECTS	7
3 OPTIMIZING THE FEEDING TIME OF LOW CRUDE PROTEIN DIETS WITH SUPPLEMENTAL L-LYSINE FOR BROILER CHICKS	10
INTRODUCTION.....	10
MATERIALS AND METHODS	11
RESULTS.....	15
DISCUSSION	24
4 SUMMARY AND CONCLUSIONS.....	32
REFERENCES.....	34
VITA	38

LIST OF TABLES

Table

3.1. Percentage composition of corn-soybean meal diets with supplemental L-Lysine used in all experiments, as-fed basis.....	13
3.2 Effects of delaying the feeding of diets low in crude protein, supplemented with L-Lysine, on the growth performance of broiler chicks in Experiment 1.....	16
3.3 Effects of delaying the feeding of diets low in crude protein, supplemented with L-Lysine, on the growth performance of broiler chicks in Experiment 2.....	18
3.4 Effects of switching from diets low in crude protein, supplemented with L-Lysine, to a L-Lysine-free positive control (PC) diet on the growth performance of broiler chicks in Experiment 3.....	19
3.5 Effect of switching to and from a diet low in crude protein, supplemented with 0.15% L-Lysine, on the growth performance of broiler chicks in Experiment 4.....	21

ABSTRACT

The objectives of this research were to determine whether delaying the feeding of a diet with reduced crude protein, supplemented with L-Lysine, for several days post-hatching, would result in improved growth performance of broiler chicks and determine an optimal time to feed such a diet to the chick. All experiments were conducted in brooder batteries from 0- to 14- or 18- days (d) post-hatching. Treatments contained a minimum of 6 replicate pens with at least 6 broilers per pen. Two experiments were conducted to determine whether delaying the feeding of a corn-soybean meal (SBM) diet with reduced CP for either the first 5 or 10 days post-hatching would result in improved growth performance of broilers. The results of these experiments show that even when the diets are not deficient in amino acids (AA), feed efficiency is negatively affected by switching birds to a low CP diet several days after post-hatching; effects on daily gain are minimal until the diet becomes deficient in AA. Two experiments were conducted to determine the optimal time to feed a diet with reduced CP, supplemented with L-Lysine, to the chick. The results of these experiments indicate that as long as the diets are not deficient in AA, overall growth performance during the starter phase is not negatively affected for broilers switched from diets with reduced CP to one with an adequate level, at day 5 or day 10 post-hatching, or those fed the reduced CP diets continuously.

CHAPTER 1

INTRODUCTION

There has been increasing pressure on the poultry industry in recent years to limit the amount of nitrogen emissions to the environment. To maximize economic returns with the increasing prices of feed ingredients, the most cost effective means to minimize nitrogen excreted to the environment by broilers is to feed diets with reduced levels of CP, utilizing commercially available AA.

However, reductions in the CP content of broiler diets, especially greater than 2%, have not always shown growth performance equal to that of a diet with a normal level of CP. Attempts to correct this decrease in performance, including the addition of nonessential AA (Si et al., 2004; Jiang et al., 2005), adjusting the dietary electrolyte balance (DEB) (Fancher and Jensen, 1989; Si et al., 2004), adding nonspecific N (Jiang et al., 2005; Pinchasov et al., 1990), and addition of essential AA exceeding the NRC (1994) recommendations (Namroud et al., 2008; Bregendahl et al., 2002) have often failed to be successful. Yet, Han et al. (1992), Parr and Summers (1991), and Edmonds et al. (1985) have shown growth performance equal to a control diet when feeding a diet with a substantially reduced CP and supplemental AA when the reduction in dietary CP was delayed, feeding a prestarter diet to the broiler chick for the first week of life. Therefore, the objective of this research was to determine the optimal time to feed a diet with a reduced CP content supplemented with L-Lysine and determine whether delaying the feeding of such a diet for several days post-hatching would result in adequate growth performance for broiler chicks.

CHAPTER 2

REVIEW OF LITERATURE

INTRODUCTION

Excessive nitrogen emissions from livestock can influence water quality and are seen as a possible cause for acid rain. As more than 60% of nitrogen taken in by the animal is excreted (Ferket et al., 2002), it is of great interest to the poultry industry to develop a feeding program that minimizes nutrient losses from livestock. By adding highly digestible crystalline AA and reducing the CP content of the diet, the amount of nitrogen excreted can be reduced (Powers and Angel, 2008). Nevertheless, use of the commercially available crystalline AA (DL-Met, L-Lys, L-Thr, and L-Thr) and other AA in diets with a reduced CP content have often shown decreased gain, decreased feed efficiency, and increased abdominal fat (Ferguson et al., 1998a; Si et al., 2004; Bregendahl et al., 2002). Unsuccessful attempts to improve growth performance have included adjustment of the DEB (Fancher and Jensen, 1989; Si et al., 2004), additions of essential (Namroud et al., 2008; Bregendahl et al., 2002) and nonessential AA (Si et al., 2004; Jiang et al., 2005), and supplementing non-specific nitrogen (Jiang et al., 2005; Pinchasov et al., 1990). However, some researchers have shown significant improvement in growth performance when delaying the feeding of a diet with reduced CP approximately one week post-hatching (Edmonds et al., 1985; Parr and Summers, 1991; Han et al., 1992; Corzo et al., 2005). Despite the physiological changes that occur during the first week post-hatching, including the transition from the yolk to feed as the main nutrient source, little research has been done on AA requirements during this phase (Garcia and Batal, 2005). As such, the reason for these discrepancies in growth and feed efficiency is unknown.

DIETARY MODIFICATIONS OF DIETS WITH REDUCED CRUDE PROTEIN

There have been numerous attempts to improve the growth performance of broilers fed AA supplemented diets with reduced CP, including adjustment of the DEB (Fancher and Jensen, 1989; Si et al., 2004), supplementation with essential (Namroud et al., 2008; Bregendahl et al., 2002) and nonessential AA (Si et al., 2004; Jiang et al., 2005), and adding a form of nonspecific nitrogen (Jiang et al., 2005; Pinchasov et al., 1990). However, these modifications have often failed to be successful in correcting the negative growth performance seen in broilers fed diets with a reduced CP content decreased greater than 2%.

Reducing the CP in C-SBM diets for broilers reduces the SBM content of the diet and thus, the potassium content. This, in combination with increasing Lysine•HCl from AA-supplementation, alters the =DEB and can create an acid-base imbalance. Si et al. (2004) supplemented low CP diets with potassium sulfate to raise the DEB up to standard diets and failed to show equal growth performance for 1- to 21-d chicks. Fancher and Jensen (1989) and Han et al. (1992) used potassium carbonate to raise the DEB of low CP diets and also failed to show equal growth performance for 7- to 21-d broilers.

Reducing the CP of broiler diets also decreases the amount of excess essential amino acids (EAA) present in the diet, possibly limiting the amount of nonessential amino acids (NEAA) the bird can synthesize. Supplementing L-Glu as a source of nonspecific nitrogen (NSN), Pinchasov et al. (1990) and Fancher and Jensen (1989) failed to maximize growth performance in 7- to 21-d broiler chicks and 21- to 42-d broilers, respectively. Bregendahl et al. (2002) also reported inadequate growth performance of diets with reduced CP using triammonium citrate as a source of NSN with crystalline NEAA supplementation. Addition of 3% L-Glu resulted in feed efficiency comparable to a 24% CP control diet, but the same effect

was not seen for weight gain (Edmonds et al., 1985). Additionally, Han et al. (1992) reported growth performance of diets with a reduced CP comparable to a 23% control diet with 2% DL-Met when supplemented with EAA and L-Glu; nonetheless, only in one experiment did the researchers find improvement of supplementing L-Glu on feed efficiency over supplementation of EAA alone for 8- to 22-d broiler chicks. Recently, L-Glu supplementation with L-Val alone, L-Ile and L-Val, or L-Val, L-Ile, and Gly showed growth performance equivalent to a control for 1- to 42-d broilers (Berres et al., 2010).

Other research has been conducted in order to determine if any NEAA became limiting in AA supplemented diets with reduced CP. However, supplementation of L-Asn or L-Gln was shown to be unsuccessful in improving gain and feed efficiency for 7- to 21-d broiler chicks (Bregendahl et al., 2002). Jiang et al. (2005) supplemented combinations of Gly, L-Pro, and L-Glu to diets with 16 or 18% CP and found an improvement in performance when Gly was included in the supplementation, but not to the level of a control diet with 22% or 24% CP. Parr and Summers (1991) supplemented Gly or a combination of L-Glu, L-Asp, L-Ala in diets with a reduced CP content. They reported growth performance superior to a control diet when L-Gly was added and no further improvement over EAA supplementation when L-Glu, L-Asp, and L-Ala were used in 7- to 21-d broiler chicks. When Gly, L-Ala, L-Asp, L-Glu, L-Pro, L-Leu were added individually or together to diets with reduced CP for 5- to 21-d broiler chicks, growth performance at day 13 was decreased compared with a control diet (22% CP) when the AA were added individually, but not when they were supplemented together. By day 21, supplementing with Gly, L-Asp, and L-Leu individually resulted in growth performance as well as supplementing all the NEAA and Leu together and the control diet (Corzo et al., 2005). Dean et

al. (2006) also reported similar growth performance for chicks fed diets low in CP from 0- to 18-d post-hatching when Gly was supplemented alone or in combination with other NEAA.

Further attempts to improve the negative growth performance seen in diets with a CP reduction greater than 2% have considered EAA supplementation. Namroud et al. (2008) and Jiang et al. (2005) supplemented EAA at 10% above the NRC (1994) recommendation and were unsuccessful in improving the growth performance of broilers to that of a control diet. Fancher and Jensen (1989) also supplemented EAA (L-Thr, L-Arg, L-Ile, and L-Trp) at 10% in excess of the NRC (1994) recommendation and failed to improve the negative growth performance seen with a reduced dietary CP. Bregendahl et al. (2002) supplemented EAA even higher, at 15, 30, and 45% above the NRC recommendations and reported growth performance below that of a control diet. Conversely, Han et al. (1992) reduced the dietary CP content by 4% and supplemented EAA to the level seen in the control diet and reported comparable growth performance among the dietary treatments. When EAA were supplemented at the minimum or 10% in excess of minimum NRC recommendations as each AA became limiting in diets with reduced CP, Parr and Summers (1991) found comparable growth performance for 7- to 21-d broiler chicks.

DELAYING THE FEEDING OF DIETS WITH REDUCED CRUDE PROTEIN

Previous research involving diets with reduced CP, supplemented with AA, has varied as to when their feeding began, often starting immediately post-hatching or one week later, following the feeding of a prestarter diet with a normal dietary CP level.

Han et al. (1992) began feeding diets with reduced CP levels to broiler chicks at day 7 and continued to day 21 post-hatching and found comparable growth performance when the limiting EAA were supplemented, with and without nonspecific nitrogen in the form of L-Glu. Si

et al. (2004) supplemented similar levels of EAA to diets with reduced CP and failed to show growth performance comparable to a control diet when feeding commenced at day one post-hatching.

Immediately, post-hatching, Jiang et al. (2005) and Waldroup et al. (2005) supplemented diets with the NEAA's Gly and L-Glu, as well as the limiting EAA in diets with a reduced level of CP and reported growth performance poorer than that of a control diet with 24% CP at 21 days of age. Feeding a prestarter diet with a normal level of CP for the first seven days post-hatching, other researchers have reported adequate growth performance when supplementing L-Glu and/or Gly with limiting EAA to diets low in CP (Edmonds et al., 1985; Parr and Summers, 1991). Corzo et al. (2005) fed a prestarter diet for the first five days post-hatching and showed growth performance of broiler chicks comparable to a control diet when diets with a reduced level of CP, supplemented with L-Leu or Gly, were fed thereafter.

Further research with supplementation of L-Glu to diets low in CP has also utilized a prestarter diet for the first week, yet failed to show adequate growth performance of broiler chicks by 21 days post-hatching (Fancher and Jensen, 1989; Pinchasov et al., 1990).

Additionally, Berres et al. (2010) started feeding diets supplemented with NEAA at day 1 and found growth performance of chicks comparable to a control diet with 26% CP.

TRANSITION TO FEED AND INTESTINAL DEVELOPMENT

For the first few days post-hatching, the intestinal tract is underdeveloped and the yolk provides the majority of the nutrients for the young broiler chick (Sweenen et al., 2010). For optimal growth and transition to feed, the loss of the yolk should coincide with the development of the gastrointestinal tract's ability to recover nutrients from the feed (Moran, 2007).

The intestinal enzymes, mucosa, and villi required for nutrient absorption is immature in the newly hatched chick. The presence of feed in the intestinal tract helps promote a several-fold increase in their development with early access to feed hastening this growth (Noy and Uni, 2010). However, villus volume doesn't reach a maximum in the duodenum until at least 7 days of age (Uni et al., 1998). Similarly, Uni et al. (1995) reported an increase in villus height and width from 4 to 10 days of age..

Increases in nitrogen and AA digestibility have also been shown to increase as the chick ages, compensating for the loss of the yolk as a nutrient source. Uni et al. (1995) reported a 20 percent increase in nitrogen digestibility from 4- to 14-d after hatch and trypsin amounts greatest at 4 days of age. For a C-SBM diet, Batal and Parsons (2002a) showed an increase in AA digestibility through 10 days of age with a New Hampshire x Columbian strain and increases through 21 days of age for a commercial broiler chick.

For the first 3 days post-hatching, the yolk is responsible for over a fifth of the energy and almost a third of the protein utilized by the chick (Murakami et al., 1992). Additionally, reducing the CP of diets fed to broiler chicks has been shown to hasten the resorption and utilization of the yolk. Feeding diets low in CP showed a higher percentage decrease in yolk weight at 2 days of age than diets low in carbohydrate or fat content (Sweenen et al., 2010). While a reduction in weight was not seen through 5 days of age, Wiertelcki and Jamroz (2003) reported a faster resorption of the yolk sac in birds fed diets with a reduced CP content.

PHASE FEEDING AND CARRYOVER EFFECTS

After dietary deficiencies and restriction, broiler chicks have been shown to grow at a faster rate than those without any previous deficiency. This compensatory growth and other

carryover effects have often been shown in phase feeding and other instances in which chicks are fed diets varying in nutrient composition (Palo et al., 1995).

Zhan et al. (2007) restricted feed for the first 21 days after hatching and saw decreased growth performance at 21 days, but no differences at 63 days, a result of compensatory growth for the last six weeks. Restricting birds fed from day 7 to day 14 after hatch showed greater feed efficiency after the restriction period through 48 days as well as larger pancreases, showing compensatory effects and some recovery from the decreased performance seen during feed restriction (Palo et al., 1995). Sklan and Noy (2003) showed full compensatory gains in feed efficiency, but not weight gain, by marketing at 40 days of age when diets with reduced CP levels were fed for the first week of life. Conversely, the same set of researchers saw full compensatory growth performance in another experiment, feeding a diet with reduced CP for the first week after hatch (Sklan and Noy, 2002). However, Leeson and Zubair (1997) showed a decline in growth rate when feeding extra dietary lysine after feeding a deficient diet from 6 to 12 days of age.

Other carryover effects have also been seen with manipulation of the CP content of diets for broiler chicks. Lemme et al. (2007) showed that increasing dietary CP fed to broilers above what is considered adequate for the first 8 or 12 days post-hatching increased weight gain through the 14 day experimental period. Wjitten et al. (2004) reported that responses in weight gain and feed efficiency to CP levels depend on the CP levels fed in the preceding phases. They reported that increased CP levels in the grower and finisher diets show a less pronounced response when higher than adequate CP levels were used in the preceding diets.

While some researchers have shown compensatory gains and improved growth performance among broiler chicks after being fed deficient diets, others have shown negative

effects to feeding diets differing in dietary CP and lysine level. Alternating CP and lysine levels to be surplus and deficient at one week intervals, Dilger et al. (2006) reported decreased feed efficiency in chicks fed the fluctuating dietary regime while gain was unaffected. Cabel and Waldroup (1991) showed decreased feed efficiency in chicks fed gradually reduced CP levels in their diets over those fed a continuous level of dietary CP. Conversely, Warren and Emmert (2004) showed no reduction in performance in broilers fed a weekly phase feeding regime through the starter phase compared with a single diet formulated on NRC recommendations fed for the whole period.

CHAPTER 3

OPTIMIZING THE FEEDING TIME OF LOW CRUDE PROTEIN DIETS WITH SUPPLEMENTAL L-LYSINE FOR BROILER CHICKS

INTRODUCTION

Reducing the amount of nitrogen lost to the environment has been an increasing concern for the livestock industry over the past couple decades (Ferket et al., 2002). Reducing the CP in diets fed to broilers has been shown to limit the amount of excess nitrogen released to the environment (Blair et al., 1999; Ferguson et al., 1998b). However, feeding broilers diets with reduced CP has often shown decreased growth performance despite additions of nonspecific N, supplementation of EAA exceeding the NRC recommendations, or crystalline NEAA supplementation (Waguespack et al., 2009).

However, much of the research feeding diets low in CP to broiler chicks has varied in its onset, often starting either immediately post-hatching or one week later. Parr and Summers (1991), Han et al. (1992), and Corzo et al. (2005) reported equal growth performance of broilers fed diets low in CP with supplemental AA when the latter approach was taken. These researchers fed a prestarter diet with a normal level of dietary CP for the first several days post-hatching, prior to the beginning of the experiments. On the other hand, Si et al. (2004), Fancher and Jensen (1989), and Waldroup et al. (2005) failed to show equal performance when similar diets with reduced CP were fed immediately post-hatching. However, the effects of delaying the feeding of diets with reduced CP are not consistent. Berres et al. (2010) showed comparable growth performance of broiler chicks fed diets with reduced CP from day 1 post-hatching while Pinchasov et al. (1990) failed to show comparable growth performance when a prestarter diet was utilized for the first week post-hatching. Based upon these results, the objective of this research was to determine whether delaying the feeding of a diet with reduced CP, supplemented

with L-Lysine, for several days post-hatching would result in adequate growth performance and determine the optimal time to feed such a diet to the broiler chick.

MATERIALS AND METHODS

Ross x Ross 708 commercial broiler chicks were used in all four experiments.

Experiments 1, 3, and 4 utilized both male and female broiler chicks. Only female chicks were used in experiment 2. Experiments 1, 2, and 3 were conducted for 18 days and experiment 4 was carried out for 14 days. Chicks for the first three experiments were obtained from a commercial hatchery and chicks for experiment 4 were obtained from the LSU Agricultural Center's School of Animal Sciences. Experiments started at day 0 post-hatching, at which time the chicks were weighed, wingbanded, and allotted to treatment to ensure a similar average starting body weight per treatment and replication. Broilers were housed in Petersime starter batteries, providing a temperature-controlled environment and continuous fluorescent lighting. Feed and water were offered ad libitum for the duration of the experiment. All chicks and feeders were weighed on day 0, at the time of a switch in diets, and at the end of the experiment for determination of average daily gain (ADG), average daily feed intake (ADFI), and gain:feed (G:F). All experimental protocols were approved by the LSU Agricultural Center Animal Care and Use Committee.

All diets were C-SBM based and formulated to contain 1.1% digestible lysine, which is the Aviagen ("Nutrient Specifications", 2007) recommendation for 11- to 24-d Ross x Ross 708 broilers. Amino acid ratios were based on those suggested by Baker (1997) for 0- to 21-d broiler chicks. Following NRC (1994) recommendations, diets were formulated to contain 3,200 kcal ME/kg, 1.0% Ca, and 0.45% nonphytate phosphorus.

In all experiments, supplementary L-Lys was provided in the form of BioLys®, containing 50.7% L-Lys (Evonik Degussa Corp., Kennesaw, GA, USA). All experiments contained a positive control (PC) diet with approximately 22% CP and free of supplemental L-Lys. The PC diet was fed for the entire experimental period for one treatment in each experiment. Table 3.1 gives the composition and calculated analysis of the diets used in all experiments.

Experiment 1 was conducted in order to determine whether delaying the feeding of a reduced CP diet, supplemented with AA, would result in adequate growth performance for broiler chicks. Each treatment consisted of 8 replications of 6 chickens per replicate pen. Treatments 1 through 5 consisted of the same diets being fed for the full experimental period with the following levels of L-Lys supplemented: 1) 0.0% (PC); 2) 0.1%; 3) 0.15%; 4) 0.2%; 5) 0.25%. Treatments 6 through 9 were fed the L-Lys-free PC diet for the first five days post-hatching and then switched to the low CP diets with L-Lys used in treatments 2 through 5 for the remainder of the experiment. Treatments 10 through 13 were identical to treatments 6 through 9 with the exception of the PC diet being fed for the first ten days post-hatching.

Experiment 2 was also conducted in order to determine whether delaying the feeding of a reduced CP diet, supplemented with AA, would result in adequate growth performance for broiler chicks. This experiment contained a treatment arrangement similar to experiment 1, but only utilized the 0.15% and 0.2% levels of L-Lys and 6 replicate pens of 6 chickens for each treatment. Treatments 1 through 3 consisted of diets with 0.0% (PC), 0.15%, and 0.2% L-Lys for the full experimental period. In treatments 4 and 5, broilers were fed the PC diet for the first five days post-hatching before being switched to the low CP diets with 0.15% and 0.2% L-Lys. Treatments 6 and 7 were identical to treatments 4 and 5 with the exception of the PC diet being

Table 3.1. Percentage composition of corn-soybean meal diets with supplemental L-Lysine used in all experiments, as-fed basis

Ingredient	Supplemental L-Lys (%)						
	Experiments 1, 2, 3					Experiment 4	
	0.0	0.1	0.15 ^a	0.2 ^b	0.25 ^b	0.0	0.15 ^a
Corn	54.97	59.16	61.26	63.34	65.45	54.13	60.42
Soybean meal	35.81	31.86	29.87	27.90	25.92	35.88	29.94
Soy oil	4.91	4.35	4.07	3.78	3.50	5.19	4.34
Monocalcium PO ₄	1.52	1.55	1.57	1.58	1.59	1.53	1.57
Limestone	1.49	1.51	1.52	1.53	1.54	1.49	1.52
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Chromic oxide	-----	-----	-----	-----	-----	0.50	0.50
Mineral mix ^c	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin mix ^d	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Choline chloride ^e	0.05	0.05	0.05	0.05	0.05	0.05	0.05
DL-Methionine	0.226	0.261	0.279	0.296	0.314	0.228	0.28
L-Threonine	0.009	0.063	0.090	0.117	0.144	0.010	0.091
Biolys ^f	-----	0.197	0.296	0.394	0.493	-----	0.296
Calculated composition							
ME	3,200	3,200	3,200	3,200	3,200	3,200	3,200
CP	21.71	20.39	19.73	19.07	18.40	21.68	19.69
Ca	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Non-phytate P	0.45	0.45	0.45	0.45	0.45	0.45	0.45
SIDLys ^g	1.10	1.10	1.10	1.10	1.10	1.10	1.10
SIDMet+Cys	0.84	0.84	0.84	0.84	0.84	0.84	0.84
SIDThr	0.73	0.73	0.73	0.73	0.73	0.73	0.73
SIDArg	1.33	1.22	1.16	1.10	1.05	1.33	1.16
SID Ile	0.86	0.79	0.75	0.72	0.68	0.85	0.75
SIDVal	0.93	0.86	0.83	0.80	0.76	0.93	0.83

^a Val is calculated to be deficient in these diets.

^b Val, Ile, & Arg are calculated to be deficient in these diets.

^c Provided per kilogram of diet: copper (copper sulfate), 7 mg; iodine (calcium iodate), 1 mg; iron (ferrous sulfate•H₂O), 50 mg; manganese (manganese sulfate), 100 mg; selenium (sodium selenite), 0.15 mg; zinc (zinc sulfate), 75 mg.

^d Provided per kilogram of diet: vitamin A, 8,003 IU; vitamin D₃, 3004 IU; vitamin E, 25 IU; menadione, 1.5 mg; vitamin B₁₂, 0.02 mg; biotin, 0.1 mg; folic acid, 1 mg; niacin, 50 mg; pantothenic acid, 15 mg; pyridoxine, 4 mg; riboflavin, 10 mg; thiamin, 3 mg.

^e Contains 750,000 mg/kg of choline chloride.

^f Provides a minimum of 50.7% L-Lysine in the form of L-Lysine•H₂SO₄ (Evonik Desgussa Corp., Kennesaw, GA, USA).

^g SID = standardized ileal digestible

fed for the first ten days post-hatching.

Experiment 3 was performed to determine the optimal time to feed a diet with low CP, supplemented with L-Lys, to broilers during the starter phase. Experiment 3 was identical to experiment 1 with the exception that the order in which the diets was fed was reversed. Additionally, each treatment consisted of 6 replicate pens of 6 chickens each. Treatments 1 through 5 were identical to the respective treatments in experiment 1. In treatments 6 through 9 chicks were fed the low CP diets containing 0.1%, 0.15%, 0.2%, and 0.25% L-Lys respectively for the first five days post-hatching before being switched to the PC diet for the remainder of the experiment. Treatments 10 through 13 were fed the diets with added L-Lys for 10 days before being switched to the PC.

Experiment 4 was also conducted in order to determine the optimal time to feed a diet with reduced CP, supplemented with L-Lys, to broiler chicks. It consisted of 8 replicate pens of 8 chicks per treatment. Treatments 1 and 2 consisted of diets with 0.0% L-Lys (PC) and 0.15% L-Lys respectively, fed for the entire duration of the experiment. Treatment 3 consisted of a PC diet for the first five days post-hatching and 0.15% L-Lys for the remainder of the experiment. For treatment 4 the order in which the diets in treatment 3 were fed was reversed. This switch was also done at day 5 post-hatching. All birds were killed at the end of the experiment by asphyxiation with CO₂ so pancreas weights could be taken.

All experiments were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) by ANOVA as a completely randomized design with pen as the experimental unit. The PDIFF option of SAS was used to compare individual treatments to the PC in all experiments and any treatment differences in experiment 4. Preplanned contrasts were utilized for multiple

treatment comparisons. In the first three experiments, a treatment by sex interaction was not significant and therefore removed from the model.

RESULTS

Experiment 1

The results of experiment 1 are shown in Table 3.2. For the first five days post-hatching, broilers fed the diet with 0.1% L-Lys showed increased gain over those fed the PC diet ($P < 0.006$). This difference was not significant from 5- to 10-d ($P > 0.10$). By 10- to 18-d, all treatments had lower ADG than the PC ($P < 0.10$). Overall, only those broilers fed 0.2% L-Lys for the entire experimental period and those broilers switched to 0.15% L-Lys at day 10 post-hatching showed gain comparable to the PC. A linear effect of L-Lys was seen for 10- to 18-d ($P < 0.003$) and overall ADG ($P < 0.04$).

For the first five days post-hatching, broilers fed 0.1% L-Lys had greater ADFI ($P < 0.006$) than the PC diet. From 10- to 18-d, broilers that were switched to the diet with 0.25% L-Lys at day 10 showed greater feed intake than the PC ($P < 0.03$). Over the entire experiment, no differences were seen in feed intake. From 5- to 10-d post-hatching, a significant effect was seen for feed intake when comparing broilers fed the PC diet with those fed diets containing L-Lys from day 0 ($P < 0.001$) and those switched to a L-Lys-containing diet at day 5 post-hatching ($P < 0.001$).

Feed efficiency was lower for broilers fed 0.25% L-Lys for the first five days post-hatching compared with the PC ($P < 0.07$). A quadratic effect of L-Lys ($P < 0.03$) was also seen for G:F during this time period. From 5- to 10-d, 10- to 18-d, and overall, G:F of all treatments was lower than the PC ($P < 0.10$). From 10- to 18-d, broilers fed the L-Lys diets for the entire

Table 3.2 Effects of delaying the feeding of diets low in crude protein, supplemented with L-Lysine, on the growth performance of broiler chicks in Experiment 1^{1,2}

Treatment ³	ADG, g				ADFI, g				G:F, g:g			
	0-5 d	5-10 d	10-18 d	0-18 d	0-5 d	5-10 d	10-18 d	0-18 d	0-5 d	5-10 d	10-18 d	0-18 d
1) PC	8.89	23.08	44.62	28.98	10.18	29.01	58.13	36.78	0.870	0.796	0.768	0.789
2) 0.1	10.20 ^a	23.36	41.37 ^a	27.71	11.24 ^a	31.17	58.21	37.65	0.908	0.749 ^a	0.711 ^a	0.736 ^a
3) 0.15	8.75	22.28	41.05 ^a	26.93 ^a	9.97	30.00	58.51	36.75	0.887	0.743 ^a	0.701 ^a	0.733 ^a
4) 0.2	9.57	23.80	41.57 ^a	27.78	10.76	31.58	59.69	38.10	0.889	0.753 ^a	0.696 ^a	0.729 ^a
5) 0.25	8.55	21.89 ^a	40.11 ^a	26.47 ^a	10.39	30.65	58.99	36.87	0.823 ^a	0.714 ^a	0.680 ^a	0.718 ^a
6) 0.1 ⁴	-----	22.23	40.44 ^a	26.47 ^a	-----	30.13	57.62	36.38	-----	0.738 ^a	0.702 ^a	0.728 ^a
7) 0.15 ⁴	-----	22.39	39.55 ^a	26.37 ^a	-----	31.21	57.39	37.12	-----	0.718 ^a	0.689 ^a	0.711 ^a
8) 0.2 ⁴	-----	21.89 ^a	39.97 ^a	26.33 ^a	-----	30.54	56.63	36.32	-----	0.716 ^a	0.706 ^a	0.725 ^a
9) 0.25 ⁴	-----	22.34	39.77 ^a	26.46 ^a	-----	31.78	57.77	37.44	-----	0.704 ^a	0.688 ^a	0.707 ^a
10) 0.1 ⁵	-----	-----	41.30 ^a	26.90 ^a	-----	-----	59.66	36.97	-----	-----	0.693 ^a	0.728 ^a
11) 0.15 ⁵	-----	-----	41.42 ^a	27.82	-----	-----	60.18	37.80	-----	-----	0.688 ^a	0.736 ^a
12) 0.2 ⁵	-----	-----	40.42 ^a	26.37 ^a	-----	-----	59.35	36.60	-----	-----	0.681 ^a	0.721 ^a
13) 0.25 ⁵	-----	-----	40.72 ^a	27.13 ^a	-----	-----	62.35 ^a	37.89	-----	-----	0.654 ^a	0.720 ^a
SEM	0.271	0.513	0.965	0.651	0.222	0.623	1.332	0.875	0.018	0.008	0.008	0.011
TRT P-value	0.030	0.190	0.059	0.128	0.040	0.004	0.263	0.933	0.162	0.001	0.001	0.001
SEX P-value	0.421	0.348	0.001	0.008	0.314	0.754	0.001	0.081	0.922	0.117	0.101	0.079
<u>Contrasts⁶</u>												
Lys Linear	0.386	0.248	0.003	0.033	0.838	0.019	0.459	0.905	0.108	0.001	0.001	0.001
Lys Quadratic	0.036	0.350	0.305	0.665	0.268	0.196	0.949	0.661	0.026	0.484	0.047	0.135
PC vs. 2-5	0.165	0.578	0.002	0.018	0.068	0.001	0.627	0.741	0.808	0.001	0.001	0.001
PC vs. 6-9	-----	0.042	0.001	0.001	-----	0.001	0.601	0.830	-----	0.001	0.001	0.001
PC vs. 10-13	-----	-----	0.001	0.007	-----	-----	0.154	0.800	-----	-----	0.001	0.001
2-5 vs. 6-13	-----	-----	0.259	0.184	-----	-----	0.954	0.570	-----	-----	0.050	0.217

¹ Data are means of 8 replications of 6 chickens each.

² A significant TRT*SEX interaction was not seen for any variables (P>0.10) and was removed from the statistical model.

³ Values represent percent supplemental L-Lysine added to broiler diets being fed.

⁴ The PC diet was fed for the first 5 days post-hatching, before diets with supplemental L-Lysine.

⁵ The PC diet was fed for the first 10 days post-hatching, before diets with supplemental L-Lysine.

⁶ Linear and quadratic contrasts were run on treatments 1 to 5, and others were run to analyze the effects of switching diets.

^a Significantly different ($P < 0.10$) from positive control.

Table 3.3 Effects of delaying the feeding of diets low in crude protein, supplemented with L-Lysine, on the growth performance of broiler chicks in Experiment 2¹

Treatment ²	ADG, g				ADFI, g				G:F, g:g			
	0-5 d	5-10 d	10-18 d	0-18 d	0-5 d	5-10 d	10-18 d	0-18 d	0-5 d	5-10 d	10-18 d	0-18 d
1) PC	9.97	23.74	41.76	27.66	12.52	30.14	59.13	37.70	0.795	0.788	0.707	0.734
2) 0.15	10.46	24.67	42.93	28.90	12.58	31.20	61.70	39.34	0.828	0.791	0.696	0.734
3) 0.2	9.96	23.08	39.90	27.01	12.46	30.23	58.96	37.62	0.799	0.763 ^a	0.677 ^a	0.718
4) 0.15 ³	-----	23.99	40.32	27.46	-----	32.64 ^a	60.18	39.36	-----	0.735 ^a	0.671 ^a	0.698 ^a
5) 0.2 ³	-----	22.37 ^a	40.79	26.95	-----	31.06	61.28	39.00	-----	0.720 ^a	0.666 ^a	0.691 ^a
6) 0.15 ⁴	-----	-----	41.78	28.44	-----	-----	62.88 ^a	40.28 ^a	-----	-----	0.665 ^a	0.706 ^a
7) 0.2 ⁴	-----	-----	40.38	27.18	-----	-----	61.78	39.08	-----	-----	0.655 ^a	0.695 ^a
SEM	0.321	0.533	0.821	0.566	0.279	0.653	1.340	0.843	0.014	0.011	0.009	0.007
TRT P-value	0.656	0.141	0.139	0.145	0.980	0.083	0.314	0.270	0.368	0.001	0.004	0.001
<u>Contrasts⁵</u>												
Lys Linear	0.758	0.727	0.338	0.873	0.944	0.618	0.713	0.691	0.530	0.161	0.039	0.039
Lys Quadratic	0.428	0.077	0.018	0.021	0.846	0.305	0.116	0.115	0.257	0.169	0.318	0.318
PC vs. 2-3	0.560	0.820	0.731	0.674	0.997	0.412	0.460	0.442	0.308	0.337	0.074	0.074
PC vs. 4-5	-----	0.342	0.241	0.518	-----	0.022	0.335	0.157	-----	0.001	0.002	0.002
PC vs. 6-7	-----	-----	0.262	0.427	-----	-----	0.127	0.068	-----	-----	0.001	0.001
2-3 vs. 4-7	-----	-----	0.403	0.370	-----	-----	0.306	0.199	-----	-----	0.008	0.001

¹ Data are means of 6 replications of 6 chickens each.

² Values represent percent supplemental L-Lysine added to broiler diets being fed.

³ The PC diet was fed for the first 5 days post-hatching, before diets with supplemental L-Lysine.

⁴ The PC diet was fed for the first 10 days post-hatching, before diets with supplemental L-Lysine.

⁵ Linear and quadratic contrasts were run on treatments 1 to 5, and others were run to analyze the effects of switching diets.

^a Significantly different (P < 0.10) from positive control.

Table 3.4 Effects of switching from diets low in crude protein, supplemented with L-Lysine, to a L-Lysine-free positive control (PC) diet on the growth performance of broiler chicks in Experiment 3^{1,2}

Treatment ³	ADG, g				ADFI, g				G:F, g:g			
	0-5 d	5-10 d	10-18 d	0-18 d	0-5 d	5-10 d	10-18 d	0-18 d	0-5 d	5-10 d	10-18 d	0-18 d
1) PC	7.57	22.50	40.69	26.44	9.50	27.60	57.53	35.44	0.794	0.816	0.708	0.747
2) 0.1	7.53	21.19	40.30	25.90	10.23	29.51 ^a	53.34 ^a	34.40	0.734	0.718 ^a	0.755 ^a	0.753
3) 0.15	7.55	20.86 ^a	40.84	26.09	10.09	27.69	56.67	34.82	0.744	0.753 ^a	0.721	0.751
4) 0.2	8.35	21.25	40.20	26.42	10.87 ^a	28.95	58.76	37.54	0.768	0.734 ^a	0.685	0.704 ^a
5) 0.25	7.26	19.14 ^a	35.92	22.98 ^a	10.19	26.52	51.91 ^a	32.88 ^a	0.709 ^a	0.722 ^a	0.694	0.700 ^a
6) 0.1 ⁴	-----	21.83	41.33	26.47	-----	28.94	55.73	35.64	-----	0.755 ^a	0.739	0.741
7) 0.15 ⁴	-----	20.22 ^a	39.16	25.20	-----	28.19	53.80	34.67	-----	0.717 ^a	0.728	0.726
8) 0.2 ⁴	-----	20.79 ^a	40.64	26.12	-----	29.54 ^a	55.33	35.77	-----	0.704 ^a	0.734	0.730
9) 0.25 ⁴	-----	19.58 ^a	38.60	24.61 ^a	-----	27.67	52.53 ^a	33.60	-----	0.706 ^a	0.735	0.732
10) 0.1 ⁵	-----	-----	38.56	25.27	-----	-----	56.84	35.57	-----	-----	0.679	0.710 ^a
11) 0.15 ⁵	-----	-----	38.59	25.03	-----	-----	53.53 ^a	34.21	-----	-----	0.721	0.731
12) 0.2 ⁵	-----	-----	37.65	24.66	-----	-----	53.79	34.59	-----	-----	0.700	0.712 ^a
13) 0.25 ⁵	-----	-----	38.88	24.99	-----	-----	55.69	35.25	-----	-----	0.700	0.710 ^a
SEM	0.309	0.563	1.280	0.786	0.229	0.632	1.649	0.998	0.019	0.012	0.015	0.014
TRT P-value	0.094	0.003	0.178	0.103	0.048	0.005	0.114	0.206	0.036	0.001	0.017	0.060
SEX P-value	0.093	0.037	0.001	0.001	0.882	0.047	0.002	0.005	0.007	0.390	0.049	0.033
<u>Contrasts⁶</u>												
Lys Linear	0.821	0.001	0.030	0.017	0.061	0.366	0.221	0.528	0.179	0.001	0.113	0.003
Lys Quadratic	0.487	0.503	0.057	0.060	0.212	0.005	0.572	0.369	0.995	0.006	0.037	0.065
PC vs. 2-5	0.820	0.009	0.334	0.211	0.073	0.471	0.203	0.636	0.208	0.001	0.734	0.171
PC vs. 6-9	-----	0.014	0.594	0.333	-----	0.239	0.087	0.643	-----	0.001	0.128	0.307
PC vs. 10-13	-----	-----	0.113	0.098	-----	-----	0.166	0.632	-----	-----	0.641	0.037
2-5 vs. 6-13	-----	-----	0.861	0.909	-----	-----	0.613	0.997	-----	-----	0.727	0.722

¹ Data are means of 6 replications of 6 chickens each.

² A significant TRT*SEX interaction was not seen for any variables (P>0.10) and was removed from the statistical model.

³ Values represent percent supplemental L-Lysine added to broiler diets being fed.

⁴ The PC diet was fed for the first 5 days post-hatching, before diets with supplemental L-Lysine.

⁵ The PC diet was fed for the first 10 days post-hatching, before diets with supplemental L-Lysine.

⁶ Linear and quadratic contrasts were run on treatments 1 to 5, and others were run to analyze the effects of switching diets.

^a Significantly different ($P < 0.10$) from positive control.

Table 3.5 Effect of switching to and from a diet low in crude protein, supplemented with 0.15% L-Lysine, diet on the growth performance of broiler chicks in Experiment 4¹

Treatment ²	ADG, g			ADFI, g			G:F, g:g			Pancreas Weight	
	0-5 d	5-14 d	0-14 d	0-5 d	5-14 d	0-14 d	0-5 d	5-14 d	0-14 d	Wt	As % of BW
1) PC; PC	11.38	31.52	24.34	11.13	41.55	30.64	1.023	0.759 ^{a,b}	0.795	1.47 ^{a,b}	0.389 ^b
2) 0.15; 0.15	11.71	31.65	24.48	11.56	41.55	30.72	1.014	0.762 ^a	0.797	1.53 ^a	0.409 ^a
3) PC; 0.15	-----	31.83	24.58	-----	42.31	30.94	-----	0.752 ^{a,b}	0.795	1.45 ^b	0.380 ^b
4) 0.15; PC	-----	31.17	24.33	-----	41.70	30.54	-----	0.747 ^b	0.796	1.43 ^b	0.380 ^b
SEM	0.212	0.527	0.404	0.205	0.550	0.403	0.009	0.006	0.007	0.026	0.0006
TRT P-value	0.277	0.831	0.964	0.152	0.721	0.907	0.476	0.261	0.995	0.070	0.017
SEX P-value	0.423	0.425	0.380	0.487	0.165	0.237	0.847	0.455	0.889	0.156	0.047
TRT*SEX P-value ³	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.023	0.021
<u>Contrasts⁴</u>											
PC vs. 3-4	-----	0.970	0.851	-----	0.493	0.843	-----	0.169	0.916	0.350	0.267
0.15 vs. 3-4	-----	0.817	0.960	-----	0.515	0.976	-----	0.101	0.897	0.010	0.002

¹ Data are means of 8 replications of 8 chickens each.

² Values represent % L-Lysine fed before and after day 5 post-hatching respectively; PC contained 0.0% L-Lysine.

³ A significant TRT*SEX interaction (P>0.10) was not seen for ADG, ADFI, or G:F and was therefore removed from the model.

⁴ Contrasts were performed comparing treatments with switching diets with those fed the same diet consistently.

^{a, b} Means in columns not sharing a common subscript are significantly different (P < 0.10).

experiment had higher G:F compared with those switched to the low CP, L-Lys-supplemented diets at day 5 and day 10 ($P = 0.05$).

Experiment 2

Table 3.3 shows the results of experiment 2. Broilers switched to the 0.2% L-Lys diet at day 5 post-hatching showed the only significant difference in ADG compared to the PC. They showed decreased ADG from 5- to 10-d ($P < 0.084$). Adding L-Lys had a quadratic effect for ADG for all time periods except from 0- to 5-d post-hatching.

Broilers switched to the 0.15% L-Lys diet had increased feed intake compared with the PC diet after being switched at day 5 ($P < 0.008$) and day 10 ($P < 0.051$). From 5- to 10-d, broilers switched to any diet with L-Lys at day 5 consumed more feed than those continuously fed the PC diet ($P < 0.023$). Additionally, those broilers switched to any diet with L-Lys at day 10 consumed more feed over the entire experiment than those fed the PC ($P < 0.062$).

From 5- to 10-d post-hatching, broilers fed 0.2% L-Lys from the start of the experiment ($P < 0.089$) or switched to a diet containing L-Lys at day 5 ($P < 0.001$) had decreased feed efficiency compared to the control. From 10- to 18-d and overall, chicks switched to a diet with L-Lys at day 5 ($P < 0.002$; $P < 0.002$) or day 10 ($P < 0.001$; $P < 0.001$) had lower G:F compared to the control. For both 0- to 10-d and 0- to 18-d, broilers switched to a diet with L-Lys from the PC diet showed decreased feed efficiency compared to broilers fed diets with L-Lys from the start of the experiment ($P < 0.008$).

Experiment 3

The results of experiment 3 are reported in Table 3.4. From 5- to 10-d post-hatching, ADG was reduced for all broilers switched to the PC diet at day 5 ($P < 0.015$) except those fed the diet with 0.1% L-Lys ($P > 0.481$) when compared with the PC. During this time period,

broilers fed 0.15% L-Lys consistently gained less than the PC ($P < 0.051$). For 0- to 18-d, broilers fed 0.25% L-Lys from the start of the experiment ($P < 0.003$) and those switched from this diet to the PC at day 5 post-hatching ($P < 0.098$) had lower gains compared to the PC. Additionally, all broilers that had diets switched at day 10 had lower gains compared with the PC ($P < 0.099$). Significant linear ($P < 0.02$) and quadratic ($P < 0.06$) effects of ADG were also seen for supplemental L-Lys.

For the first five days post-hatching, ADFI was increased for chicks fed diets with L-Lys compared to the PC ($P < 0.074$). For the next five days, ADFI was increased for broilers fed 0.1% L-Lys from the start of the experiment compared to the PC ($P < 0.038$). Furthermore, added L-Lys had a quadratic effect on ADFI for this time period ($P < 0.006$). Conversely, from 10- to 18-d, broilers fed 0.1% L-Lys had a lower feed intake compared to the PC ($P < 0.073$). Additionally, chicks ate less than the PC for the last 8 days of the experiment when broilers were fed 0.25% L-Lys for the entire time period ($P < 0.017$), or switched to the PC from this diet at day 5 ($P < 0.033$). From 10- to 18-d, all broilers switched to the PC diet at day 5 had lower ADFI compared with the PC ($P < 0.09$). However, from 0- to 18-d, only broilers fed 0.25% L-Lys for the entire experiment ate significantly less than the PC ($P < 0.07$).

For the first five days, only broiler chicks fed 0.25% L-Lys had decreased G:F when compared with the PC diet ($P = 0.041$). From 5- to 10-d post-hatching, all chicks fed or switched from diets with L-Lys had lower feed efficiency than the L-Lys-free PC diet fed from the start of the experiment ($P < 0.01$). However, for the last 8 days of the experiment, broilers fed 0.1% L-Lys for the entire experiment had greater G:F compared to the PC ($P < 0.029$). Overall G:F was decreased in chicks fed 0.2% and 0.25% L-Lys for the first 10 days of the experiment ($P < 0.075$;

$P < 0.051$) and for the entire experiment ($P < 0.023$; $P < 0.015$ respectively) compared to the PC. Added L-Lys had a linear ($P < 0.004$) and quadratic ($P < 0.066$) effect for G:F from 0- to 18-d.

Experiment 4

The results of experiment 4 are shown in Table 3.5. ADG and ADFI were similar for all treatments. From 5- to 14-d, chicks fed 0.15% L-Lys had improved G:F compared to chicks switched from a diet with 0.15% L-Lys to the PC diet at day 5 ($P < 0.079$). Pancreas weights were greater for chicks fed 0.15% L-Lys for the entire experiment compared with chicks that had their diets switched ($P = 0.010$). When analyzed as a percentage of BW, broilers fed 0.15% L-Lys had increased pancreas weights compared to chicks fed the PC ($P < 0.043$). There was also a treatment by sex interaction for pancreas weights ($P < 0.024$).

DISCUSSION

Results from experiment 1 showed decreased ADG and G:F for nearly all broilers fed diets with reduced CP when compared with the PC, regardless of supplemental L-Lys level or when the diets were fed. Initially, from day 0- to 5-d post-hatching, broilers fed 0.1% L-Lys showed increased ADG compared with the PC, but this result was most likely caused by increased feed intake during this time.

The negative effects on growth performance seen with the L-Lys diets in experiment 1 led to experiment 2 to confirm these results. Utilizing the same experimental design with only the 0.15% and 0.2% levels of L-Lys, the results of experiment 2 are somewhat inconsistent with those of the first experiment. Despite the AA deficiencies calculated in the 0.15% and 0.2% L-Lys diets, no differences were seen among treatments for overall ADG. As in the first experiment, reductions in G:F were also seen in experiment 2 for broilers switched to 0.15% and 0.2% L-Lys at day 5 and day 10 compared with the PC. However, unlike in experiment 1, no

reductions were seen for feed efficiency in broilers fed 0.15% or 0.2% L-Lys for the full 18 days. It is unclear why these inconsistencies occurred.

In both experiments, ADFI was increased in broilers after being switched to a diet with L-Lys at day 5 post-hatching when compared with the PC. Additionally, both experiments showed decreased feed efficiency in chicks that were switched to diets with L-Lys at day 5 and day 10 post-hatching compared with those fed L-Lys consistently.

According to Aviagen (2007) recommendations, Val, Ile, and Arg were calculated to be deficient in the diets containing 0.2% and 0.25% supplemental L-Lys, possibly explaining the decreased growth performance shown by broilers switched to these diets at day 5 or day 10 post-hatching. It is unclear why broilers fed 0.1% or 0.15% L-Lys in experiment 1 showed decreased ADG and G:F as the former is calculated to be adequate for the AA requirements of broilers and the latter is calculated to be only minimally deficient in Val. While Aviagen (2007) AA recommendations for day 11 to day 24 broilers are slightly lower than those for day 0 to day 10 broilers, the composition of the diets was based on the same recommendations for both experiments. Furthermore, Garcia and Batal (2003) reported that the digestible lysine requirements of the broiler chick change little for the first three weeks post-hatching. As such, this should not be an explanation for the decreased growth performance seen in experiment 1 and the decreased feed efficiency seen in experiment 2 for broiler chicks fed L-Lys.

Previous research on the effects of feeding and switching to a diet with reduced CP in the first week post-hatching is minimal. It is unknown why broilers switched to diets with reduced CP, supplemented with L-Lys, showed decreased growth performance when compared with the PC or the L-Lys diets fed from day 0.

However, one possible explanation may be effects caused by the changes in intestinal morphology that take place in the broiler chick during the first few weeks post-hatching. While anatomically complete at hatching, the gastrointestinal system is not functionally mature until at least two weeks post-hatching (Sulistiyanto et al., 1999). Intestinal villi and enzyme levels are still developing for the first several days post-hatching, resulting in a reduced ability to absorb and digest nutrients (Moran, 2007). Dietary composition has been shown to affect development of these variables (Batal and Parsons, 2002a, b), and it is possible that the changing dietary composition used in these experiments negatively affected the intestinal tract's ability to recover nutrients from the feed compared with those kept on the same diet.

Uni et al. (1995) reported the greatest amounts of trypsin at day 4 post-hatching but nitrogen digestibility increased through the first 14 days. Similarly, Batal and Parsons (2002a) showed increases in apparent AA digestibility through day 21 post-hatching; however, the lowest values were seen at day 3 to 4 post-hatching. While part of this may be due to the adaptation from the yolk to feed as the main nutrient source during this time, it leaves room for speculation as to whether intestinal adaption to changes in CP can efficiently occur during this time. In both experiments, for each time period, G:F was lowest for treatments that were just switched to diets containing L-Lys. Also in support of this, broilers switched at day 5 post-hatching showed consistently lower overall feed efficiency than those switched at day 10 and those fed L-Lys for the entire experiment.

The gastrointestinal tract develops rapidly immediately after post-hatching, with villus volume not plateauing until a week after hatching in the duodenum and even later in the jejunum and ileum (Uni et al., 1998). Batal and Parsons (2002b) found decreased height and less absorptive surface area of villi from birds that were switched from a C-SBM diet to a crystalline

AA diet (14.4%) at day 7 post-hatching compared with those fed either diet consistently. From 0- to 21-d, Batal and Parsons (2002b) also reported feed efficiency of broilers switched to the crystalline AA diet was as low as birds fed this diet for the entire experiment. While the dietary restrictions of this diet are more severe than the L-Lys diets used in our experiments, these experiments suggest a reduced capability of the gastrointestinal tract to efficiently adapt to dietary CP changes before the intestine is functionally mature.

The decreased growth performance seen by switching birds to diets with L-Lys at day 5 and 10 post-hatching led to experiment 3 to determine whether the same effects would be seen if broilers were switched from diets low in CP, supplemented with L-Lys, to a PC diet. From 5- to 10-d, ADG and G:F was decreased for broilers switched to the PC diet at day 5. However, overall ADG and G:F were not significantly different from the control, except for broilers fed the diets containing 0.2% or 0.25% L-Lys, calculated to be deficient in Val, Ile, and Arg, for 10 days or the entire experiment.

The results of experiment 3 indicate that additional time may be needed for broilers to adapt to a diet with a different CP level when switched at day 5 post-hatching. Since overall ADG and G:F were similar to the PC for treatments fed 0.1% or 0.15% supplemental L-Lys, broilers may be able to adapt more efficiently when being switched to diets with higher, rather than lower, CP. It is unclear why this adaptation period was not seen in broilers switched to the PC at day 10 post-hatching. Broiler chicks may be able to better adapt to changes in dietary CP at day 10 or the next experimental measurements at 18 days of age may have been too late to notice these changes. These results agree with Wiertelcki and Jamroz (2003), who reported that for the first five days of life, chicks can adapt to a lower dietary CP level; however, feeding a reduced CP level significantly changed the rate of yolk resorption.

In experiment 4, feed efficiency was decreased in birds switched to the PC at day 5 post-hatching compared with birds fed 0.15% L-Lys for the entire experiment. Additionally, mean pancreas weight (as % of BW) was increased for this treatment compared with all other treatments. The observation that the treatment with the greatest pancreas weight also showed the greatest feed efficiency is interesting because of the role of pancreatic enzymes in digestion and absorption. Palo et al. (1995) also reported larger pancreas weights in birds with higher feed efficiency. Yet, no significant correlation was shown for these two variables in our research (data not shown). Additionally, the treatment by sex interaction shown for pancreas weight limits the conclusions that can be made.

Contrary to our previous results, broilers that had diets switched at day 5 in experiment 4 showed average daily gain and feed efficiency similar to the PC. It is unknown why these differences occurred but it is possible that the shorter length of this experiment may have been a factor. Additionally, delaying access to feed initially post-hatching depresses the development of the mucosal function of the intestine for several days (Uni et al., 1995), and in a commercial hatchery, chicks can be delayed for up to 48 hours post-hatching without feed. The broilers used for experiment 4 were obtained locally and quite possibly had a more rapid transition to feed than those obtained from commercial hatcheries. Early access to feed can enhance growth and intestinal development as well as provide long term metabolic effects (Noy and Uni, 2010). This could explain the improved growth performance as well as the increased feed efficiency seen in these birds for the first five days post-hatching when compared with the other experiments.

In all experiments, feed efficiency was a more sensitive variable than daily gain. This is in agreement with other researchers who reported higher requirements are needed for maximal feed efficiency than ADG (Han and Baker, 1993). Additionally, this reduction in feed efficiency

has also been reported in other research that fed differing levels of dietary CP. While Cabel and Waldroup (1991) fed broilers for 42 days rather than just the starter phase, broilers fed reducing levels of dietary CP had decreased G:F compared with those fed diets with a constant dietary percentage. Furthermore, Dilger et al. (2006) also reported lower feed efficiency among broilers fed fluctuating CP levels over those fed more traditional diets. While this experiment was over the full 42 day growth period, the main differences were in the starter period. However, our results do not agree with Warren and Emmert (2000), who also fed diets with reduced CP levels during the starter phase but found no differences in growth performance. Their dietary CP changes may have been too small (less than 2%) to detect any differences in gain or feed efficiency.

Most studies that observe compensatory growth and carryover effects are performed for at least 42 days, and only minimal effects of this nature were seen during our research focusing on the starter phase. In experiment 3, broilers fed L-Lys diets until day 5 with decreased feed efficiency from 5- to 10-d post-hatching, showed feed efficiency similar to the PC by 18 days of age. However, those fed the L-Lys diets for the first 10 days were unable to reach a comparable level of G:F to the PC by 8 days later. Daily gain that was also decreased by 10 days of age in broilers fed diets supplemented with L-Lys was comparable to the PC by 18 days. These results are in general agreement with other studies that showed full compensatory growth by marketing (Noy and Sklan, 2002; Zhan et al., 2007); as such, it is likely that broilers would have fully compensated for any previous restriction and reduction in growth performance had the experiment been carried out to the full 42 day marketing period.

Other researchers have reported enhanced effects on growth performance after switching dietary CP level, when diets with high CP were previously fed. Wjitten et al. (2004) reported

increased daily gain in the grower phase when a high level of CP was fed in the starter phase. No such carryover effect was seen by switching broiler chicks from the PC to a lower dietary CP at either day 5 or day 10 post-hatching in our research, and this phenomenon may not be possible in birds during the starter phase of the growing period. Similarly, Lemme et al. (2007) reported increased growth performance through 14 days of age when a dietary CP greater than a control level was fed for either 8 or 12 days. It is unclear why our research showed decreased feed efficiency and gain when dietary protein was decreased during the starter period while the research of Lemme et al. (2007) showed no such effects. Possible explanations for this lack of effect may be due to the high CP levels or the “transition period” that Lemme et al. (2007) utilized and was not present in our research.

In conclusion, utilizing only the commercially available AA, a diet with 0.2% L-Lys and 19% CP can achieve daily gain equivalent to a positive control diet (21.7% CP), free of supplemental L-Lys. For feed efficiency, diets with greater than 0.15% L-Lys will result in decreased feed efficiency comparable to the PC diet.

In addition, delaying the feeding of a diet with reduced CP, supplemented with L-Lys, for several days post-hatching does not result in growth performance comparable to a L-Lysine-free control diet or often even a L-Lys diet fed consistently. These results show broilers adapt more efficiently when being switched to a diet with a higher level of CP than a diet with reduced dietary CP, supplemented with AA. It is still unclear why previous research has shown trends for improved growth performance when delaying the feeding of diets low in crude protein approximately one week post-hatching, and it is most likely due to multiple aspects of variation among experiments. Further research in this area should focus on changes in intestinal

morphology and development that occur when dietary CP levels are changed in the chick shortly after hatching, including alterations in AA digestibility, intestinal villi, and enzyme levels.

CHAPTER 4

SUMMARY AND CONCLUSIONS

This research was conducted to determine whether delaying the feeding of a diet low in crude protein, supplemented with AA, for several days post-hatching would result in growth performance comparable to broiler chicks fed a diet with an adequate level of dietary CP, free of supplemental L-Lys, and determine the optimal time to feed such a diet to the broiler chick.

Two experiments were conducted to determine whether delaying the feeding an AA-supplemented C-SBM diet, low in CP, improved growth performance of broiler chicks. These experiments indicate that as long as the diet is not extremely deficient in the AA requirements of the chick, negative effects on daily gain are limited. However, any reduction in dietary CP during the starter phase resulted in decreased feed efficiency through 18 days post-hatching.

One experiment was conducted to determine the optimal time to feed an AA-supplemented C-SBM diet to the broiler chick. As long as the diets are not extremely deficient for the AA requirements of the chick, chicks show no negative effects on growth performance from being fed these diets continuously or switched from them to one with an adequate level of CP, during the starter phase.

Another experiment was also conducted in order to determine the optimal time to feed a 0.15% L-Lys diet to the broiler chick. Through 14 days post-hatching, no negative effects were seen on overall growth performance.

In conclusion, delaying the feeding of a diet with reduced CP to the broiler chick does not result in growth performance comparable to those fed a diet with an adequate level of CP or those fed AA-supplemented diets continuously. Chicks seem to adapt better when switched to diets with a higher rather than lower dietary CP than what was fed previously. A 0.15% and

0.2% level of L-Lys fed continuously allows adequate feed efficiency and daily gain respectively. Further research is needed to elicit the reasoning behind the negative effects of growth performance seen when switching broiler chicks to lower levels of dietary CP within the first several days post-hatching.

REFERENCES

- Baker, D. H. 1997. Ideal amino acid profiles for swine and poultry and their applications in feed formulation. BioKyowa Technical Review No. 9. pp. 15- 17.
- Batal, A. B. and C. M. Parsons. 2002a. Effects of age on nutrient digestibility in chicks fed different diets. Poult. Sci. 81:400-407.
- Batal, A. B. and C. M. Parsons. 2002b. Effects of age on development of digestive organs and performance of chicks fed a corn-soybean meal versus a crystalline amino acid diet. Poult. Sci. 81:1338-1341.
- Berres, J., S. L. Vieira, W. A. Dozier III, M. E. M. Cortês, R. de Barros, E. T. Nogueira, and M. Kutschenko. 2010. Broiler responses to reduced-protein diets supplemented with valine, isoleucine, glycine, and glutamic acid. J. Appl. Poult. Res. 19:68-79.
- “Biolys: product information.” 2010. Evonik Degussa Corp. 1 Dec. 2010. <<http://feed-additives.evonik.com/product/feed-additives/en/products/biolys/pages/default.aspx>>.
- Blair, R., J. P. Jacob, S. Ibrahim, and P. Wang. 1999. A quantitative assessment of reduced protein diets and supplements to improve nitrogen utilization. J. Appl. Poult. Res. 8:25-47.
- 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.
- Cabel, M. C. and P. W. Waldroup. 1991. Effect of dietary protein level and length of feeding on performance and abdominal fat content of broiler chickens. Poult. Sci. 70:1550-1558.
- Corzo, A., C. A. Fritts, M. T. Kidd, and B. J. Kerr. 2005. Response of broiler chicks to essential and non-essential amino acid supplementation of low crude protein diets. Anim. Feed Sci. Technol. 118:319-327.
- Dean, D. W., T. D. Bidner, and L. L. Southern. 2006. Glycine supplementation to low protein, amino acid-supplemented diets supports optimal performance of broiler chicks. Poult. Sci. 85:288-296.
- Dilger, R. N., C. Martinez Amezcua, P. B. Pillai, J. L. Emmert, C. M. Parsons, and D. H. Baker. 2006. Effect of reciprocating dietary lysine fluctuations on chick growth and carcass yield. Poult. Sci. 85:1226-1231.
- Edmonds, M. S., C. M. Parsons, and D. H. Baker. 1985. Limiting amino acids in low-protein corn-soybean meal diets fed to growing chicks. Poult. Sci. 64:1519-1526.

- Fancher, B. I., and L. S. Jensen. 1989b. Male broiler performance during the starting and growing periods as affected by dietary protein, essential amino acids, and potassium levels. *Poult. Sci.* 68:1385-1395.
- Ferguson, N. S., R. S. Gates, J. L. Taraba, A. H. Cantor, A. J. Pescatore, M. J. Ford, and D. J. Burnham. 1998a. The effect of dietary crude protein on growth, ammonia concentration, and litter composition in broilers. *Poult. Sci.* 77:1481-1487
- Ferguson, N. S., R. S. Gates, J. L. Taraba, A. H. Cantor, A. J. Pescatore, M. L. Straw, M. J. Ford, and D. J. Burnham. 1998b. The effect of dietary protein and phosphorous on ammonia concentration and litter composition in broilers. *Poult. Sci.* 77:1085-1092.
- Ferket, P. R., E. van Heugten, T. A. T. G. van Kempen, and R. Angel. 2002. Nutritional strategies to reduce environmental emissions from nonruminants. *J. Anim. Sci.* 80:E168-E182.
- Garcia, A. and A. B. Batal. 2005. Changes in the digestible lysine and sulfur amino acid needs of broiler chicks during the first three weeks posthatching. *Poult. Sci.* 84:1350-1355.
- Han, Y., and D. H. Baker. 1993. Effects of sex, heat stress, body weight, and genetic strain on the dietary lysine requirement of broiler chicks. *Poult. Sci.* 72:701-708
- Han, Y., H. Suzuki, C. M. Parsons, and D. H. Baker. 1992. Amino acid fortification of a low-protein corn and soybean meal diet for chicks. *Poult. Sci.* 71:1168-1178.
- Jiang, Q., P. W. Waldroup, and C. A. Fritts. 2005. Improving the utilization of diets low in crude protein for broiler chicken 1. Evaluation of special amino acid supplementation to diets low in crude protein. *Int. J. Poult. Sci.* 4:115-122.
- Leeson, S., and A. K. Zubair. 1997. Nutrition of the broiler chicken around the period of compensatory growth. *Poult. Sci.* 78:992-999.
- Lemme, A., M. G. T. Janssen, P. J. A. Wijtten, J. K. W. M. Sparla, and M. Redshaw. 2007. Increased dietary balanced protein levels at varying length of application in 1-14 days old broilers. Pages 193-196 in *Proc. 16th European Symposium on Poultry Nutrition*, Strasbourg, France.
- Moran Jr., E. T. 2007. Nutrition of the developing embryo and hatchling. *Poult. Sci.* 86:1043-1049.
- Murakami, H., Y. Akiba, and M. Horiguchi. 1992. Growth and utilization of nutrients in newly hatched chicks with or without removal of residual yolk. *Growth Dev. Aging.* 56:75-84.
- National Research Council. 1994. *Nutrient requirements of poultry*. 9th rev. ed. National Academy Press, Washington, DC.

- Namroud, N. F., M. Shivazad, and M. Zaghari. 2008. Effects of fortifying low crude protein diet with crystalline amino acids on performance, blood ammonia level, and excreta characteristics of broiler chicks. *Poult. Sci.* 87:2250-2258.
- Noy, Y. and D. Sklan. 2002. Nutrient use in chicks during the first week posthatch. *Poult. Sci.* 81:391-399.
- Noy, Y. and Z. Uni. 2010. Early nutritional strategies. *Worlds Poult. Sci. J.* 66:639-646.
- “Nutrient specification.” 2007. Aviagen. 1 Dec. 2009.
<http://en.aviagen.com/assets/Tech_Center/Ross_Broiler/Ross_708_Broiler_Nutrition_Spec.pdf>.
- Palo, P. E., J. L. Sell, F. J. Piquer, M. F. Soto-Salanova, and L. Vilaseca. 1995. Effect of early nutrient restriction on broiler chickens. 1. performance and development of the gastrointestinal tract. *Poult. Sci.* 74:88-101.
- Parr, J. F., and J. D. Summers. 1991. The effect of minimizing amino acid excesses in broiler diets. *Poult. Sci.* 70:1540-1549.
- Pinchasov, Y., C. X. Mendonca, and L. S. Jensen. 1990. Broiler chick response to low protein diets supplemented with synthetic amino acids. *Poult. Sci.* 69:1950-1955.
- Powers, W., and R. Angel. 2008. A review of the capacity for nutritional strategies to address environmental challenges in poultry production. *Poult. Sci.* 87:1929-1938.
- Si, J., C. A. Fritts, D. J. Burnham, and P. W. Waldroup. 2004. Extent to which crude protein may be reduced in corn-soybean meal broiler diets through amino acid supplementation. *Int. J. Poult. Sci.* 3:46-50.
- Sklan, D. and Y. Noy. 2003. Crude protein and essential amino acid requirements in chicks during the first week posthatch. *Br. Poult. Sci.* 44:266-274.
- Sulistiyanto, B., Y. Akiba, and K. Sato. 1999. Energy utilisation of carbohydrate, fat, and protein sources in newly hatched broiler chicks. *Br. Poult. Sci.* 40:653-659.
- Sweenen, Q., N. Everaert, M. Debonne, I. Verbaeys, C. Careghi, K. Tona, P. J. Janssens, E. Decuypere, V. Bruggeman, and J. Buyse. 2010. Effect of macronutrient ratio of the pre-starter diet on broiler performance and intermediary metabolism. *J. Anim. Physiol. Anim. Nutr.* 94:375-384.
- Uni, Z., S. Ganot, and D. Sklan. 1998. Posthatch development of mucosal function in the broiler small intestine. *Poult. Sci.* 77:75-82.
- Uni, Z., Y. Noy, and D. Sklan, 1995. Posthatch changes in morphology and function of the small intestines in heavy- and light-strain chicks. *Poult. Sci.* 74:1622-1629.

- Waguespack, A. M., S. Powell, T. D. Bidner, R. L. Payne, and L. L. Southern. 2009. Effects of incremental levels of L-lysine and determination of the limiting amino acids in low crude protein corn-soybean meal diets for broilers. *Poult. Sci.* 88:1216-1226.
- Waldroup, P. W., Q. Jiang, and C. A. Fritts. 2005. Effects of supplementing broiler diets low in crude protein with essential and nonessential amino acids. *Int. J. Poult. Sci.* 6:425-431.
- Warren, W. A., and J. L. Emmert. 2000. Efficacy of phase-feeding in supporting growth performance of broiler chicks during the starter and finisher phases. *Poult. Sci.* 79:764-770.
- Wertelecki, T. J., and D. Jamroz. 2003. The effect of different protein level in feed on yolk sac resorption and changes of some allometric parameters of gastrointestinal tract in chicks. *Annals Anim. Sci.* 3(Supp. 2):243-247.
- Wijtten, P. J. A., A. Lemme, and D. J. Langhout. 2004. Effects of different dietary ideal protein levels on male and female broiler performance during different phases of life: single phase effects, carryover effects, and interactions between phases. *Poult. Sci.* 83:2005-2015.
- Zhan, X. A., M. Wang, H. Ren, R. Q. Zhao, J. X. Li, and Z. L. Tan. 2007. Effect of early feed restriction on metabolic programming and compensatory growth in broiler chickens. *Poult. Sci.* 86:654-660.

VITA

Stephen T. Treese was born in New Orleans, Louisiana, on September 28, 1987. Son of Thomas and Kathy Treese, he is the middle of three children. He graduated from Northshore High School in Slidell, Louisiana, in 2005. In August of that year, he attended Louisiana State University in pursuit of a degree in physics. Four years later, in May 2009, Stephen graduated with a Bachelor of Science in animal sciences. In the following summer, he began his pursuit of a Master of Science degree in animal sciences under the advisement of Dr. Lee Southern. In August of 2011, he will continue his education at the College of Veterinary Medicine at the University of Missouri.