DIGESTIBLE LYSINE AND THREONINE REQUIREMENTS OF MALE TURKEYS AND THEIR EFFECTS ON PERFORMANCE OF MALE TURKEYS FED PRACTICAL DIETS TO MARKET AGE

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by

LEONARDO BRETAS LINARES

Dr. David R. Ledoux, Dissertation Supervisor

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The undersigned, appointed by the Dean of the Graduate School, have examined the dissertation entitled

DIGESTIBLE LYSINE AND THREONINE REQUIREMENTS OF MALE TURKEYS AND THEIR EFFECTS ON PERFORMANCE OF MALE TURKEYS FED PRACTICAL DIETS TO MARKET AGE

Presented by Leonardo Bretas Linares,

a candidate for the degree of Doctor of Philosophy

and hereby certify that, in their opinion, it is worthy of acceptance.

David R. Ledoux

Jeffre D. Firman

Gary L. Allee

William R. Lamberson

Joseph L. Parcell

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Leonardo Bretas Linares

Dr. David R. Ledoux, Dissertation Supervisor

ABSTRACT

Seven experiments were conducted to determine the minimum requirements of digestible lysine (dLys) and digestible threonine (dThr) from 1 to 21 weeks of age for male turkeys. Requirement values were similar to NRC (1994) recommendations, after application of digestibility coefficients. The minimum requirements for dLys and dThr were then used to formulate low crude protein diets for male turkeys from 1 to 18 weeks of age, using safety factors of 0, 5 and 10% over the minimum amino acid requirements, compared with an industry average diet. Results indicate that a low crude protein diet formulated with a 10% safety factor with respect to the minimum recommended levels of digestible AA did not negatively affect performance, carcass, or meat yield, and resulted in significantly higher revenues as compared with an industry standard diet.

CHAPTER I

INTRODUCTION

A goal of poultry nutritionists is to decrease the cost of the feed, which comprises 70 to 75% of total production costs, while at the same time improving or at least maintaining animal performance. Energy and protein (as amino acids; AA) are major cost components of poultry diets. The industry has responded by making synthetic AA commercially available for use in diets to partially replace high protein feed ingredients, such as soybean meal. Research results have been favorable when substituting synthetic AA into poultry diets with studies either showing no reduction in growth, or in some cases, showing improvement in growth.

Over the past decades, the poultry industry has moved from formulation of diets on a crude protein basis to a least-cost and total AA basis, especially with the advent of computing software. More recently, the poultry industry has begun to switch to newer approaches that are more cost effective. There are a variety of these approaches, including precision feeding, modeling, digestible formulation, and ideal protein, among others. Many of these approaches have been adopted by the broiler production sector, primarily because of the availability of research data. However, the turkey industry has fallen behind because of the lack of research data to facilitate utilization of these approaches.

The objectives of this dissertation are to: provide data on the minimum requirements for digestible lysine and digestible threonine of male turkeys raised to market weight; use these data to formulate diets; and determine the validity of these requirements with respect to performance and economics.

CHAPTER II

LITERATURE REVIEW

Amino Acids

In animal systems, protein is necessary for tissue accretion (organs and muscles), and for production of structural and protective tissues (skin, feathers, bone matrix, and ligaments, etc.). Proteins are dehydration polymers of amino acids (AA), with each AA residue joined to its neighbor by a specific type of covalent bond. Proteins can be hydrolyzed to their constituent AA by a variety of methods, and the earliest studies of proteins naturally focused on the free AA derived from them. The first to be discovered was asparagine in 1806. The last of the 20 to be discovered was threonine in 1938 (Nelson and Cox, 2000).

Amino acids are used for many metabolic functions including protein synthesis and degradation, incorporation of AA nitrogen into uric acid, conversion of AA carbon skeletons into glucose, fat, CO_2 and water, and the formation of non-protein derivatives, such as enzyme systems (Kidd and Kerr, 1996).

Amino acids can be divided into two categories: non-essential AA (NEAA) or dispensable AA, and essential AA (EAA) or non-dispensable AA. The need for the EAA arises from the inability of all animals to synthesize the corresponding carbon skeleton or keto acid, and provision of these nutrients is mandatory. The EAA include arginine (Arg), lysine (Lys), histidine (His), isoleucine (Ile), leucine (Leu), methionine (Met), phenylalanine (Phe), threonine (Thr), thyptophan (Trp) and valine (Val). The

NEAA are those that the animals are able to synthesize from simple substrates, and include: alanine (Ala), aspartic acid (Asp), asparagine (Asn), cysteine (Cys), glutamic acid (Glu), glutamine (Gln), glycine (Gly), proline (Pro), serine (Ser), and tyrosine (Tyr).

Of those EAA, several are more limiting than others in poultry diets. A limiting AA is defined as an AA which, if it does not meet the minimum requirement, causes deficiency signs such as depression in growth. Once the limiting AA is supplemented to meet the requirement, normal growth returns assuming the other AA are adequately provided.

It is well documented that Met and Lys are the two most limiting AA in corn-soybean meal based diets for turkeys (Baldini et al., 1954; Fitzsimmons and Waibel, 1962; Atkinson et al., 1976; Jackson et al., 1983). As crude protein (CP) in starter and grower turkey feeds is higher than in broiler feeds (NRC, 1994), high inclusion levels of soybean meal occurs, and the main limiting AA in that ingredient is Met (Warnick and Anderson, 1968). On the other hand, the other ingredient with high inclusion levels in turkey diets is corn, and Lys is the most limiting AA in this ingredient for poultry (Fernandez et al., 1994). After Lys and Met, the other EAA considered limiting are Ile, Thr, Trp and Val, not necessary in this order (Stas and Potter, 1982; Jackson et al., 1983; Blair and Potter, 1987; Jackson and Potter, 1987; Waibel et al., 2000a,b; Lemme et al., 2004). The order of limitation will depend on the age of the turkeys and on the feed ingredients used in the formulation.

In general, high CP diets fulfill the requirements of the animal, but this practice results in excessive nitrogen excretion, leading to pollution, as well high feed costs

(Firman, 2001). When formulating low CP diets, the order of limitation of EAA in dietary ingredients has to be accounted for, in order to provide diets that will meet the requirements of the bird. Factors that affect the utilization of these ingredients and the requirements for the EAA are discussed further in this chapter.

Lysine and Threonine Metabolism

The pathways of AA catabolism normally account for only 10 to 15% of human body energy production and these pathways vary greatly, depending on the balance between requirements for biosynthetic processes and the availability of a particular AA. The 20 catabolic pathways converge to form only five products, all of which enter the citric acid cycle. From here the carbon skeletons are diverted to gluconeogenesis or ketogenesis, or are completely oxidized to CO_2 and H_2O.

All or part of the carbon skeletons of 10 AA are ultimately broken down to acetyl-CoA. Five of the 10 – Ala, Cys, Gly, Ser, and Trp - are degraded to acetyl CoA via pyruvate, which can be used to synthesize glucose. Portions of the carbon skeletons of six AA – Ile, Leu, Lys, Phe, Tyr, and Trp – yield acetyl-CoA or acetoacetyl-CoA or both; the latter is converted to acetyl-CoA. The carbon skeletons of five AA – Arg, Gln, Glu, His, and Pro – enter the citric acid cycle as α-ketogluterate. The carbon skeletons of four AA – Ile, Met, Thr, and Val – are degraded by pathways that yield succinyl CoA, an intermediate of the citric acid cycle. The carbon skeletons of Asp and Asn ultimately enter the citric acid cycle as oxaloacetate, and the carbon skeletons of Phe and Tyr enter the citric acid cycle as fumarate (Nelson and Cox, 2000).

Lysine

Lysine functions as a building block for proteins. It is also a key player in the production of various enzymes, hormones, and disease-fighting antibodies. It is important in the absorption of calcium in the intestines, and also contributes to the formation of collagen.

Lysine metabolism yields acetoacetyl-CoA, which is cleaved to produce acetyl-CoA, which can then directly enter the citric acid cycle. The degradation of Lys can also produce ketone bodies in the liver, where acetoacetyl-CoA is converted to acetoacetate and β-hydroxybutyrate (Nelson and Cox, 2000). The ketone bodies are further used by skeletal and cardiac muscles to produce adenosine triphosphate (ATP), which is a source of readily available energy essential in several metabolic reactions.

Threonine

Threonine is an EAA that promotes normal growth by helping to maintain the proper protein balance in the body, supporting cardiovascular, liver, central nervous, and immune system functions. Threonine is also needed to generate Gly and Ser, two AA that are necessary for the production of collagen and muscle tissue (Bell and Turner, 1976). Glycine is needed for uric acid production, conversion to Ser, and synthesis of creatine and glutathione (Kidd et al., 1998). Baker et al. (1972) fed Gly-free diets to chicks, and they responded with improved body weight gain when the diets were supplemented with Thr.

Threonine is one of the precursors of isoleucine. It is first dehydrated and deaminated to produce α-ketobutyrate by the enzyme threonine deaminase – a pyridoxal phosphate (PLP) enzyme – then converted to Ile (Nelson and Cox, 2000). Threonine also combines with Met to help the liver with respect to its lipotropic function, and the digestion of fats and fatty acids (Singal et al., 1953; Khairallah and Wolf, 1965).

Low Crude Protein Diets

The requirement for CP for growing turkeys has been a topic of research for many years. The young poult has a high protein requirement – about 28% according to NRC (1994). This requirement falls to almost half of this amount by market weight. Much research has been done trying to decrease the CP levels in turkey diets by adding free AA to the diets, starting with Klain et al. (1954) and Ferguson (1956) who found that adding Met and Lys to low CP starter turkey diets improved performance, but not to the same level as the performance obtained by high CP diets. Stas and Potter (1982), Jackson et al. (1983), Jackson and Potter (1984, 1987) fed starter 22% CP diets to poults and had growth performance results equal to the 30% CP diets, when diets were supplemented with all EAA. Jackson and Potter (1987) confirmed that Met was the first limiting AA by supplementing Met to low CP diets and obtaining incremental increases in body weight gain. However, when Leeson and Caston (1991) fed hen turkeys, up to 70 and 105 days, low CP diets with reduced levels of Lys and Met, significant differences were noticed in body weight gain in favor of high CP diets. Waldroup et al. (1997a) fed turkeys, from hatch to 20 weeks of age, corn-soybean diets varying in total AA ranging from 85 to 120% of the NRC (1994) recommendations without restricting a minimum requirement for CP. Results suggested that diets formulated to provide 105% of the NRC (1994) recommended requirements were needed to provide maximum body weight gain, feed conversion, and breast meat yield. A similar trial was conducted by Waibel et al. (1995) who fed turkeys diets formulated to provide 80 to 120% of NRC (1984) Lys recommendations up to 18 weeks of age. Performance results suggested that diets with 90% NRC Lys were equal to diets with higher Lys, when Met + Cys was provided at 100% of the recommendations. Sell (1993) found that feeding a reduced CP diet (93% of the NRC 1984 recommendation), supplemented with Met and Lys, had no effect on body weight gain and feed conversion of the turkeys; however, there was a reduction in breast meat yield. Lemme et al. (2004) reduced the CP by 10 and 20% of the recommendation in turkey diets from 2 to 20 weeks while maintaining the recommended levels of all EAA or only supplementing Lys, Met, Thr and Trp. Results suggested that diets with 10% CP reduction can be fed without adverse effects on animal performance and carcass traits provided the whole range of EAA is balanced. Also, it was concluded that Arg, Ile, Leu and Val are important for optimum growth and should be considered in diets containing 10% less than recommended CP. Lemme et al. (2006) conducted a trial to verify how the combination of balanced CP – based on Lys – that ranged from 90 to 120% of the recommendations would affect the performance and economic results in a six phase feeding regimen up to 22 weeks of age. Performance data in combination with economic simulations suggested that feeding regimens starting either with 120% of the recommendation in phases I and II, decreasing to 100% in phases III and IV, and finishing phases V and VI with 90% of the recommendation, or with 90% in phases I through III, and 100% in phases IV through VI might be the alternatives to improve overall profitability. Waldroup et al. (2003) reevaluated the CP requirement of male turkeys from 16 to 20 weeks of age, with diets formulated to contain at least the minimum recommended levels of Met, Met + Cys, Lys and Thr. Reducing the CP content of the diet to less than 85% of NRC (1994) resulted in a significant reduction in weight at 20 weeks and body weight gain from 16 to 20 weeks.

Ideal Protein Concept

Protein is one of the major cost components in turkey diets. When diets are formulated on a ideal protein (IP) basis, the levels of CP in the diet decreases with the use of synthetic AA, performance is maintained (Boling and Firman, 1997a,b), feed costs are decreased (Dudley-Cash, 1998) and nitrogen excretion is minimized, reducing the potential for environmental pollution (Ferket et al., 2002).

The concept of IP – when diets are formulated to reach the minimum requirements of digestible AA – is extensively used by the broiler industry, but not by the turkey industry because the lack of information on the requirements of digestible AA for turkeys. In order to determine an ideal AA ratio it is necessary to know the digestible AA requirement of each essential AA for the turkey and its relationship to lysine.

The basic goal of the IP approach is to provide a blend of EAA that exactly meets an animal needs for protein accretion and maintenance, with no deficiencies and no excesses. The ideal protein concept uses Lys as a reference AA, with the requirements for all other EAA expressed as a percentage of Lys. Lysine was chosen as a reference AA for several reasons: 1) in practical poultry diets, Lys is the second limiting amino acid after Met + Cys, and Lys supplementation is economically feasible; 2) Lys analysis in feedstuffs is straightforward; 3) dietary Lys is used only for protein accretion and maintenance, with no precursor role; and 4) Lys requirement data for a variety of dietary, environmental, and body compositional circumstances are readily available, mainly for broilers. Table 2.1 shows a portion of the IP broiler profile, which might be applied to turkeys, including those AA typically considered most important in practical diets (Lys, Met + Cys, Thr, Val, Arg, Trp, and Ile).

The AA requirements for turkeys in the NRC (1994) are based on research conducted on a total AA basis. Lately, studies have been conducted to determine digestible AA requirements, and so far digestible levels of Lys and sulfur AA have been established (Boling and Firman, 1997a,b, 1998; Firman and Boling, 1998; Moore et al., 2001, 2003, 2004; Baker et al., 2003a,b, Firman, 2004, Thompson et al., 2004, 2005, Firman and Guaiume, 2006). To date, only one study has been conducted to determine the requirements for digestible Thr for starter poults (Kamyab and Firman, 2000). It has been suggested that the AA profiles for turkeys would be close to those required for broilers and that additional Thr, sulfur AA and Trp would aid growing turkeys from 16 to 20 weeks of age (Baker and Chung, 1992). To date, no data on requirements for digestible Thr for turkeys is available in the literature.

Table 2.1. Ideal ratios (%) for selected amino acids at the three broiler growth periods[1].

Amino acid	0 to 21 d	21 to 42 d	42 to 56 d
	% Lys	% Lys	% Lys
Lys	100	100	100
Met + Cys	72	75	75
Met	36	37	37
Cys	36	38	38
Thr	67	70	70
Val	77	80	80
Arg	105	108	108
Trp	16.6	19	ND
Ile	61.4	71	ND

[1]Adapted from Emmert and Baker (1997), Mack et al. (1999), and Baker et al. (2002).
ND: not determined

Expression of Nutrient Requirements

Nutrient requirements can be expressed in two ways: on an intake basis (e.g., mg/day or mg/kg body weight/day), referred to as the daily requirement; or on a concentration basis (e.g. percent of the diet or g/kg diet), referred to as the dietary requirement. In practice, the more common form is to express it as a percentage rate of the diet, because it is more convenient for three reasons. First, expressing requirements as concentrations, such as percentages of the diet, permits their direct comparison with nutrient levels in feeds, which are typically expressed as concentrations. Second, this form of expression is necessary to formulate novel diets from a collection of individual feeds or specific ingredients. Third, requirements expressed on a percentage basis change slowly and linearly throughout the life cycle of the bird (Klasing, 1998).

Other factors which might influence the determination of the nutrient requirements include feed type, genetic lines, and environmental conditions, such as temperature, moisture, and disease challenge. Data by Scott (2002) and Greenwood et al. (2005) even suggested interactions between feed form and quality and optimum dietary nutrient levels in broilers. Nicholas White, Hybrid and British United Turkeys (BUT) are the most common genetic lines used in trials for nutrient requirement determination. Due to genetic selection of these strains, they have different growth rates. According to Waldroup et al. (1998c), Nicholas White turkeys tend to grow rapidly during starting phases, while BUT turkeys tend to grow faster in the latter phases. Therefore, depending on age, the requirements for optimal growth may differ. Younger birds are more tolerable of high temperatures, since they have a less developed thermoregulatory system. Older birds are less tolerant, because they produce more metabolic heat and have relatively less surface area to eliminate that heat. However, in periods of continuous heat, older birds are able to acclimatize to the heat, and tolerate higher temperatures (Macari et al., 2002). In many of the requirement studies, the temperature was not mentioned; however, it is an important factor, as elevated temperatures can cause depressed feed intake, consequently reducing body weight gain (Klasing, 1998).

__Lysine Requirements for Turkeys__

The NRC (1994) lists the requirements for nutrients by turkeys in 4-week intervals from hatch to 24 weeks of age, and the AA recommendations for each phase are on a total basis, as in Table 2.2.

Table 2.2. Crude protein (CP), total lysine (tLys) and total threonine (tThr) recommendations for turkeys from hatch to 24 weeks of age.

	0 to 4 wk	4 to 8 wk	8 to12 wk	12 to 16 wk	16 to 20 wk	20 to24 wk
CP (%)	28.0	26.0	22.0	19.0	16.5	14.0
tLys (%)	1.60	1.50	1.30	1.00	0.80	0.65
tThr (%)	1.00	0.95	0.80	0.75	0.60	0.50

There is a significant amount of research published on the Lys requirements of female turkeys during the starter period. Attempts at determining the total Lys (tLys) requirement for poults from hatch to 3 weeks of age have determined the tLys requirement to be between 1.42 and 1.60% of the diet (Kummero et al., 1971; Tuttle and Balloun, 1974; D'Mello and Emmans, 1975, Hurwitz et al., 1983). Warnick and Anderson (1968) reported the tLys minimum requirement for turkeys from 5 to 17 days to be 1.68%. Waldroup et al. (1997a) suggested that level of tLys recommended by NRC (1994) should be increased by at least 5% to improve the body weight gain. Jackson and Potter (1984) fed turkey diets with 22% CP and different levels of tLys from 7 to 19 days and reported better performance when diets contained 1.89% tLys, and the other EAA were balanced. More recently, research has been conducted to determine the requirements for Lys on a digestible base (dLys). Boling and Firman (1998) reported the dLys requirement for Hybrid female poults from 8 to 27 days of age raised in battery cages to be 1.32% for optimal weight gain and 1.34% for optimal feed conversion. Thompson et al. (2004) reported the dLys requirement for Nicholas White female poults from 4 to 15 days of age raised in floor pens to be 1.29% for body weight gain. Similar results were reported by Firman (2004) when male Nicholas White poults were fed experimental diets from 7 to 18 days, and determined the dLys requirement for optimum body weight gain to be 1.31%.

However, not much research has been conducted to establish the Lys requirement for turkeys after the third or fourth weeks of age. Kratzer et al. (1956) determined the tLys requirement for male and female turkeys from 4 to 8 weeks of age to be 0.96%. For the same period, Hurwitz et al. (1983) determined the tLys requirement for male turkeys from 4 to 8 weeks of age to be 1.12%, based on carcass content and maintenance. Balloun and Phillips (1957) found the tLys requirement for both genders to be 1.55% for the first six weeks of age. However, in 1974 Tuttle and Balloun recommended 1.40% tLys for male turkeys from 4 to 8 weeks of age. Firman (2004) estimated that 1.19% dLys was the minimum requirement for male Nicholas White turkeys from day 23 to day 37 for optimum body weight gain. Working with female Nicholas White turkeys, Thompson et al. (2004) estimated the requirement for dLys from 29 to 40 days to be 1.16% and 1.12% for body weight gain and feed conversion, respectively.

The NRC (1994) recommendation for tLys for turkeys between 8 and 12 weeks is 1.30%. However, Kratzer et al. (1956) determined that the tLys requirement for Bronze turkeys of both sexes to be 0.96% for that period. Research on Large White male turkeys (Tuttle and Balloun, 1974) reported that increasing tLys above 1.40% in a 22% CP diet did not result in further increases in body weight gain from 4 to 8 weeks of age. Recent research with male Nicholas White determined that the dLys requirement in the period from 49 to 61 days of age was 1.09% for body weight gain, and 1.11% for feed conversion (Baker et al., 2003a). Different results were obtained with female Nicholas White where Thompson et al. (2005) determined the dLys requirement in the period from 46 to 57 days of age to be 1.04% for body weight gain, and 1.07% for feed conversion. These differences between male and female birds confirm results reported in 1957 with Balloun and Phillips who found higher CP requirements for males than females in starting phases, and also in later phases (Potter et al., 1981). Differences in tLys requirement in favor of males were also confirmed by Potter and Shelton (1980).

From 8 to 12 weeks of age, Potter et al. (1981) reported minimum requirement for tLys for Nicholas White turkeys to be 1.34% for males and 1.46% for females, while Noll and Waibel (1989) reported 1.25% tLys for males of the same turkey line for the same period. Lehmann et al. (1996) suggested dietary levels of tLys for BUT males ranging from 1.17 to 1.27% for optimum weight gain and feed conversion from 8 to 12 weeks of age. More recently, Baker et al. (2003a) and Thompson et al. (2005) determined the requirements for Lys on a digestible basis for male and female Nicholas White for the period between 9 and 12 weeks. Baker et al. (2003a) determined the dLys requirement for males from 72 to 83 days to be 0.87 and 0.86% for optimum body weight gain and feed conversion, respectively. Thompson et al. (2005) determined the dLys requirement for females from 71 to 85 days to be 0.86 and 0.82% for optimum body weight gain and feed conversion, respectively.

Jensen et al. (1976) suggested a requirement for Lys of 3.11 g Lys/Mcal of metabolizable energy (ME), which represents 0.95% tLys in the diets of male for the period between 12 and 16 weeks. However, Potter et al. (1981) suggested levels of 1.15% dietary tLys for male turkeys for the same time period. Recently, Baker et al. (2003b) determined the dLys requirement for male Nicholas turkeys from 12 to 18 weeks. The authors reported dLys requirements of 0.68 and 0.67% for body weight gain and feed conversion, respectively, for the 84 to 95 days period. For 105 to 116 days, Baker et al. (2003b) determined the dLys requirement to be 0.53% for optimum body weight gain and 0.54% for feed conversion. Potter et al. (1981) estimated the tLys requirement for the period of 16 to 20 weeks to be 0.97% for males and 0.87% for female turkeys. However, Jensen et al. (1976) estimated the minimum requirement for tLys for male turkeys to be 0.73% in the same period, while Noll and Waibel (1989) suggested the minimum requirement for tLys to be 0.77% for Nicholas White male turkeys. However, in a more recent trial, Lehmann et al. (1996) concluded that the dietary tLys requirement of male BUT turkeys is 0.96% or higher. For the period between 20 and 23 weeks of age, Kratzer et al. (1956) recommended 0.60% tLys for Broad Breast Bronze turkeys.

A review of the data cited previously indicates that there are many differences among the results obtained by researchers cited above, and much the variance can be explained by the development of genetic lines over the time that the research was conducted, the different genetic lines used in the trials, nutrient and ingredient composition of the diets, and also by the different environmental condition where the trials were done. However, the consensus is that the determination of digestible AA requirements methodology is more precise and accurate and will facilitate the formulation of turkey diets using the IP concept.

Threonine Requirements for Turkeys

Only one experimental study has been conducted to determine the requirements for dThr for turkeys (Kamyab and Firman, 2000). This work was done in batteries with hen poults from hatch to 3 weeks, and the authors estimated the requirements for dThr to be 0.67 and 0.74% for body weight gain and feed conversion, respectively.

Lehmann et al. (1997) determined that an adequate dietary levels of total Thr (tThr) for BUT male turkeys for growth and feed conversion for the hatch to 4 weeks period was 0.95%. Kidd et al. (1998) determined that adequate dietary levels of tThr for BUT male turkeys for body weight gain and feed conversion for the hatch to 3 weeks period were 0.93 and 0.97% of the diet, respectively. The NRC (1994) recommended 1.00% of tThr in diets for turkeys from hatch to 4 weeks, and recent report of Firman and Guaiume (2006) suggested levels between 0.83 and 0.86% of dThr for male poults for the first three-week period for optimum growth and feed conversion.

For the 3 to 6 week period, Kidd et al. (1998) reported that the level of dietary tThr needed to support adequate body weight gain and feed conversion was 0.88% of the diet for BUT male turkeys. However, Waldroup et al. (1998b) reported that the requirements for total dietary Thr for the same period were 0.92 and 0.87% for body weight gain and feed conversion, respectively, for Nicholas White male turkeys.

Meanwhile, NRC (1994) recommended 0.95% dietary tThr for turkeys from 4 to 8 weeks. Firman and Guaiume (2006) reported levels between 0.76 and 0.81% dThr for male poults from 3 to 6 weeks of age for optimum growth and feed conversion.

For the period of 6 to 9 weeks of age, Kidd et al. (1998) determined the level of total dietary Thr needed to support adequate body weight gain and feed conversion ratio of BUT male turkeys to be 0.77% of the diet. Waldroup et al. (1998b) reported different levels of total dietary Thr for body weight gain and feed conversion (0.86 and 0.84%, respectively) for Nicholas White toms, for the same period. Results obtained by Barbour et al. (2008) suggested levels of 0.85% of tThr for BUT male turkeys from 8 to 13 weeks of age, confirming Waldroup et al. (1998b), even though they did not use the same genetic line. From 6 to 9 weeks of age, Firman and Guaiume (2006) reported minimum level of dThr to be 0.67% for optimum performance results for Nicholas White. Lehmann et al (1997) observed no significant response to dietary tThr beyond 0.69% from BUT male turkeys for the 8 to 12 week period. However, NCR (1994) currently gives a recommendation of 0.80% dietary tThr for turkeys from 8 to 12 weeks of age. Meanwhile, Firman and Guaiume (2006) recommended dietary dThr for male turkeys to be 0.59% from 9 to 12 weeks for optimum performance results. The NRC (1994) recommendation for tThr for turkeys in the period 12 to 16 weeks of age is 0.75%. Firman and Guaiume (2006) recommended 0.51% dietary dThr for male turkeys from 12 to 15 weeks, and dietary dThr 0.45% from 15 to 18 weeks of age to achieve optimum growth performance and feed efficiency. From 16 to 20 week of age, a total dietary Thr level of 0.58% appeared to be adequate to obtain optimum body weight gain, whereas for breast meat deposition, 0.64% of total dietary Thr is required

(Lehmann et al., 1997). The NRC (1994) currently lists a recommendation for this phase range (16 to 20 weeks) of 0.60% of dietary tThr.

CHAPTER III

APPARENT DIGESTIBILITY OF AMINO ACIDS IN FEED INGREDIENTS FOR TURKEYS

SUMMARY

An experiment was conducted to determine the apparent digestibility of amino acids (AA) in five feed ingredients, corn, soybean meal (SBM), meat and bone meal (MBM), poultry by-product meal (PBM) and peanut meal (PNM), used in turkey rations. Male Nicholas White poults were raised in batteries for 18 days with feed and water available. At day 19, no feed was offered to poults, and they were randomized to five dietary treatments, with six replicates per treatment and five poults per pen. On day 20, diets containing only one source of protein were offered to the poults. In the corn assay, the diet contained 97% corn. In the plant and animal protein meals assays, diets were based on dextrose and the test ingredient, with the content of protein meal fixed at 50% and the dextrose content was 46 and 47% for plant and animal origin ingredients, respectively. All diets contained chromic oxide. Total pen excreta was collected from days 21 to 24, and on day 25, poults were euthanized and ileal digesta were sampled on a pen basis. Ingested and digested amounts of AA were determined for each pen. The influence of site of measurement was found to vary among food ingredients and among different AA within an ingredient. Ileal AA digestibility values were similar in some ingredients, but significantly lower or higher in others than the corresponding excreta values. Average ileal and excreta AA digestibilities in corn

were similar, but significant differences were observed for individual AA. In contrast, ileal AA digestibility values were lower than the corresponding excreta digestibility values in SBM, and the opposite was observed in AA digestibilities of PNM. Site of measurement had no effect on the digestibility of AA in PBM. However, ileal AA digestibility values were lower than the corresponding excreta digestibility values in MBM. Threonine, valine and tryptophan were the essential AA more frequently influenced by the site of measurement. Of the non-essential AA, cysteine, serine, glutamic acid and proline were the most affected. Differences determined between ileal and excreta digestibilities in the present study clearly demonstrate that AA metabolism by hindgut microflora in turkeys may be substantial, and that digestibilities measured in the terminal ileum are more accurate measures of AA availability than those measured in the excreta.

INTRODUCTION

It is recognized that amino acid (AA) digestibility is a sensitive indicator of AA availability in dietary ingredients for poultry. The most common method used to measure AA digestibility in poultry is excreta analysis, as developed by Kuiken and Lyman (1948). The majority of published values currently available on digestible AA for poultry are based on excreta analysis because of its simplicity and because the assay can be carried out on large numbers without sacrificing the birds (McNab, 1994). Excreta-based digestibility measurements, however, are criticized because of the possible effects of microorganisms in the avian hindgut on protein utilization and the contribution of microbial proteins to AA excretion in the feces (Payne et al., 1968; Parsons et al., 1982; Raharjo and Farrell, 1984).

Furthermore, excreta analysis does not measure digestibility as classically defined but rather AA metabolizability, because feces and urine are voided together in birds. An alternative method of determining AA digestibility in poultry dietary ingredients is ileal digesta analysis. However, published data on turkey AA digestibility of raw material using either total excreta collection or ileal digesta collection analysis are very limited (Pierson et al., 1980, Parsons, 1982; Firman, 1992, Firman and Remus, 1993; Kluth and Rodehutscord, 2006; Adedokun et al., 2007).

The objective of the present study was to determine the AA digestibility in five feed ingredients, corn, soybean meal, meat and bone meal, poultry by-product meal and peanut meal used in turkey rations. A second objective was to compare total excreta and ileal digesta collection methods.

MATERIAL AND METHODS

General Procedures

A total of five samples representing five ingredients were tested. The ingredients tested included one sample of a cereal (corn), two samples of plant protein meals (soybean meal – SBM, and peanut meal - PNM), and two samples of animal protein meals (meat and bone meal – MBM, and poultry by-product meal - PBM). Ingredients were obtained from commercial feed mill suppliers of the University of Missouri-Columbia feed mill.

Two hundred male Nicholas White poults were purchased from a commercial hatchery and raised in batteries for 18 days with commercial starter feed and water available. At day 19, no feed was offered to poults, and a total of 150 poults were randomized to five dietary treatments, with six replicates per treatment and five poults per pen. On day 20, the diet treatments were offered to the poults. All procedures were conducted in accordance with the University of Missouri Animal Care and Use Guidelines and approved protocols.

Test ingredients were incorporated as the sole source of dietary protein in assay diets (Table 3.1). Different assay diets were used for cereal grain and protein meals. In the case of corn, the assay diet contained 97% corn, 2.3% corn oil, and 0.7% vitamin and mineral supplements and chromic oxide (CrO). In the case of protein meals, assay diets were based on dextrose and the test ingredient. The content of protein meal was fixed in 50%, and the dextrose content was 46 and 47%, for plant and animal origin ingredients, respectively.

The poults were fed assay diets from days 20 to 24, and total excreta collection was carried out for four days (days 21 to 24). Excreta were collected daily and frozen. On day 24, all poults were killed by using an intracardial injection of a sodium pentabarbitone solution, and the contents of the lower half of the ileum were collected. The ileum was defined as distal two-thirds of the section between Meckel's diverticulum up to 1 cm anterior to the ileocecal junction. At the end of the collection period, all excreta and digesta collected were dried for 48 h at 60ºC in forced-air ovens. Ileal digesta of poults within a pen were pooled, and the same procedure was applied to the total excreta of poults. Dried ileal digesta and excreta were ground to pass a 1.0 mm sieve, and representative samples of the total were collected and stored. All ileal digesta samples content were stored.

Duplicate samples of excreta, ileal digesta, and feed were digested by nitric-perchloric acid wet digestion. Chromium concentrations in excreta, in ileal digesta, and in the feed were determined by flame atomic absorption spectrophotometry (AOAC, 2006). Complete AA profiles for excreta, ileal digesta and diets were analyzed as described by AOAC (2006).

Calculations

Apparent ileal and excreta AA digestibilities were calculated, using CrO as the indigestible marker, as shown below.

$AAAD = 100 – (100 \times ((\%Cr_f / \%Cr_{e(d)}) \times (\%AA_{e(d)} / AA_f))$

Where:

AAAD = Apparent Amino Acid Digestibility

Cr_f = Chromium in the feed;

$Cr_{e(d)}$ = Chromium in the excreta or digesta;

$AA_{e(d)}$ = AA in the excreta or digesta;

AA_f = AA in the feed.

Statistical Analyses

The GLM procedure of SAS (2003) was used and the classification of the independent variables was the treatments. The model included the digestibility values of all AA and the overall mean of the digestibility. Post test comparisons were done to compare means of digestibility of AA for ileal digesta and total excreta methods after obtaining a significant F-test in the analyses of variance. Significant differences were accepted at level of $P < 0.05$.

RESULTS

The crude protein and amino acid concentrations of the feed ingredients evaluated are presented in Table 3.2. The difference between ileal and excreta values varied depending on the feed ingredient and the AA considered. The apparent ileal and excreta digestibilities of AA in corn, SBM and PNM are presented in Table 3.3. The overall means of ileal and excreta AA digestibility values for corn were similar. In contrast, the AA digestibility estimates for SBM and PNM were influenced by the site of measurement, with ileal AA digestibility values being higher ($P < 0.05$) than the corresponding excreta AA digestibility values in PNM, and excreta AA digestibility values being higher ($P < 0.01$) than ileal AA digestibility values in SBM. The average ileal digestibilities of AA in corn, SBM and PNM were 80.8, 79.5, and 83.0%, respectively. The corresponding values for the excreta collection method for corn, SBM, and PNM were 79.6, 84.2, and 80.5%, respectively. Ileal-excreta differences were noted for individual AA within corn, SBM and PNM. Digestibilities of cysteine ($P < 0.01$), glutamic acid ($P < 0.01$), glycine ($P < 0.001$), histidine ($P < 0.05$), lysine ($P < 0.01$), proline ($P < 0.001$), serine ($P < 0.01$), threonine ($P < 0.01$) and valine ($P < 0.05$) in corn were influenced by the site of measurement. With the exception of histidine and glycine, all excreta AA digestibility values were significantly higher than ileal digestibility AA values for SBM. The digestibilities of alanine ($P < 0.001$), arginine (P < 0.01), cysteine (P < 0.01), histidine (P < 0.001), isoleucine (P < 0.01), leucine (P < 0.05), methionine (P < 0.001), serine (P < 0.01), threonine (P < 0.001), and valine (P < 0.05) in PNM were significantly different between the two methods.

Table 3.4 presents the apparent ileal and excreta digestibilities of AA in PBM and MBM. The overall mean of ileal and excreta AA digestibility values in PBM were similar. In contrast, the digestibility estimates for MBM were influenced by the site of measurement with the excreta AA digestibility values being higher (P < 0.001) than the corresponding ileal AA digestibility values. The average ileal digestibilities of AA in PBM and MBM were 76.3 and 74.7%, respectively. The corresponding values for the excreta collection method of PBM and MBM were 77.4 and 83.0%, respectively. Ileal-excreta differences were noted for individual AA within PBP and MBM. Digestibilities of glutamic acid (P < 0.01), glycine (P < 0.001), cysteine (P < 0.05), histidine (P < 0.001), proline (P < 0.01), serine (P < 0.01), threonine (P < 0.01) and tryptophan (P < 0.01) in PBM differed between the two methods. Except for glycine, all the excreta AA digestibility values were significantly higher than ileal digestibility AA values for MBM.

DISCUSSION

The influence of hindgut microflora on protein nutrition in poultry is not as clearly established for the turkey as for the pig (Sibbald, 1987). It is generally assumed that the influence of the avian hindgut on protein nutrition is insignificant and that there is little advantage over conventional excreta analysis in using other methods to determine amino acid digestibility in chickens (Papadopoulos, 1985). Differences between ileal and excreta digestibilities in the present study, however, demonstrate that AA metabolism by hindgut microflora in poults may be substantial and that determination of AA digestibility by excreta analysis may not be a valid procedure for all food ingredients.

Nitrogen metabolism in the hindgut comprises both the degradation of nitrogenous substances (dietary and non-dietary origin) and the synthesis of microbial proteins. The balance between both activities determines whether the recovery of AA in excreta, relative to the ileum, will decrease or increase. Deamination of AA leads mainly to the formation of ammonia, which may be absorbed but not utilized by the bird and almost completely excreted in the urine as uric acid (Salter and Coates, 1971; Salter et al., 1974). When the net result is degradation, the output of AA in excreta will be decreased, resulting in the overestimation of AA digestibility. On the other hand, when the net result of microbial activity is synthesis, the reverse situation will occur resulting, in underestimation of digestibility.

In the present study the influence of site of measurement was inconsistent varying among feed ingredients and among different AA within an ingredient.
Ileal AA digestibility values in some feed ingredients were similar to the corresponding excreta values but significantly lower or higher in some others. These findings highlight the need for the development of standard ileal digestibility assays for measuring AA availability in food ingredients for poultry. Assays based on ileal digesta also have the added advantage of not being influenced by urinary AA, which may confound digestibility estimates based on excreta. Because the quantity of AA

excreted in the urine is small (O'Dell et al., 1960) with the exception of glycine (Soares et al., 1971), their contribution to excreta AA concentrations is normally assumed negligible (Sibbald, 1987). Another advantage of ileal digesta analysis is the elimination of contamination by skin tissue and feathers as in the excreta.

In peanut meal, the overall excreta digestibility was lower than the ileal values. This suggests a preponderance of microbial protein synthesis over microbial degradation. This ingredient might contain significant amounts of carbohydrates that are poorly digested in the small intestine. Fermentation of these carbohydrate components in the hindgut is likely responsible for the observed net microbial protein synthesis. The supply of fermentable carbohydrates in the hindgut therefore appears to modify the balance in microbial activity towards synthesis. This phenomenon has been reported in studies with pigs by Gargallo and Zimmerman (1981) and Misir and Sauer (1982), both cited by Ravindran et al. (1999). By infusing starch into the large intestine, these workers demonstrated that, as more energy becomes available to the microflora, relatively more ammonia and amines (from the degradation of nitrogenous substances) may become incorporated into microbial proteins which are voided in the feces. On the other hand, the amounts of dietary AA digested and absorbed at the terminal ileum were markedly lower than the values determined over the entire digestive tract for most animal protein sources. The lower digestibility values obtained by ileal digesta analysis indicate that more AAs were recovered in the ileal digesta than in the excreta, suggesting a significant net disappearance of AA in the hindgut.

Digestibility of AA in SBM and MBM were significantly higher in the excreta analysis, compared with ileal-digesta analysis. This is to be expected because the lower the AA digestibilities at the ileum, the more undigested nitrogen will reach the hindgut, providing a substrate for microbial degradation resulting in large differences between ileal and excreta digestibilities. However, non-significant differences were recorded for corn and PBM.

Among the essential AA, threonine, valine and tryptophan were more frequently modified by microbial fermentation in the hindgut. Of the non-essential AA, serine, glutamic acid and proline were most affected, a finding which is in agreement with reports on pigs (Sauer et al., 1991; Fan et al., 1995). The significance of this observation is unclear, but it is noticeable that endogenous secretions in poultry contain relatively large proportions of threonine, serine and glutamic acid (Salter and Fulford, 1974; Bielorai and Iosif, 1987; Siriwan et al., 1994; Angkanaporn et al., 1997). It would appear that the hindgut microflora preferentially metabolize these AA.

Overall, the catabolism and synthesis of AA in the hindgut, along with the inability of poultry to retain nitrogen absorbed from or synthesized in the hindgut (Salter and Coates, 1971; Salter et al., 1974), suggest that digestibilities determined in the terminal ileum are more accurate measures of AA availability than those determined in the excreta. The magnitude and direction of differences between ileal and excreta AA digestibilities were dependent on the type of ingredient and the individual AA.

Amino acid digestibility in some ingredients such as PNM may be significantly underestimated, whereas in SBM and MBM they may be overestimated by excreta analysis. Similarly, the differences were larger for some AA (e.g. threonine) than for others. As suggested by Sauer and Ozimek (1986), the amount of energy-yielding carbohydrates reaching the hindgut appears to determine whether net degradation or net synthesis of AA will take place. When fermentable carbohydrates are limiting, the undigested nitrogenous substances will be deaminated by the microbes to ammonia and amines resulting in net disappearance of amino acids. When fermentable carbohydrates are available, the microbes will utilize the ammonia and amines for the *de novo* synthesis of microbial proteins, resulting in net synthesis of AA.

CONCLUSIONS

Differences determined between ileal and excreta digestibilities in the present study clearly demonstrate that AA metabolism by hindgut microflora in turkeys may be substantial and that digestibilities measured in the terminal ileum are more accurate measures of AA availability than those measured in the excreta.

The determined digestibility coefficients of each AA for feed ingredients in this study were very important for the determination of the digestible requirement for Lys and Thr for male turkeys, which is reported in the following chapters in this dissertation.

Table 3.1. Composition of diets for amino acid digestibility assays in poults (%)

Component	Corn	SBM	PNM	PBP	MBM
Test ingredient	97.00	50.00	50.00	50.00	50.00
Dextrose	-	46.00	46.00	47.00	47.00
Corn oil	2.33	3.33	3.33	2.33	2.33
Choline chloride	0.15	0.15	0.15	0.15	0.15
NaCl	0.20	0.20	0.20	0.20	0.20
Mineral mix[1]	0.10	0.10	0.10	0.10	0.10
Vitamin mix[2]	0.10	0.10	0.10	0.10	0.10
Selenium mix[3]	0.06	0.06	0.06	0.06	0.06
Copper sulfate	0.01	0.01	0.01	0.01	0.01
CrO	0.05	0.05	0.05	0.05	0.05

[1]Trace mineral mix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_4.7H_2O$); I, 2.0 (ethylenediamine dihydroiodide).
[2]Vitamin mix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg.
[3]Selenium premix provided 0.3 mg/kg of Se (Na_2SeO_3).

Table 3.2. Crude protein and amino acid concentrations in the feed ingredients (%)

Component	Corn	SBM	PNM	PBP	MBM
Crude protein	7.56	47.45	49.48	60.76	54.22
Alanine	0.59	1.99	1.75	4.02	3.70
Arginine	0.39	3.53	5.46	4.33	3.31
Aspartic ac.	0.50	5.46	5.09	5.13	4.05
Cysteine	0.17	0.68	0.58	0.73	0.63
Glutamic ac.	1.37	8.41	8.11	8.24	6.17
Glycine	0.32	1.96	2.60	5.57	5.74
Histidine	0.23	1.29	0.98	1.31	1.19
Isoleucine	0.28	2.32	1.62	2.51	1.86
Leucine	0.95	3.69	2.87	4.51	3.51
Lysine	0.25	2.95	1.54	4.04	2.41
Methionine	0.18	0.68	0.48	1.31	0.76
Phenylalanine	0.39	2.45	2.30	2.52	1.59
Proline	0.55	2.31	1.67	3.73	4.06
Serine	0.32	2.24	2.09	2.36	3.62
Threonine	0.28	1.73	1.16	2.33	1.81
Tryptophan	0.06	0.61	0.45	0.51	0.30
Tyrosine	0.20	1.67	1.70	2.08	1.37
Valine	0.41	2.38	1.84	3.15	2.27

Table 3.3. Apparent ileal and excreta digestibilities of amino acids in corn, soybean meal (SBM), and peanut meal (PNM)[1].

	Corn				SBM				PNM			
	ID	ED	SEM	P	ID	ED	SEM	P	ID	ED	SEM	P
Ala	87.2	86.6	1.1	ns	81.8	85.5	0.8	**	86.9	78.5	1.2	***
Arg	90.1	88.1	0.8	ns	89.0	90.6	0.5	*	92.6	90.1	0.6	**
Asp	77.9	81.2	1.4	ns	77.3	84.6	0.9	***	82.9	82.4	1.0	ns
Cys	71.0	80.1	1.4	**	65.3	78.7	1.4	***	69.7	76.7	1.2	***
Glu	86.1	88.9	0.8	**	84.5	89.8	0.6	***	87.4	87.9	0.6	ns
Gly	73.2	53.6	1.3	***	72.9	51.4	2.6	***	74.4	48.4	2.8	***
His	86.4	88.6	0.7	*	85.8	85.1	0.8	ns	90.2	75.2	1.2	***
Ile	82.8	83.3	1.2	ns	81.8	86.0	0.8	***	85.3	81.0	1.1	**
Leu	89.5	90.2	0.7	ns	84.9	89.7	0.7	***	88.8	86.9	0.6	*
Lys	88.1	80.6	1.3	**	84.7	89.8	0.5	***	85.6	85.6	0.8	ns
Met	90.1	89.3	0.9	ns	86.5	89.0	0.7	**	89.5	84.8	0.8	***
Phe	84.7	86.9	1.0	ns	83.0	88.4	0.7	***	87.9	86.3	0.8	ns
Pro	81.2	87.6	0.9	***	79.4	87.6	0.7	***	81.0	83.7	0.9	ns
Ser	72.9	82.1	1.5	**	74.7	84.6	0.8	***	77.4	82.4	1.0	**
Thr	61.7	77.1	2.6	**	65.8	80.4	1.5	***	68.5	75.2	0.8	***
Trp	68.6	72.7	3.1	ns	77.3	82.3	1.5	**	77.1	79.9	1.7	ns
Tyr	83.9	84.9	1.1	ns	81.7	86.4	0.7	***	86.8	84.8	0.9	ns
Val	79.4	84.1	1.3	*	77.6	85.4	0.8	***	82.4	79.6	1.2	ns
Mean	80.8	79.6	2.2	ns	79.5	84.2	0.8	**	83.0	80.5	1.1	*

[1]Means of six replicated pens per feed ingredient.
ID: ileal digestibility; ED: excreta digestibility; SEM: standard error of the means.
ns: not significant; ***P < 0.001; **P < 0.01; *P < 0.05.

Table 3.4. Apparent ileal and excreta digestibilities of amino acids in poultry by-products (PBP) meal and meat and bone meal (MBM)[1].

	PBM				MBM			
	ID	ED	SEM	P	ID	ED	SEM	P
Ala	81.1	79.6	1.2	ns	79.9	86.3	1.1	***
Arg	86.2	85.8	0.9	ns	82.9	88.7	0.9	***
Asp	69.5	71.5	1.8	ns	66.2	80.3	1.4	***
Cys	59.3	66.4	2.0	*	57.2	75.9	1.6	***
Glu	79.1	83.2	1.0	**	79.2	87.3	0.9	***
Gly	70.6	53.4	2.1	***	68.8	64.0	2.5	*
His	85.7	77.2	1.3	***	75.9	81.7	1.3	**
Ile	77.9	77.7	1.3	ns	76.4	83.8	1.2	***
Leu	83.5	83.3	1.0	ns	82.4	88.8	0.8	***
Lys	82.4	83.1	1.0	ns	79.6	87.4	0.8	***
Met	84.7	84.3	0.9	ns	81.9	87.8	0.9	***
Phe	80.2	81.3	1.1	ns	80.7	86.9	1.0	***
Pro	73.9	80.1	1.3	**	74.8	86.4	1.0	***
Ser	69.7	76.6	1.5	**	71.5	81.0	1.3	***
Thr	63.5	72.7	1.9	**	68.8	78.7	1.8	**
Trp	71.1	78.9	1.9	**	75.2	81.0	1.9	*
Tyr	79.7	80.7	1.2	ns	78.1	84.6	1.1	***
Val	74.8	77.1	1.4	ns	75.9	84.1	1.1	***
Mean	76.3	77.4	1.3	ns	74.7	83.0	1.2	***

[1]Means of six replicated pens per feed ingredient.
ID: ileal digestibility; ED: excreta digestibility; SEM: standard error of the means.
ns: not significant; ***P < 0.001; **P < 0.01; *P < 0.05.

CHAPTER IV

DIGESTIBLE LYSINE AND THREONINE REQUIREMENTS OF MALE TURKEYS FROM DAYS 8 TO 21 AND DAYS 29 TO 42

SUMMARY

Two experiments were conducted to determine the digestible lysine (dLys) and digestible threonine (dThr) requirement of Nicholas White male turkeys from days 8 to 21 (Phase I), and from days 29 to 42 (Phase II). In both phases, birds were randomized to floor pens with 12 treatments and seven replicates per treatment, plus an additional two treatments with six replicates. A total of 1,152 birds were used in Phase I (12 birds/pen) and 1,056 birds were used in Phase II (11 birds/pen). In Phase I, the reduced crude protein (25% CP, and 3,000 kcal/kg ME) corn-soybean meal (SBM)-peanut meal (PNM)- meat and bone meal (MBM) basal diet supplied 1.14% dLys and 0.56% dThr. To determine the requirement for dThr, the level of dLys was kept at 1.50%, and the seven dietary dThr treatment levels ranged from 0.56 to 1.04%, in 0.08% increments. For the dLys requirement, the level of dThr was kept at 1.04%, and the seven dietary dLys treatment levels ranged from 1.14 to 1.50%, in 0.06% increments. The positive control (PC) diet was an industry average diet containing 29% CP and was based on Agri Stats (2006). Broken-line analyses of SAS was used to estimate the requirement for dLys in Phase I which was found to be 1.36% for body weight gain (BWG) and 1.39% for feed to gain ratio (F:G), and the requirement for dThr to be 0.74% for BWG and 0.81% for F:G ratio. Using the highest required levels

the calculated ratio of dThr to dLys is 0.58. In Phase II, the reduced CP (24% CP, and 3,100 kcal/kg ME) corn-SBM-PNM-MBM basal diet supplied 1.06% dLys and 0.50% dThr. To determine the requirement for dThr, the level of dLys was kept at 1.42%, and the seven dietary dThr treatment levels ranged from 0.51 to 0.99%, in 0.08% increments. For the dLys requirement, the level of dThr was kept at 0.99%, and the seven dietary dLys treatment levels ranged from 1.06 to 1.42%, in 0.06% increments. The PC industry average diet had 27.5% CP. Broken-line analyses was used to estimate the requirement for dLys in Phase II which were found to be 1.27% for BWG and 1.29% for F:G ratio, and the requirement for dThr to be 0.72% for BWG and 0.76% for F:G ratio. Using the highest required levels the calculated ratio of dThr to dLys is 0.59.

INTRODUCTION

There is increasing demand for poultry meats worldwide, mainly because of the lower cost, when compared to other selected meats, such as beef and pork, and also because they are an excellent source of protein with a low concentration of fat, and this is especially true for turkey meat. The overall consumption of turkey meat in the world is about 4.7 million metric tons annually, and the USA is responsible for almost 50% of all consumption (USDA, 2006). The USA is the number one producer of turkey meat as well, with 2.5 million metric tons produced annually, which is about 50% of worldwide production.

In order to stimulate production and consumption of turkey meat, it is necessary to decrease the cost of the diets, without impairing the growth performance of the birds. The use of the ideal protein (IP) concept to formulate diets for turkeys is one tool to reduce the cost of the diets, with the additional benefit of a reduction of fecal nitrogen excretion, when compared to turkeys fed diets formulated on a crude protein (CP) basis and using total amino acid (AA) values.

Current NRC (1994) AA requirement recommendations for turkeys are based on research done using total AA. Agri Stats (2006) nutrient recommendations for turkeys are also based on CP and total AA. There are few reports in the literature on digestible AA requirements of turkeys. To date, digestible levels of lysine (dLys) and sulfur AA (SAA) have been determined for turkeys up to market weight (Boling and Firman, 1997a,b, 1998; Firman and Boling, 1998; Moore et al., 2001, 2003, 2004; Baker et al., 2003a,b; Firman, 2004; Thompson et al., 2004, 2005; Firman and Guaiume, 2006). Only one experimental trial has been conducted to determine the requirements for digestible Thr (dThr) by starter poults (Kamyab and Firman, 2000). It has been suggested that AA profiles for turkeys would be close to those required for broilers and that additional Thr, SAA and tryptophan would aid growing turkeys from 16 to 20 weeks of age (Baker and Chung, 1992). To date, no data on requirements for dThr by turkeys raised to market weight are available in the literature.

The objective of this research was to determine the dLys and dThr requirement of Nicholas White male turkeys from days 8 to 21 and from days 29 to 42, in order to recommend digestible levels of these AA in IP formulated diets for starter poults.

MATERIAL AND METHODS

General Procedure

A total of 3,800 one-day-old Nicholas White male poults were purchased from a commercial hatchery and housed in brooding floor pens with feed and water available *ad libitum*. The birds were raised in a different house from what where the requirement study was conducted, and only the number of birds necessary for each two week study period was moved to the experimental house. After data collection, birds fed deficient diets were culled and the rest of the birds were moved back to the brooding house for a minimum of four weeks prior to be used again. This procedure avoided the same birds being used in two simultaneous collection data periods.

Experiment 1

Housing: A total of 1,400 eight-day-old Nicholas White male poults were wing banded and weighed individually, and after the sorting procedure, 1,152 poults were distributed to the 14 treatments, in 96 pens, with 12 birds per pen. Birds were fed experimental diets from days 8 to 21. Poults were housed and maintained using standard husbandry practices. Birds were housed in curtain sided building with temperature controlled by circulating fans for ventilation and a heater for warming. Birds were maintained on a 24 hour constant-light schedule and allowed access to feed and water *ad libitum*. All procedures were conducted in accordance with the University of Missouri Animal Care and Use Guidelines and approved protocols.

Sorting procedures for Experiments 1 and 2: The number of birds needed to be used in the two week experimental periods plus an additional 20% were weighed individually, and the lighter and heavier birds were not used. The birds were then randomized to the 96 pens according to their weight, using the Microsoft™ Excel randomization tool, to obtain similar average pen weights.

Dietary Treatments: There were seven titration levels of dLys and seven titration levels of dThr, totaling 13 treatments (the summit treatment was common for both dLys and dThr trials), plus an industry average Positive Control (PC). The reduced crude protein (25% CP, and 3,000 kcal/kg ME) corn-soybean meal (SBM)-peanut meal(PNM)-meat and bone meal(MBM) basal diet (Table 4.1) supplied 1.14% dLys and 0.56% dThr. To determine the requirement for dThr, the level of dLys was kept at 1.50%, and the seven dietary dThr treatment levels ranged from 0.56% to 1.04%, in 0.08% increments. For the dLys requirement, the level of dThr was kept at 1.04%, and the seven dietary dLys treatment levels ranged from 1.14 to 1.50%, in 0.06% increments. The PC diet was an industry average diet containing 29% CP and 3,000 kcal/kg ME (Agri Stats, 2006), based on corn-SBM-MBM as presented in Table 4.1.

Dietary treatments included:

A. Basal diet with 25% CP, 1.50% dLys, and 0.56% dThr;

B. Basal diet with 25% CP, 1.50% dLys, and 0.64% dThr;

C. Basal diet with 25% CP, 1.50% dLys, and 0.72% dThr;

D. Basal diet with 25% CP, 1.50% dLys, and 0.80% dThr;

E. Basal diet with 25% CP, 1.50% dLys, and 0.88% dThr;

F. Basal diet with 25% CP, 1.50% dLys, and 0.96% dThr;

G. Basal diet with 25% CP, 1.50% dLys, and 1.04% dThr;

H. Basal diet with 25% CP, 1.44% dLys, and 1.04% dThr;

I. Basal diet with 25% CP, 1.38% dLys, and 1.04% dThr;

J. Basal diet with 25% CP, 1.32% dLys, and 1.04% dThr;

K. Basal diet with 25% CP, 1.26% dLys, and 1.04% dThr;

L. Basal diet with 25% CP, 1.20% dLys, and 1.04% dThr;

M. Basal diet with 25% CP, 1.14% dLys, and 1.04% dThr;

N. Complete diet with 29% CP, 1.55% dLys and 0.89% dThr.

Measurements for Experiments 1 and 2: Mortality was recorded as it occurred. All birds were inspected daily and health related problems were recorded. Data were collected during the last two weeks of each three weeks period (for example, in phase I, data were collected during the 2nd and 3rd weeks). The birds were weighed by pen at the end of the last week of the period. The initial body weight was subtracted from the final body weight to determine body weight gain (BWG) of the birds in the two week period. Total feed intake (TFI) was determined by subtracting the feed left from the initial feed offered to the birds. Average feed intake (AFI) was adjusted for mortality to more accurately reflect the access of individual birds in a pen to feed during the testing period, by using the following equation:

AFI = (TFI / TBD) * D,

where:

TFI = Total Feed Intake (kg), TBD = Total Bird Days (d), D = Duration of test period (d)

TBD = (no. living birds/pen at the conclusion of the trial * D) + (no. days which dead bird(s) had access to feed)

Feed to gain ratio (F:G) was calculated by dividing the AFI by the BWG.

Statistical Analyses for Experiments 1 and 2: The experimental design for the two studies was a completely randomized design with 14 treatments and pen designated as the experimental unit. Data were analyzed using the ANOVA procedure of SAS (2003). All statements of significance are based on the 0.05 level of probability using the 14 treatment means (treatments A to N). Then, the broken-line analyses procedure of SAS (2003) was used to estimate the requirements for dLys (treatments G to M) and for dThr (treatments A to G) in each phase using BWG and F:G ratio as dependent variables. The NRM.xls Microsoft™ Excel workbook was used as a tool to prepare charts fitting the segmented regression with linear segments of broken-line model ($y = L + U * (R - x) + V * (x - R)$, where $(R - x)$ is defined as zero at values of $x > R$, and $(x - R)$ is defined as zero when $x < R$) and the segmented regression with quadratic segments model ($y = L + U * (R - x)^2$), where L is the constant rate of the asymptote of the first segment, R is the abscissa of the inflection in the curve, U is the slope of the line for $x < R$, and V is the slope of the line at $x > R$ (Robbins et al., 2006, Vedenov and Pesti, 2008).

RESULTS

Digestible Threonine

Feed intake, body weight gain, and feed efficiency of turkeys from 8 to 21 days were affected by treatments ($P < 0.0001$) (Table 4.2). There was a gradual increase in feed intake of turkeys in response to an increase in dietary Thr from 0.56 to 0.64%. There was a gradual increase of BWG and a gradual decrease in F:G ratio of turkeys in response to an increase in dietary Thr from 0.56 to 0.80%. Beyond that level there was no significant change in BWG or F:G ratio. Body weight gain of birds fed the PC treatment did not differ significantly (P > 0.05) from the treatments containing a minimum of 0.64% dThr. Feed intake and and F:G ratio of birds fed the PC treatment differ significantly (P > 0.05) from all treatments.

Broken-line analyses of the data for BWG and F:G ratio are presented in Figures 4.1 and 4.2, respectively. The dThr requirements for male turkeys from 8 to 21 days were determined to be 0.744% for BWG, and 0.808% for F:G ratio.

Digestible Lysine

Feed intake, body weight gain, and feed efficiency of turkeys from 8 to 21 days were affected by treatments (P < 0.0001) (Table 4.4). There was a gradual increase in feed intake of turkeys in response to an increase in dietary Lys from 1.14 to 1.20%. There was a gradual increase of BWG and a gradual decrease in F:G ratio of turkeys in response to an increase in dietary lysine from 1.14 to 1.26%. Beyond that level there was no significant change in BWG or F:G ratio. Body weight gain of birds fed the PC treatment did not differ significantly (P > 0.05) from the treatments containing a minimum of 1.20% dLys. Feed intake and and F:G ratio of birds fed the PC treatment differ significantly (P < 0.05) from all treatments.

Broken-line analyses of the data for BWG and F:G ratio are presented in Figures 4.3 and 4.4, respectively. The dLys requirements for male turkeys from 8 to 21 days were determined to be 1.361% for BWG, and 1.392% for F:G ratio. Using the highest required levels the calculated ratio of dThr to dLys is 0.58.

MATERIAL AND METHODS

Experiment 2

Housing: A total of 1,280 29-day-old Nicholas male poults were weighed individually, and after the sorting procedure, 1,056 poults were distributed to the 14 treatments, in 96 pens, with 11 birds per pen. Birds were fed experimental diets from days 29 to 42.

Dietary Treatments: There were seven titration levels of dLys and seven titration levels of dThr, totaling 13 treatments (the summit treatment was common for both dLys and dThr trials), plus an industry average PC dietary treatment. The reduced CP (24% CP, and 3,100 kcal/kg ME) corn-SBM-PNM-MBM meal basal diet supplied 1.06% dLys and 0.51% dThr (Table 4.4). To determine the requirement for dThr, the level of dLys was kept at 1.42%, and the seven dietary dThr treatment levels ranged from 0.51 to 0.99%, in 0.08% increments. For the dLys requirement, the level of dThr was kept at 0.99%, and the seven dietary dLys treatment levels ranged from 1.06 to 1.42%, in 0.06% increments. The PC industry average diet had 27.5% CP and 3,100 kcal/kg ME (Agri Stats, 2006), based on corn-SBM-MBM as presented in Table 4.4.

Dietary treatments included:

A. Basal diet with 24% CP, 1.42% dLys, and 0.51% dThr;

B. Basal diet with 24% CP, 1.42% dLys, and 0.59% dThr;

C. Basal diet with 24% CP, 1.42% dLys, and 0.67% dThr;

D. Basal diet with 24% CP, 1.42% dLys, and 0.75% dThr;

E. Basal diet with 24% CP, 1.42% dLys, and 0.83% dThr;

F. Basal diet with 24% CP, 1.42% dLys, and 0.91% dThr;

G. Basal diet with 24% CP, 1.42% dLys, and 0.99% dThr;

H. Basal diet with 24% CP, 1.36% dLys, and 0.99% dThr;

I. Basal diet with 24% CP, 1.30% dLys, and 0.99% dThr;

J. Basal diet with 24% CP, 1.24% dLys, and 0.99% dThr;

K. Basal diet with 24% CP, 1.18% dLys, and 0.99% dThr;

L. Basal diet with 24% CP, 1.12% dLys, and 0.99% dThr;

M. Basal diet with 24% CP, 1.06% dLys, and 0.99% dThr;

N. Complete diet with 27.5% CP, 1.55% dLys and 0.89% dThr.

RESULTS

Digestible Threonine

Feed intake, body weight gain, and feed efficiency of turkeys from 29 to 42 days were affected by treatments ($P < 0.0001$) (Table 4.5). There was a gradual increase in feed intake of turkeys in response to an increase in dietary Thr from 0.51 to 0.75%. There was a gradual increase in BWG of turkeys in response to an increase in dietary Thr from 0.51 to 0.91%, and a gradual improvement in F:G ratio from 0.51 to 0.83%. Beyond these levels there was no significant change in FI, BWG, or F:G ratio. Body weight gain and F:G ratio of birds fed the PC treatment did not differ significantly ($P > 0.05$) from treatments containing the minimum of 0.91 and 0.75% dThr, respectively.

Broken-line analyses of the data for BWG and F:G ratio are presented in Figures 4.5 and 4.6, respectively. The dThr requirements for male turkeys from 29 to 42 days were determined to be 0.722% for BWG, and 0.759% for F:G ratio.

Digestible Lysine

Feed intake, body weight gain, and feed efficiency of turkeys from 29 to 42 days were affected by treatments ($P < 0.0001$) (Table 4.6). There was a gradual increase in feed intake of turkeys in response to an increase in dietary Lys from 1.06 to 1.18%. There was a gradual increase in BWG of turkeys in response to an increase in dietary Lys from 1.06 to 1.30%, and a gradual improvement in F:G ratio from 1.06 to 1.24%. Beyond those levels there was no significant change in FI, BWG, or F:G ratio. Body weight gain and F:G ratio of birds fed the PC treatment did not differ significantly ($P > 0.05$) from treatments containing the minimum of 1.24 and 1.18% dLys, respectively.

Broken-line analyses of the data for BWG and F:G ratio are presented in Figures 4.7 and 4.8, respectively. The dLys requirements for male turkeys from 29 to 42 days were determined to be 1.269% for BWG, and 1.285% for F:G ratio. Using the highest required levels the calculated ratio of dThr to dLys is 0.59.

DISCUSSION

Feed intake and body weight gain responses to dietary Thr and Lys in both experiments indicated that the basal diet was deficient in both AA (Tables 4.2, 4.3, 4.5, and 4.6). Supplementation of DL-Met, L-Lys-HCl, L-Thr, L-His, L-Ile, L-Trp, and L-Val were required so that the essential AA met the ideal protein ratio compared to the summit dLys level. Supplementation of L-Glu was necessary to the dietary treatments reach the minimum CP level reported in Tables 4.1 and 4.4.

Data from Exp. 1 indicated the dThr requirements for male turkeys from 8 to 21 days to be 0.74% for BWG (Figure 4.1) and 0.81% for feed conversion (Figure 4.2). These requirements are high when compared with the results for dThr reported by Kamyab and Firman (2000), who found the requirement for dThr to be 0.67 and 0.74% for body weight gain and feed conversion, respectively, for the same period. However, Kamyab and Firman (2000) estimated the requirements for turkey hens, and the trial was conducted in battery cages, which diminishes the maintenance requirements of the poults (Ketelaars, 1987). Firman and Guaiume (2006) reported dThr requirement levels between 0.83 and 0.86% for male poults for the first three-week period. Kidd et al. (1998) determined the optimum dietary levels of tThr for BUT male turkeys for body weight gain and feed conversion for the hatch to three week period to be 0.93 and 0.97%, respectively. Lehmann et al. (1997) reported the optimum dietary level of tThr for male turkeys for growth and feed conversion for the hatch to four week period to be 0.95%. Applying a digestibility coefficient of 82% for Thr (Pierson et al., 1980, Parsons, 1982; Firman, 1992, Firman and Remus, 1993; NRC, 1994; Kluth and Rodehutscord, 2006; Adedokun et al., 2007, ileal digestibility values in Chapter III of this dissertation), results of Kidd et al. (1998) and Lehmann et al. (1997) agree with the dThr requirements determined in the current study.

An important function of dietary Thr is to provide Gly via Thr dehydrogenase and Thr aldolase (Davis and Austic, 1982) to support the metabolic need for uric acid, synthesis of protein, serine, creatine, and glutathione. Thus, increased AA deamination in high CP diets increases the need for uric acid, primarily because poultry lack carbamoyl phosphate synthetase activity (Kidd et al., 1998), which plays a key role in the hydrolysis of glutamine and the resulting ammonia (Thoden et al., 1999). This may increase the need for Thr. In diets with excess protein, the Gly requirement may also be very high, because one molecule of Gly is lost with each molecule of uric acid excreted (Lehmann et al., 1997). The loss of Gly might be of particular importance in turkey starter diets with their current high requirements for CP (NRC, 1994; Agri Stats, 2006). It is possible that part of the live weight response to supplemental Thr in the first four weeks of age may be due to a metabolic conversion of Thr to Gly (Lehmann et al., 1997).

The requirement levels of dLys in Exp. 1 were 1.36% for BWG (Figure 4.3) and 1.39% for feed conversion (Figure 4.4). Firman (2004) fed Nicholas White male turkeys experimental diets from day 7 to 18, and the dLys requirement determined for optimum body weight gain was 1.31%. Boling and Firman (1998) reported the dLys requirement for Hybrid female poults from 8 to 27 days of age raised in battery cages to be 1.32% for optimal weight gain, and 1.34% for optimal feed conversion.

Thompson et al. (2004) reported the dLys requirement for Nicholas White female poults from 4 to 15 days of age raised in floor pens to be 1.29% for body weight gain. There were few differences when comparing the results of the dLys requirement for starting males and females, supporting the conclusions of Potter and Shelton (1980), who suggested that protein requirements are similar between male and female turkeys until about 8 weeks of age. However, if the Lys requirements for the starting period are expressed on a total basis, a wide range in requirement values (1.40 to 1.68%) has been reported by several authors (Warnick and Anderson, 1968; Kummero et al., 1971; Tuttle and Balloun, 1974; D'Mello and Emmans, 1975; Hurwitz et al., 1983).

Warnick and Anderson (1968) fed male and female Broad Breast Bronze turkeys from 5 to 17 days and reported the tLys minimum requirement for optimum growth to be 1.68%. However, they used purified diets with high digestibility coefficients, and their recommendation is certainly higher than the range of 1.36 to 1.39% suggested in this study. Research conducted by Tuttle and Balloun (1974) using corn-soybean meal based diets determined the tLys requirement to be 1.50%, which after adjustment to a digestible basis – 85% digestibility coefficient for Lys (Pierson et al., 1980, Parsons, 1982; Firman, 1992, Firman and Remus, 1993; NRC, 1994; Kluth and Rodehutscord, 2006; Adedokun et al., 2007, ileal digestibility values in Chapter III of this dissertation) – would be very close to the range observed in this study.

Results of Exp. 2 showed the dThr requirements for male turkeys from 29 to 42 days to be of 0.72% for BWG (Figure 4.5) and 0.76% for feed conversion (Figure 4.6). Firman and Guaiume (2006) reported dThr levels between 0.76 and 0.81% for male poults from three to six weeks of age to reach optimum growth performance and feed conversion, which agrees with the results of this trial. However, Kidd et al. (1998) observed that the levels of dietary tThr needed to support adequate body weight gain and feed conversion in the same period was 0.88% for BUT male turkeys, which seems lower than the results of this experiment when 82% digestibility coefficient of a typical turkey feed are applied to the diets. Waldroup et al. (1998b) determined the requirements for total dietary Thr for the same period to be 0.92 and 0.87% for body weight gain and feed conversion, respectively, for Nicholas male turkeys, which agree with the results of this trial, after applying digestibility coefficients to the diets.

The requirements for dLys in Exp. 2 were 1.27% for BWG (Figure 4.7) and 1.29% for feed conversion (Figure 4.8). Firman (2004) fed male Nicholas White experimental diets from 23 to 37 days in floor pens, and determined the dLys requirement to be 1.17% for optimum BWG, which is significantly lower than the levels observed in this study. Thompson et al. (2004) observed the same trend and suggested levels of 1.16 and 1.12% dLys for BWG and F:G ratio, respectively, for Nicholas White hen turkeys from 29 to 40 days. However, Firman and Guaiume (2006) obtained best performance when Nicholas toms were fed 1.33% dLys from 3 to 6 weeks of age. Kratzer et al. (1956) determined the tLys requirement for male and female turkeys from 4 to 8 weeks of age to be 0.96%, whereas Hurwitz et al. (1983) determined the tLys requirement for male turkeys for the same period to be 1.12%, based on carcass content and maintenance. Balloun and Phillips (1957) found the tLys requirement for both genders to be 1.55% for the first 6 weeks of age, and Tuttle and Balloun (1974) recommended 1.40% tLys for male turkeys from 4 to 8 weeks of age. When the coefficient of digestibility of the corn-soybean meal typical diet are applied to the tLys results, the level of Balloun and Phillips (1957) is closer to the results of the current study.

CONCLUSIONS

According to the results of these two experiments, the requirement for dLys from 8 to 21 days for male turkeys was estimated to be 1.36% for BWG and 1.39% for F:G ratio, whereas the requirement for dThr was estimated to be 0.74% for BWG and 0.81% for F:G ratio for the same period, with the ratio of dThr to dLys being 0.58. For the next phase, from 29 to 42 days, the requirement for dLys for male turkeys was estimated to be 1.27% for BWG and 1.29% for F:G ratio, and the requirement for dThr was estimated to be 0.72% for BWG and 0.76% for F:G ratio for the same period, with the ratio of dThr to dLys being 0.59.

Table 4.1. Composition of Negative Control Basal and Positive Control diets of turkeys from 8 to 21 days of age (%).

Ingredient	Negative Control Basal Diet	Positive Control Diet
Corn	53.887	42.367
Soybean meal	9.388	41.280
Peanut meal	19.697	-
Meat and bone meal	9.742	10.000
Dicalcium phosphate	1.573	1.326
Limestone	0.792	0.727
Salt	0.131	0.282
Soy oil	1.497	2.447
L-Lysine.HCl	0.862	0.420
DL-Methionine	0.439	0.496
L-Threonine	0.487	0.227
Choline Cl	0.171	0.070
Trace mineral premix[1]	0.100	0.100
Vitamin premix[2]	0.075	0.075
Selenium premix[3]	0.060	0.060
Copper sulfate	0.013	0.013
Sodium bicarbonate	0.151	0.022
Avatec® 20%[4]	0.038	0.038
BMD®-50[5]	0.050	0.050
L-Histidine	0.096	-
L-Isoleucine	0.309	-

Table 4.1. (Continued)

Ingredient	Negative Control Basal Diet	Positive Control Diet
L-Tryptophan	0.126	-
L-Valine	0.316	-
Calculated Composition		
EM	3,000	3,000
CP	25.80	29.00
Digestible Lys	1.14	1.55
Digestible Thr	0.57	0.89
Analyzed Composition		
CP	25.13	30.32
Total Lys	1.35	1.95
Total Thr	0.77	1.27

[1]Trace mineral mix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_4.7H_2O$); I, 2.0 (ethylenediamine dihydroiodide).
[2]Vitamin mix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg.
[3]Selenium premix provided 0.3 mg/kg of Se (Na_2SeO_3).
[4]Avatec® 20% provided 75 mg/kg of lasalocid sodium.
[5]BMD®-50 provided 25 mg/kg of bacitracin methylene disalicylate.

Table 4.2. Growth performance of male turkeys fed graded levels of digestible threonine (dThr) from 8 to 21 days of age[1]

Treatment	dThr (%)	Feed Intake (g)	Body Weight Gain (g)	Feed to Gain (g:g)
A	0.56	415[b]	247[d]	1.677[c]
B	0.64	452[a]	277[c]	1.633[c]
C	0.72	447[a]	286[b]	1.565[bc]
D	0.80	447[a]	291[ab]	1.536[b]
E	0.88	448[a]	293[ab]	1.531[b]
F	0.96	453[a]	296[a]	1.534[b]
G	1.04	453[a]	299[a]	1.514[b]
N	0.89	371[c]	269[c]	1.380[a]
Pooled SEM		22	11	0.076

[a-d]Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of 12 poults per pen, except treatment F with six replicate pens of 12 poults per pen.

Table 4.3. Growth performance of male turkeys fed graded levels of digestible lysine (dLys) from 8 to 21 days of age[1]

Treatment	dLys (%)	Feed Intake (g)	Body Weight Gain (g)	Feed to Gain (g:g)
M	1.14	426[b]	267[c]	1.597[c]
L	1.20	435[ab]	274[c]	1.585[c]
K	1.26	455[a]	288[b]	1.579[bc]
J	1.32	449[a]	292[ab]	1.538[bc]
I	1.38	456[a]	299[a]	1.522[b]
H	1.44	460[a]	301[a]	1.529[b]
G	1.50	453[a]	299[a]	1.514[b]
N	1.55	371[c]	269[c]	1.380[a]
Pooled SEM		19	9	0.063

[a-c]Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of 12 poults per pen, except treatment H with six replicate pens of 12 poults per pen.

Table 4.4. Composition of Negative Control Basal and Positive Control diets of turkeys from 29 to 42 days of age (%).

Ingredient	Negative Control Basal Diet	Positive Control Diet
Corn	57.910	45.506
Soybean meal	2.983	37.061
Peanut meal	20.966	-
Meat and bone meal	9.997	10.000
Dicalcium phosphate	1.189	0.876
Limestone	0.636	0.625
Salt	0.106	0.300
Soy oil	2.695	3.751
L-Lysine.HCl	0.942	0.567
DL-Methionine	0.441	0.515
L-Threonine	0.487	0.314
Choline Cl	0.195	0.070
Trace mineral premix[1]	0.100	0.100
Vitamin premix[2]	0.075	0.075
Selenium premix[3]	0.060	0.060
Copper sulfate	0.013	0.013
Sodium bicarbonate	0.170	0.080
Avatec® 20%[4]	0.038	0.038
BMD®-50[5]	0.050	0.050
L-Histidine	0.112	-
L-Isoleucine	0.392	-

Table 4.4. (Continued)

Ingredient	Negative Control Basal Diet	Positive Control Diet
L-Tryptophan	0.139	-
L-Valine	0.306	-
Calculated Composition		
EM	3,100	3,100
CP	24.00	27.50
Digestible Lys	1.06	1.55
Digestible Thr	0.51	0.89
Analyzed Composition		
CP	23.92	29.80
Total Lys	1.24	1.92
Total Thr	0.67	1.25

[1]Trace mineral mix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_4.7H_2O$); I, 2.0 (ethylenediamine dihydroiodide).
[2]Vitamin mix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg.
[3]Selenium premix provided 0.3 mg/kg of Se (Na_2SeO_3).
[4]Avatec® 20% provided 75 mg/kg of lasalocid sodium.
[5]BMD®-50 provided 25 mg/kg of bacitracin methylene disalicylate.

Table 4.5. Growth performance of male turkeys fed graded levels of digestible threonine (dThr) from 29 to 42 days of age[1]

Treatment	dThr (%)	Feed Intake (g)	Body Weight Gain (g)	Feed to Gain (g:g)
A	0.51	1,541[d]	742[e]	2.077[e]
B	0.59	1,724[c]	933[d]	1.849[d]
C	0.67	1,859[b]	1,082[c]	1.719[c]
D	0.75	1,946[a]	1,190[b]	1.635[b]
E	0.83	1,919[ab]	1,184[b]	1.623[ab]
F	0.91	1,899[ab]	1,213[ab]	1.567[a]
G	0.99	1,888[ab]	1,204[ab]	1.568[a]
N	0.89	1,962[a]	1,237[a]	1.587[ab]
Pooled SEM		77	41	0.055

[a-e]Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of 11 poults per pen, except treatment F with six replicate pens of 11 poults per pen.

Table 4.6. Growth performance of male turkeys fed graded levels of digestible lysine from 29 to 42 days of age[1]

Treatment	dLys (%)	Feed Intake (g)	Body Weight Gain (g)	Feed to Gain (g:g)
M	1.06	1,674^{d}	996^{d}	1.681^{c}
L	1.12	1,816^{c}	1,093^{c}	1.662^{c}
K	1.18	1,825^{bc}	1,130^{c}	1.615^{b}
J	1.24	1,847^{bc}	1,162^{bc}	1.589^{ab}
I	1.30	1,865^{bc}	1,196^{ab}	1.560^{a}
H	1.36	1,888^{b}	1,206^{ab}	1.565^{a}
G	1.42	1,888^{b}	1,204^{ab}	1.568^{a}
N	1.55	1,962^{a}	1,237^{ab}	1.587^{ab}
Pooled SEM		67	41	0.037

$^{a-d}$Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of 11 poults per pen, except treatment H with six replicate pens of 11 poults per pen.

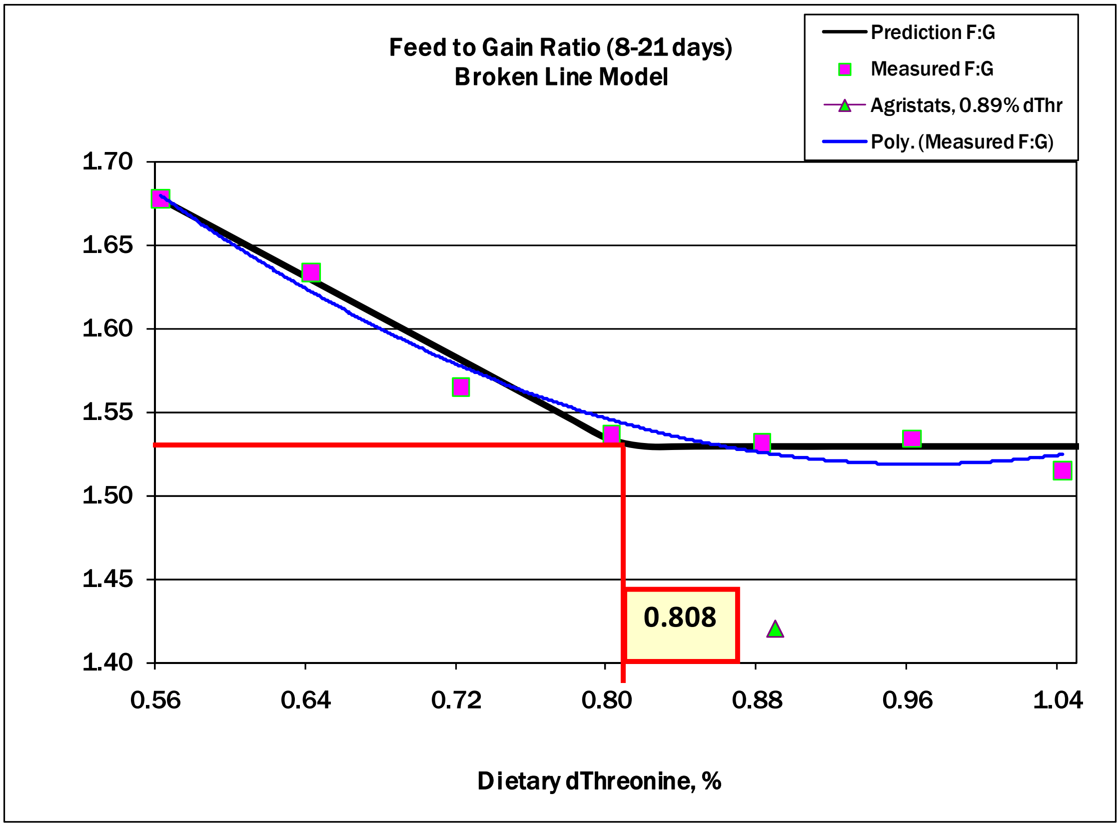


Figure 4.1. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible threonine (dThr) from 8 to 21 days of age[1].

[1]Broken-line response ($P < 0.0001$).

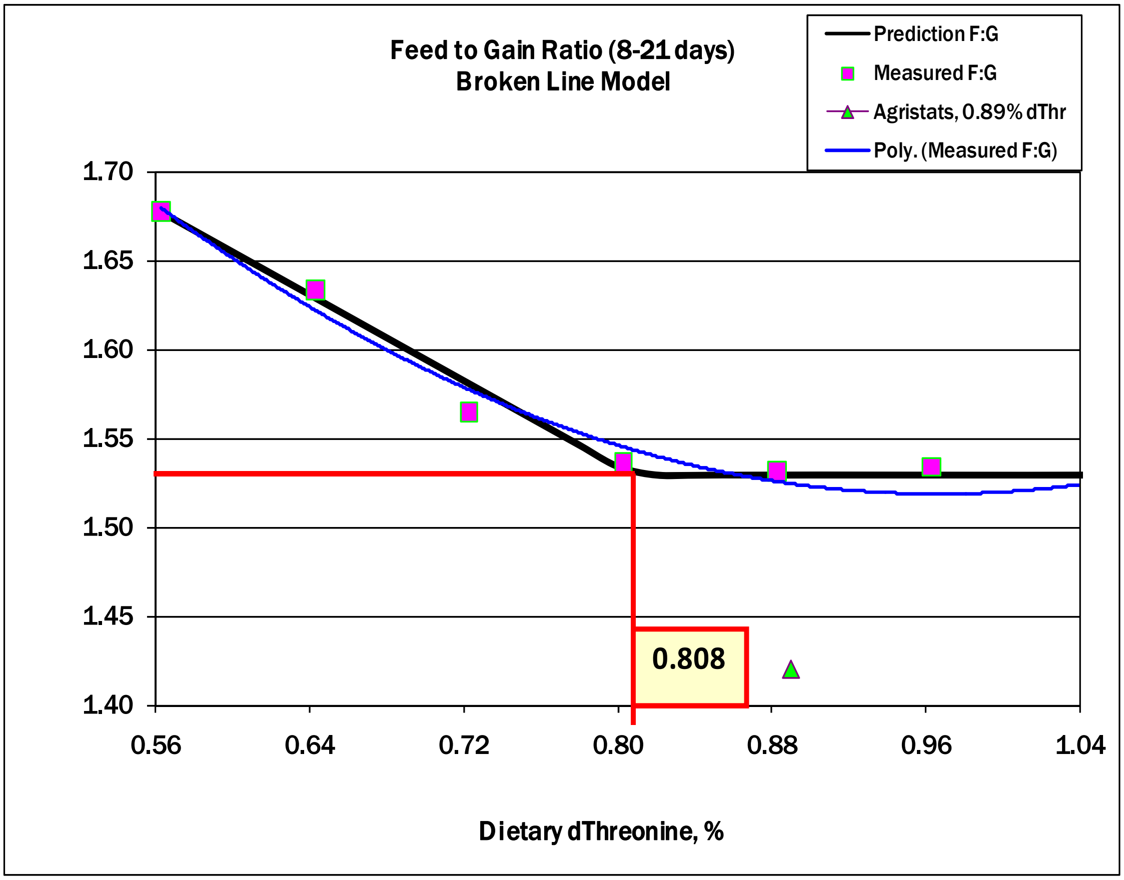


Figure 4.2. Broken-line analyses of feed to gain ratio of male turkeys fed graded levels of digestible threonine (dThr) from 8 to 21 days of age[1].

[1]Broken-line response ($P < 0.0001$).

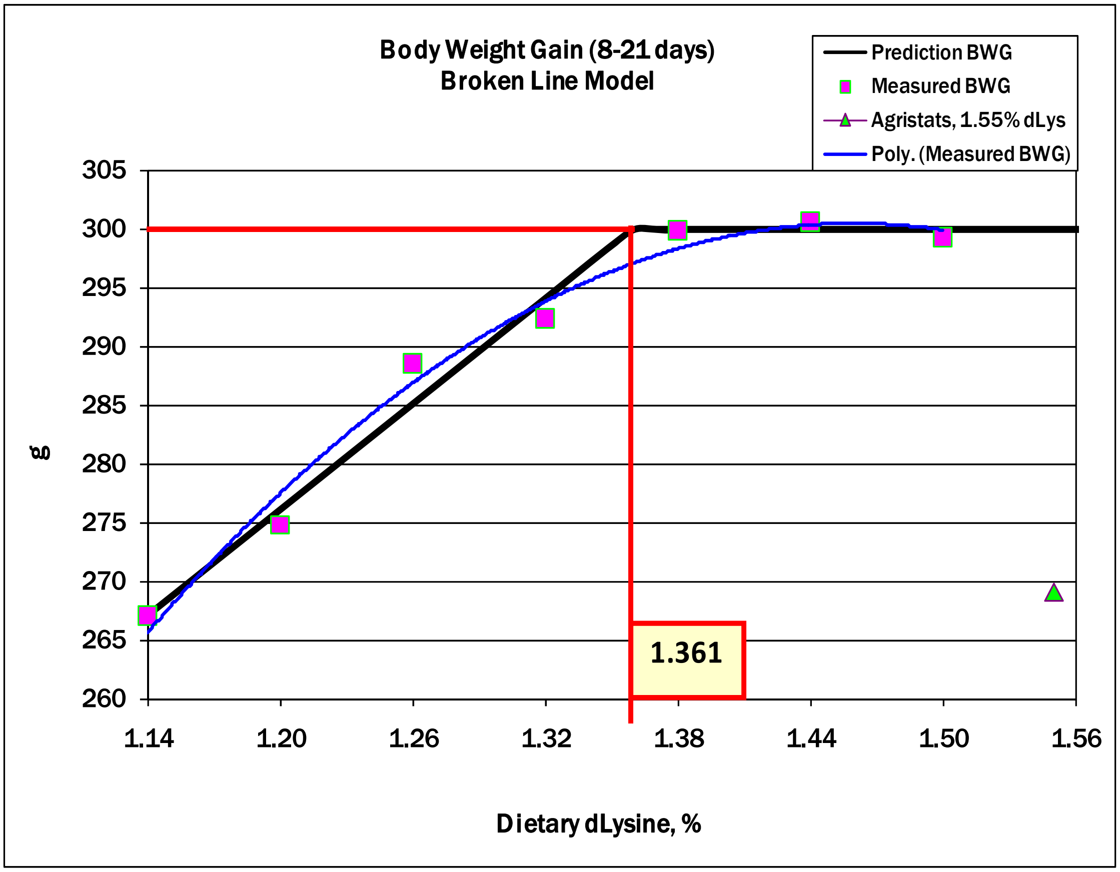


Figure 4.3. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible lysine (dLys) from 8 to 21 days of age[1].

[1]Broken-line response ($P < 0.0001$).

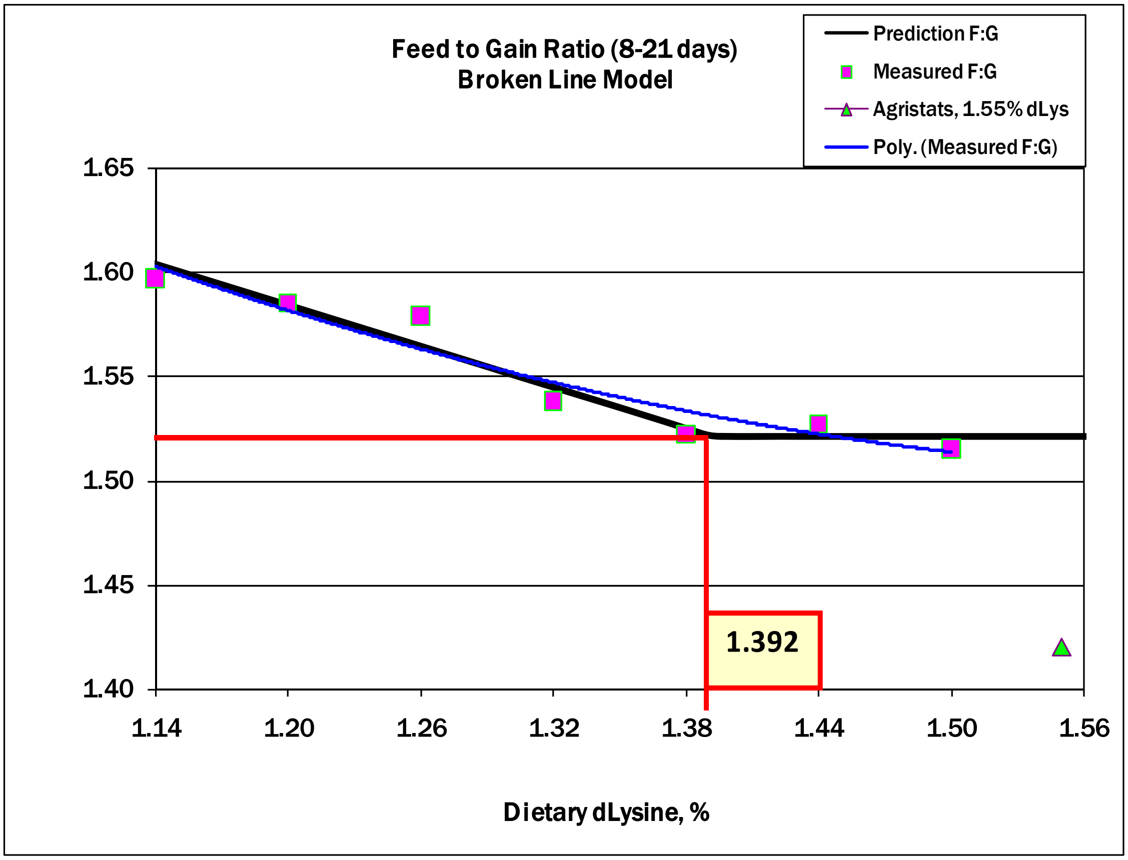


Figure 4.4. Broken-line analyses of feed to gain ratio of male turkeys fed graded levels of digestible lysine (dLys) from 8 to 21 days of age[1].

[1]Broken-line response ($P < 0.0001$).

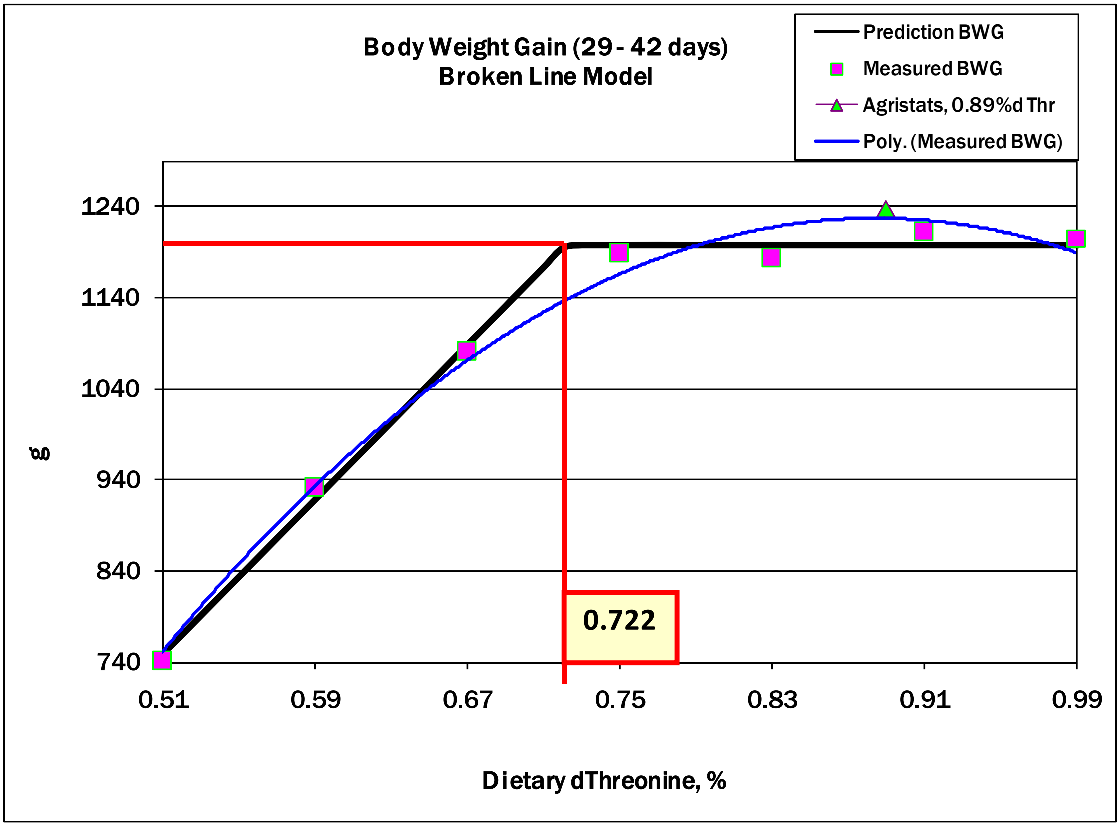


Figure 4.5. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible threonine (dThr) from 29 to 42 days of age[1].

[1]Broken-line response (P < 0.0001).

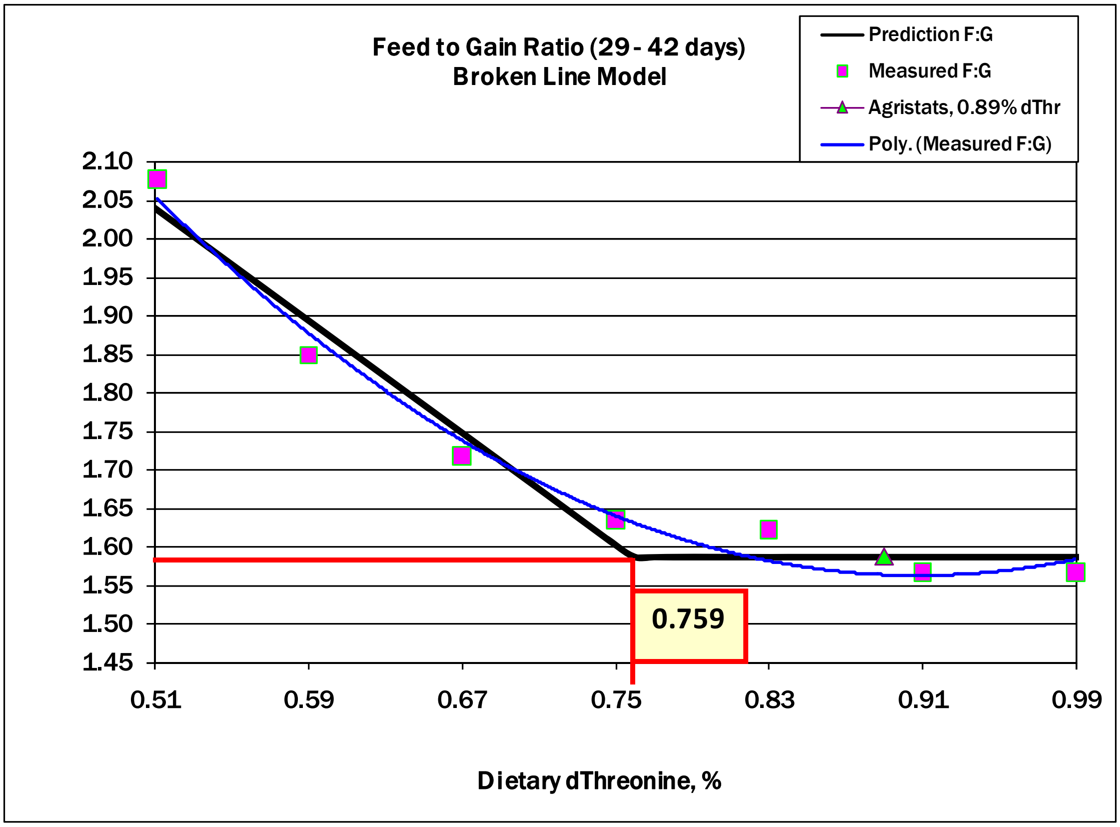


Figure 4.6. Broken-line analyses of feed to gain ratio of male turkeys fed graded levels of digestible threonine (dThr) from 29 to 42 days of age[1].

[1]Broken-line response ($P < 0.0001$).

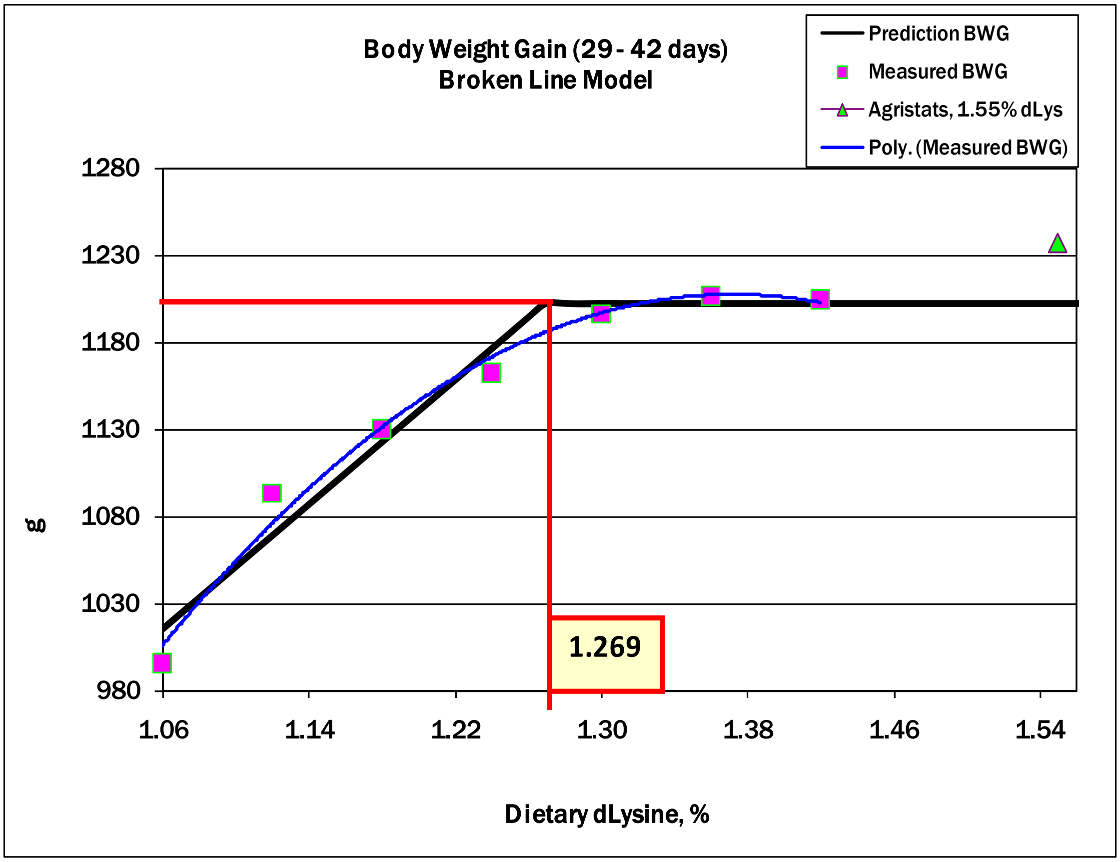


Figure 4.7. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible lysine (dLys) from 29 to 42 days of age[1].

[1]Broken-line response ($P < 0.0001$).

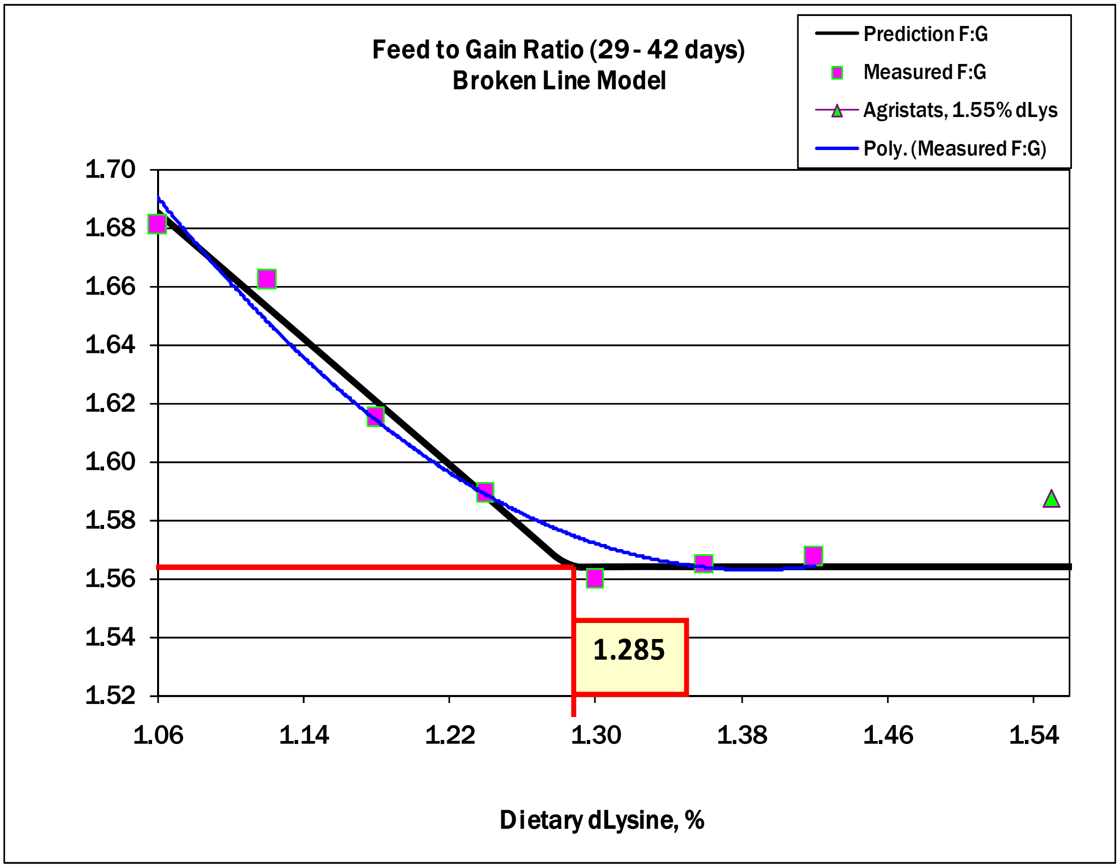


Figure 4.8. Broken-line analyses of feed to gain ratio of male turkeys fed graded levels of digestible lysine (dLys) from 29 to 42 days of age[1].

[1]Broken-line response ($P < 0.0001$).

CHAPTER V

DIGESTIBLE LYSINE AND THREONINE REQUIREMENTS OF MALE TURKEYS FROM DAYS 50 TO 63 AND DAYS 71 TO 84.

SUMMARY

Two experiments were conducted to determine the digestible lysine (dLys) and digestible threonine (dThr) requirement of Nicholas White male turkeys from days 50 to 63 (Phase III), and days 71 to 84 (Phase IV). In both phases, birds were raised in floor pens and randomized across 13 treatments. Sharing a common summit diet, requirement study included six levels of each amino acid, plus an additional industry control diet. A total of 768 birds were used in Phase III (eight birds/pen), and 672 birds were used in Phase IV (seven birds/pen). In Phase III, a reduced low crude protein (CP) corn-soybean meal (SBM)-peanut meal (PNM)-meat and bone meal basal diet (21.5% CP, and 3,150 kcal/kg ME) supplied 0.90% dLys and 0.39% dThr. To determine the requirement for dThr, the level of dLys was maintained at 1.32% while dThr levels ranged from 0.39 to 0.87%, in 0.08% increments across seven dietary treatments. To determine the dLys requirement, the level of dThr was maintained at 0.87% while dLys levels ranged from 0.90 to 1.32%, in 0.07% increments across the seven dietary treatments. The positive control (PC) diet was an industry average diet containing 25% CP. Broken-line analyses from SAS was used to estimate the requirement for dLys in Phase III which was found to be 1.15% for BWG and 1.12% for F:G ratio, and the requirement for dThr to be 0.63% for both BWG and F:G ratio.

Using the highest required levels the calculated ratio of dThr to dLys is 0.55. In Phase IV, a reduced CP (19% CP, and 3,200 kcal/kg ME) corn-SBM-PNM basal diet supplied 0.79% dLys and 0.40% dThr. To determine the requirement for dThr, the level of dLys was maintained at 1.15% while dThr levels ranged from 0.40 to 0.79%, in 0.065% increments. For the dLys requirement, the level of dThr was maintained at 0.79% while dLys levels ranged from 0.79 to 1.15%, in 0.06% increments. The PC industry average diet contained 21.5% CP. Broken-line analyses from SAS was used to estimate the dLys requirement in Phase IV which was found to be 1.01% for BWG and 1.03% for F:G ratio, and the dThr requirement to be 0.57% for BWG and 0.58% for F:G ratio. Using the highest required levels the calculated ratio of dThr to dLys is 0.56.

INTRODUCTION

Lack of accurate determinations of limiting amino acids (AA) has limited the practical implementation of low crude protein (CP) diets for young turkeys. Methionine (Met) and lysine (Lys) are the first and second limiting AA in corn-soybean meal (SBM) diets for turkeys and threonine (Thr) is considered the third limiting AA (Kidd and Kerr, 1996). Studies by Stas and Potter (1982), Jackson et al. (1993), and Blair and Potter (1987) demonstrated that the protein needs of turkey poults fed sufficient Met could be reduced by supplementation of Lys, Thr, isoleucine and valine. Protein is one of the most costly turkey diet components, and also has major effects on performance of the birds. The implementation of the ideal protein (IP) concept is an opportunity to feed the exact needs for maintenance and growth of the turkey, with the benefits of a reduction in feed cost and nitrogen excretion (Firman, 2001). Using digestible AA in requirement studies result in the requirements being expressed more accurately. However, the turkey industry lacks enough information on digestible AA requirements for turkeys to build up an AA profile sufficient to determine the ideal ratio of AA to dLys.

Previous research on the determination of the digestible Lys (dLys) requirement for male (Baker et al., 2003a) and female (Thompson et al., 2005) turkeys for optimum growth performance from 6 to 9 weeks has shown that males have higher a requirement than females. Balloun and Phillips (1957) also observed that males need more total Lys (tLys) than females to achieve optimum growth when fed low CP diets from 6 to 12 weeks of age. However, on the period from 9 to 12 weeks, Baker et al. (2003a) and Thompson et al. (2005) observed small differences in dLys requirements (0.82 to 0.87%) between males and females. To date, no research on the requirements of digestible Thr (dThr) has been done from this period (6 to 9 weeks) to market weight. Kidd et al. (1998) and Waldroup et al. (1998b) estimated the requirements for total threonine (tThr) for BUT turkeys from 6 to 9 weeks of age to range from 0.77 to 0.92%. Two other studies (Lehmann et al., 1997; Barbour et al., 2008) were conducted to determine the turkey tThr requirement for the period between 8 and 13 weeks, and reported that the minimum requirement ranged from 0.69 to 0.85%, which can be considered a very wide range.

The objective of this research was to determine the dLys and dThr requirement of Nicholas White male turkeys from days 50 to 63 and from days 71 to 84, in order to recommend digestible levels of these AA in IP formulated diets for growing turkeys.

MATERIAL AND METHODS

Experiment 3

Housing: A total of 1,100 50-day-old Nicholas White male turkeys were weighed individually, and after the sorting procedure, 768 turkeys were distributed to the 14 treatments, in 96 pens, with eight birds per pen. Birds were fed experimental diets from day 50 to 63. Poults were housed and maintained using standard husbandry practices. Birds were housed in curtain sided building with temperature controlled by ceiling circulating fans for ventilation and a heater for warming. Birds were maintained on a 24 hour constant-light schedule and allowed access to feed and water *ad libitum*. All procedures were conducted in accordance with the University of Missouri Animal Care and Use Guidelines and approved protocols.

Sorting procedures for Experiments 3 and 4: The number of birds needed to be used in the two week experimental periods plus an additional 20% were weighed individually, and the lighter and heavier birds were not used. The birds were then randomized to the 96 pens according to their weight, using the Microsoft™ Excel randomization tool, to obtain similar average pen weights.

Dietary Treatments: There were seven titration levels of dLys and seven titration levels of dThr, totaling 13 treatments (the summit treatment was common for both dLys and dThr trials), plus an industry average Positive Control (PC). The reduced CP (21.5% CP, and 3,150 kcal/kg ME) corn-SBM-peanut meal (PNM)-meat and bone meal (MBM) basal diet (Table 5.1) supplied 0.90% dLys and 0.39% dThr. To determine the requirement for dThr, the level of dLys was kept at 1.32%, and the seven dietary dThr treatment levels ranged from 0.39 to 0.87%, in 0.08% increments. To determine the dLys requirement, the level of dThr was kept at 0.87%, and the seven dietary dLys treatment levels ranged from 0.90 to 1.32%, in 0.07% increments. The PC diet was an industry average diet containing 25% CP and 3,150 kcal/kg ME (Agri Stats, 2006), based on corn-SBM-MBM as presented in Table 5.1.

Dietary treatments included:

A. Basal diet with 21.5% CP, 1.32% dLys, and 0.39% dThr;

B. Basal diet with 21.5% CP, 1.32% dLys, and 0.47% dThr;

C. Basal diet with 21.5% CP, 1.32% dLys, and 0.55% dThr;

D. Basal diet with 21.5% CP, 1.32% dLys, and 0.63% dThr;

E. Basal diet with 21.5% CP, 1.32% dLys, and 0.71% dThr;

F. Basal diet with 21.5% CP, 1.32% dLys, and 0.79% dThr;

G. Basal diet with 21.5% CP, 1.32% dLys, and 0.87% dThr;

H. Basal diet with 21.5% CP, 1.25% dLys, and 0.87% dThr;

I. Basal diet with 21.5% CP, 1.18% dLys, and 0.87% dThr;

J. Basal diet with 21.5% CP, 1.11% dLys, and 0.87% dThr;

K. Basal diet with 21.5% CP, 1.04% dLys, and 0.87% dThr;

L. Basal diet with 21.5% CP, 0.97% dLys, and 0.87% dThr;

M. Basal diet with 21.5% CP, 0.90% dLys, and 0.87% dThr;

N. Complete diet with 25.0% CP, 1.39% dLys and 0.83% dThr.

Measurements for Experiments 3 and 4: Mortality was recorded as it occurred. All birds were inspected daily and health related problems were recorded. Data were collected during the last two weeks of each three weeks period (for example, in phase III, data were collected during the 8^{th} and 9^{th} weeks). The birds were weighed by pen at the end of the last week of the period. The initial body weight was subtracted from the final body weight to determine body weight gain (BWG) of the birds in the two week period. Total feed intake (TFI) was determined by subtracting the feed left from the initial feed offered to the birds. Average feed intake (AFI) was adjusted for mortality to more accurately reflect the access of individual birds in a pen to feed during the testing period, by using the following equation:

AFI = (TFI / TBD) * D,

where:

TFI = Total Feed Intake (kg), TBD = Total Bird Days (d), D = Duration of test period (d)

TBD = (no. living birds/pen at the conclusion of the trial * D) + (no. days which dead bird(s) had access to feed)

Feed to gain ratio (F:G) was calculated by dividing the AFI by the BWG.

Statistical Analyses for Experiments 3 and 4: The experimental design for the two studies was a completely randomized design with 14 treatments and pen designated as the experimental unit. Data were analyzed using the ANOVA procedure of SAS (2003). All statements of significance are based on the 0.05 level of probability using the 14 treatment means (treatments A to N). Then, the broken-line analyses procedure of SAS (2003) was used to estimate the requirements for dLys (treatments G to M) and for dThr (treatments A to G) in each phase using BWG and F:G ratio as dependent variables. The NRM.xls Microsoft™ Excel workbook was used as a tool to prepare charts fitting the segmented regression with linear segments of broken-line model ($y = L + U * (R – x) + V * (x – R)$, where $(R – x)$ is defined as zero at values of $x > R$, and $(x – R)$ is defined as zero when $x < R$) and the segmented regression with quadratic segments model ($y = L + U * (R – x)^2$), where L is the constant rate of the asymptote of the first segment, R is the abscissa of the inflection in the curve, U is the slope of the line for $x < R$, and V is the slope of the line at $x > R$ (Robbins et al., 2006, Vedenov and Pesti, 2008).

RESULTS

Digestible Threonine

Feed intake, body weight gain, and feed efficiency of turkeys from 50 to 63 days were affected by treatments ($P < 0.0001$) (Table 5.2). There was a gradual increase in feed intake of turkeys in response to an increase in dietary Thr from 0.39 to 0.55%. There was a gradual increase in BWG and a gradual improvement in F:G ratio of turkeys in response to an increase in dietary Thr from 0.39 to 0.63%. Beyond that level there was no significant change in BWG and F:G ratio. Body weight gain and F:G ratio of birds fed the PC treatment did not differ significantly ($P > 0.05$) from treatments containing the minimum of 0.63% dThr.

Broken-line analyses of the data for BWG and F:G ratio are presented in Figures 5.1 and 5.2, respectively. The dThr requirement for male turkeys from 50 to 63 days was determined to be 0.632% for BWG, and 0.633% for F:G ratio.

Digestible Lysine

Feed intake, body weight gain, and feed efficiency of turkeys from 50 to 63 days were affected by treatments ($P < 0.0001$) (Table 5.3). There was a gradual increase of feed intake and BWG of turkeys in response to an increase in dietary Lys from 0.90 to 1.11%. Beyond that level there was no significant change in FI and BWG. However, the F:G ratio of turkeys improved in response to an increase in dietary Lys from 0.90 to 1.04%. Beyond that level there was no significant change in F:G ratio. The PC treatment did not differ significantly ($P > 0.05$) from the treatments containing the minimum of 1.11% dLys for BWG and 1.04% dLys for F:G ratio.

Broken-line analyses of the data for BWG and F:G ratio are presented in Figures 5.3 and 5.4, respectively. The dLys requirement for male turkeys from 50 to 63 days was determined to be 1.146% for BWG, and 1.123% for F:G ratio. Using the highest resulting requirement for both AA, the ratio of dThr to dLys was determined to be 0.55.

MATERIAL AND METHODS

Experiment 4

Housing: A total of 1,020 71-day-old Nicholas White male turkeys were weighed individually, and after the sorting procedure, 672 turkeys were distributed to the 14 treatments, in 96 pens, with seven birds per pen. Birds were fed experimental diets from day 71 to 84.

Dietary Treatments: There were seven titration levels of dLys and seven titration levels of dThr, totaling 13 treatments (the summit treatment was common for both dLys and dThr trials), plus an industry average PC treatment. The reduced CP (19% CP, and 3,200 kcal/kg ME) corn-SBM-PNM basal diet supplied 0.79% dLys and 0.40% dThr (Table 5.4). To determine the requirement for dThr, the level of dLys was kept at 1.15%, and the seven dietary dThr treatment levels ranged from 0.402%to 0.792%, in 0.065% increments. For the dLys requirement, the level of dThr was kept at 0.792%, and the seven dietary dLys treatment levels ranged from 0.79 to 1.15%, in 0.06% increments. The PC diet was an industry average diet containing 21.5% CP and 3,200 kcal/kg ME (Agri Stats, 2006), based on corn-SBM-MBM as presented in Table 5.4.

Dietary treatments included:

A. Basal diet with 19% CP, 1.15% dLys, and 0.402% dThr;

B. Basal diet with 19% CP, 1.15% dLys, and 0.467% dThr;

C. Basal diet with 19% CP, 1.15% dLys, and 0.532% dThr;

D. Basal diet with 19% CP, 1.15% dLys, and 0.597% dThr;

E. Basal diet with 19% CP, 1.15% dLys, and 0.662% dThr;

F. Basal diet with 19% CP, 1.15% dLys, and 0.727% dThr;

G. Basal diet with 19% CP, 1.15% dLys, and 0.792% dThr;

H. Basal diet with 19% CP, 1.09% dLys, and 0.792% dThr;

I. Basal diet with 19% CP, 1.03% dLys, and 0.792% dThr;

J. Basal diet with 19% CP, 0.97% dLys, and 0.792% dThr;

K. Basal diet with 19% CP, 0.91% dLys, and 0.792% dThr;

L. Basal diet with 19% CP, 0.85% dLys, and 0.792% dThr;

M. Basal diet with 19% CP, 0.79% dLys, and 0.792% dThr;

N. Complete diet with 21.5% CP, 1.18% dLys and 0.706% dThr.

RESULTS

Digestible Threonine

Feed intake, body weight gain, and feed efficiency of turkeys from 71 to 84 days were affected by treatments ($P < 0.0001$) (Table 5.4). There was a gradual increase in feed intake of turkeys in response to an increase in dietary Thr from 0.402 to 0.532%. There was a gradual improvement in BWG and F:G ratio of turkeys in response to an increase in dietary Thr from 0.402 to 0.597%. Beyond those levels there was no significant change in FI, BWG or F:G ratio. Body weight gain and F:G ratio of birds fed the PC treatment did not differ significantly ($P > 0.05$) from the treatments containing the minimum of 0.597% dThr.

Broken-line analyses of BWG and F:G ratio data are presented in Figures 5.5 and 5.6, respectively. The dThr requirement for male turkeys from 71 to 84 days was determined to be 0.572% for BWG, and 0.581% for F:G ratio.

Digestible Lysine

Feed intake, body weight gain, and feed efficiency of turkeys from 71 to 84 days were affected by treatments ($P < 0.0001$) (Table 5.5). There was an increase in feed intake of turkeys in response to an increase in dietary Lys from 0.79 to 0.85%. Beyond that level there was no significant change in FI. There was a gradual improvement on the BWG and F:G ratio of turkeys in response to an increase in dietary Lys from 0.79 to 0.97%. Beyond those levels there was no significant change in BWG and F:G ratio. Body weight gain and F:G ratio of birds fed the PC treatment did not differ significantly ($P > 0.05$) from the treatments containing a minimum of 0.97% dLys.

Broken-line analyses of the data for BWG and F:G ratio are presented in Figures 5.7 and 5.8, respectively. The dLys requirement for male turkeys from 71 to 84 days was determined to be 1.006% for BWG, and 1.026% for F:G ratio. Using the highest determined requirement for both AA, the ratio of dThr to dLys was determined to be 0.56.

DISCUSSION

Feed intake and body weight gain responses to dietary Thr and Lys in both experiments indicated that the basal diet was deficient in both AA (Tables 5.2, 5.3, 5.5, and 5.6). Supplementation of DL-Met, L-Lys-HCl, L-Thr, L-His, L-Ile, L-Trp, and L-Val were required so the EAA met the ideal protein ratio compared to the summit dLys level. Supplementation of L-Glu was necessary to the dietary treatments reach the minimum CP level reported in Tables 5.1 and 5.4.

Results of Exp. 3 indicated the dThr requirements for male turkeys from 50 to 63 days to be 0.63% for both BWG and F:G ratio (Figures 5.1 and 5.2). Firman and

Guaiume (2006) suggested 0.67% dThr for the same period for optimum growth and feed efficiency, which is close to the results of this trial. Kidd et al. (1998) suggested the level of dietary tThr needed to support adequate body weight gain and feed conversion ratio of BUT male turkeys was 0.77% of the diet from 6 to 9 weeks of age. Waldroup et al. (1998b) suggested 0.87 and 0.84% dietary tThr for body weight gain and feed conversion, respectively, for Nicholas White in the same period. According to Waldroup et al. (1998c), Nicholas White turkeys tend to grow rapidly in the starting phases, whereas BUT turkeys tend to have rapid the gain in the later phases. This might explain the higher requirements for Nicholas White turkeys, compared to the BUT turkeys. However, if the digestibility coefficient of 82% is applied to the tThr results, the suggestion by Kidd et al. (1998) is in agreement with the results of this study.

The requirement values for dLys in Exp. 3 were determined to be 1.15% for BWG (Figure 5.3) and 1.12% for feed conversion (Figure 5.4). Baker et al. (2003a) fed male Nicholas White turkeys experimental diets from 49 to 61 days, and the dLys requirement determined for optimum BWG was 1.09%, and 1.11% for F:G ratio, which are very similar to the results of this trial for the same period. Thompson et al. (2005) reported the dLys requirement for Nicholas White female poults from 46 to 57 days of age to be 1.04% dLys for BWG, and 1.07% dLys for F:G ratio, showing a slight difference between genders. Firman and Guaiume (2006) achieved best performance results when 1.10% dLys diets were fed to male turkeys from 6 to 9 weeks of age.

Results of Exp. 4 indicated the dThr requirements for male turkeys from 71 to 84 days to be 0.57% for BWG (Figure 5.5) and 0.58% for feed conversion (Figure 5.6). Firman and Guaiume (2006) reported a minimum dietary dThr requirement of 0.59% for best performance results, which is very close to the levels determined by the current study. Results obtained by Barbour et al. (2008) suggested a requirement of 0.85% of tThr for BUT male turkeys from 8 to 13 weeks of age. However, Lehmann et al. (1997) observed no significant response to dietary tThr beyond 0.69% from BUT male turkeys for the 8 to 12 week period, which is closer to the results of this experiment if the digestibility coefficient of 82% is applied to the diets. Meanwhile, NRC (1994) lists a value of 0.80% of dietary tThr for turkeys from 8 to 12 weeks of age based on mathematical calculation models of Hurwitz et al. (1983).

The requirements for dLys determined in Exp. 4 were 1.00% for BWG (Figure 5.7) and 1.03% for feed conversion (Figure 5.8) for Nicholas White male turkeys from 71 to 84 days. Baker et al. (2003a) determined the requirements for Lys on a digestible basis for male Nicholas White from 72 to 83 days to be 0.87 and 0.86% for optimum BWG and F:G ratio, respectively. Thompson et al. (2005) determined the dLys requirement for females from 71 to 85 days to be 0.86 and 0.82% for optimum body weight gain and feed conversion, respectively. The requirements for dLys determined in this trial are higher compared to studies cited previously. However, Firman and Guaiume (2006) obtained best performance results feeding Nicholas males with diets containing a minimum of 0.93% dLys. Potter et al. (1981) reported minimum requirement for tLys for Nicholas White turkeys from 8 to 12 weeks of age to be 1.34% for males and 1.46% for females. However, Noll and Waibel (1989) reported a requirement of 1.25% tLys for males of the same turkey breed line for the same period, agreeing with Lehmann et al. (1996), who suggested dietary levels of tLys for BUT males ranging from 1.17 to 1.27% for optimum weight gain and feed conversion from 8 to 12 weeks of age. Balloun and Phillips (1957) suggested a minimum of 1.21% dietary tLys for male turkeys to achieve the best performance results from 6 to 12 weeks of age. If the digestibility coefficient of 85% is applied to the data of Noll and Weibel (1989), Lehmann et al. (1996), and Balloun and Phillips (1957), their results would be close to the results of this experiment.

CONCLUSIONS

According to the results of these two experiments, the requirement for dLys from 50 to 63 days for male turkeys was estimated to be 1.15% for BWG and 1.12% for F:G ratio, while the requirement for dThr was estimated to be 0.63% for BWG and F:G ratio for the same period, with the ratio of dThr to dLys determined to be 0.55. For the next phase, from 71 to 84 days, the requirement for dLys for male turkeys was estimated to be 1.01% for BWG and 1.03% for F:G ratio, and the requirement for dThr was estimated to be 0.57% for BWG and 0.58% for F:G ratio for the same period, with the ratio of dThr to dLys determined to be 0.56.

Table 5.1. Composition of Negative Control Basal and Positive Control diets of turkeys from 50 to 63 days of age (%).

Ingredient	Negative Control Basal Diet	Positive Control Diet
Corn	61.047	53.621
Soybean meal	6.000	28.294
Peanut meal	18.344	-
Meat and bone meal	0.285	12.000
Dicalcium phosphate	2.826	0.188
Limestone	1.711	0.369
Salt	0.099	0.300
Soy oil	3.812	3.463
L-Lysine.HCl	1.017	0.543
DL-Methionine	0.452	0.488
L-Threonine	0.487	0.298
Choline Cl	0.221	0.070
Trace mineral premix[1]	0.100	0.100
Vitamin premix[2]	0.075	0.075
Selenium premix[3]	0.060	0.060
Copper sulfate	0.013	0.013
Sodium bicarbonate	0.500	0.030
Avatec® 20%[4]	0.038	0.038
BMD®-50[5]	0.050	0.050
L-Arginine	0.248	-
L-Glutamic acid	1.501	-

Table 5.1. (Continued)

Ingredient	Negative Control Basal Diet	Positive Control Diet
L-Histidine	0.131	-
L-Isoleucine	0.431	-
L-Tryptophan	0.133	-
L-Valine	0.420	-
Calculated Composition		
EM	3,150	3,150
CP	21.50	25.00
Digestible Lys	0.90	1.39
Digestible Thr	0.39	0.83
Analyzed Composition		
CP	21.41	26.26
Total Lys	1.07	1.73
Total Thr	0.61	1.20

[1]Trace mineral mix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_5 \cdot 7H_2O$); I, 2.0 (ethylenediamine dihydroiodide).
[2]Vitamin mix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg.
[3]Selenium premix provided 0.3 mg/kg of Se (Na_2SeO_3).
[4]Avatec® 20% provided 75 mg/kg of lasalocid sodium.
[5]BMD®-50 provided 25 mg/kg of bacitracin methylene disalicylate.

Table 5.2. Growth performance of male turkeys fed graded levels of digestible threonine (dThr) from 50 to 63 days of age[1]

Treatment	dThr (%)	Feed Intake (kg)	Body Weight Gain (kg)	Feed to Gain (kg:kg)
A	0.39	2.975[c]	0.851[d]	3.502[d]
B	0.47	3.223[b]	1.128[c]	2.872[c]
C	0.55	3.793[a]	1.440[b]	2.635[b]
D	0.63	3.672[a]	1.555[a]	2.361[a]
E	0.71	3.634[a]	1.594[a]	2.281[a]
F	0.79	3.650[a]	1.600[a]	2.286[a]
G	0.87	3.743[a]	1.628[a]	2.303[a]
N	0.83	3.768[a]	1.620[a]	2.327[a]
Pooled SEM		0.207	0.080	0.153

[a-d]Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of eight turkeys per pen, except treatment F with six replicate pens of eight turkeys per pen.

Table 5.3. Growth performance of male turkeys fed graded levels of digestible lysine (dLys) from 50 to 63 days of age[1]

Treatment	dLys (%)	Feed Intake (kg)	Body Weight Gain (kg)[2]	Feed to Gain (kg:kg)[2]
M	0.90	3.342^{d}	1.356^{c}	2.466^{b}
L	0.97	3.479^{cd}	1.423^{bc}	2.447^{b}
K	1.04	3.537^{bc}	1.494^{b}	2.370^{ab}
J	1.11	3.677^{ab}	1.588^{a}	2.316^{a}
I	1.18	3.700^{ab}	1.603^{a}	2.311^{a}
H	1.25	3.776^{a}	1.629^{a}	2.320^{a}
G	1.32	3.743^{a}	1.628^{a}	2.303^{a}
N	1.39	3.768^{a}	1.620^{a}	2.327^{a}
Pooled SEM		0.175	0.070	0.095

[a-d]Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of eight turkeys per pen, except treatment H with six replicate pens of eight turkeys per pen.

Table 5.4. Composition of Negative Control Basal and Positive Control diets of turkeys from 71 to 84 days of age (%).

Ingredient	Negative Control Basal Diet	Positive Control Diet
Corn	64.574	62.831
Soybean meal	5.000	19.974
Peanut meal	18.513	-
Meat and bone meal	-	12.000
Dicalcium phosphate	2.558	-
Limestone	1.656	0.235
Salt	0.180	0.293
Soy oil	4.215	3.168
L-Lysine.HCl	0.814	0.494
DL-Methionine	0.346	0.351
L-Threonine	0.396	0.248
Choline Cl	0.223	0.070
Trace mineral premix[1]	0.100	0.100
Vitamin premix[2]	0.075	0.075
Selenium premix[3]	0.060	0.060
Copper sulfate	0.013	0.013
Sodium bicarbonate	0.387	0.000
Avatec® 20%[4]	0.038	0.038
BMD®-50[5]	0.050	0.050
L-Arginine	0.013	-
L-Histidine	0.078	-

Table 5.4. (Continued)

Ingredient	Negative Control Basal Diet	Positive Control Diet
L-Isoleucine	0.317	-
L-Tryptophan	0.104	-
L-Valine	0.290	-
Calculated Composition		
EM	3,200	3,200
CP	19.10	21.60
Digestible Lys	0.79	1.18
Digestible Thr	0.40	0.71
Analyzed Composition		
CP	19.02	22.57
Total Lys	0.91	1.47
Total Thr	0.59	0.97

[1]Trace mineral mix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_4.7H_2O$); I, 2.0 (ethylenediamine dihydroiodide).
[2]Vitamin mix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg.
[3]Selenium premix provided 0.3 mg/kg of Se (Na_2SeO_3).
[4]Avatec® 20% provided 75 mg/kg of lasalocid sodium.
[5]BMD®-50 provided 25 mg/kg of bacitracin methylene disalicylate.

Table 5.5. Growth performance of male turkeys fed graded levels of digestible threonine (dThr) from 71 to 84 days of age[1]

Treatment	dThr (%)	Feed Intake (kg)	Body Weight Gain (kg)[2]	Feed to Gain (kg:kg)[2]
A	0.402	4.553[b]	1.529[d]	2.998[d]
B	0.467	4.660[b]	1.737[c]	2.701[c]
C	0.532	5.393[a]	2.184[b]	2.477[b]
D	0.597	5.381[a]	2.358[a]	2.286[a]
E	0.662	5.277[a]	2.324[ab]	2.272[a]
F	0.727	5.317[a]	2.337[ab]	2.278[a]
G	0.792	5.265[a]	2.354[ab]	2.239[a]
N	0.706	5.248[a]	2.360[a]	2.227[a]
Pooled SEM		0.338	0.160	0.163

[a-d]Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of seven turkeys per pen, except treatment F with six replicate pens of seven turkeys per pen.

Table 5.6. Growth performance of male turkeys fed graded levels of digestible lysine (dLys) from 71 to 84 days of age[1]

Treatment	dLys (%)	Feed Intake (kg)	Body Weight Gain (kg)[2]	Feed to Gain (kg:kg)[2]
M	0.79	4.842[b]	1.925[c]	2.520[b]
L	0.85	4.868[ab]	1.970[bc]	2.477[b]
K	0.91	5.011[ab]	2.076[b]	2.415[b]
J	0.97	5.282[a]	2.308[a]	2.289[a]
I	1.03	5.170[a]	2.308[a]	2.236[a]
H	1.09	5.262[a]	2.338[a]	2.251[a]
G	1.15	5.265[a]	2.354[a]	2.239[a]
N	1.18	5.248[a]	2.360[a]	2.227[a]
Pooled SEM		0.322	0.133	0.110

[a-c]Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of seven turkeys per pen, except treatment H with six replicate pens of seven turkeys per pen.

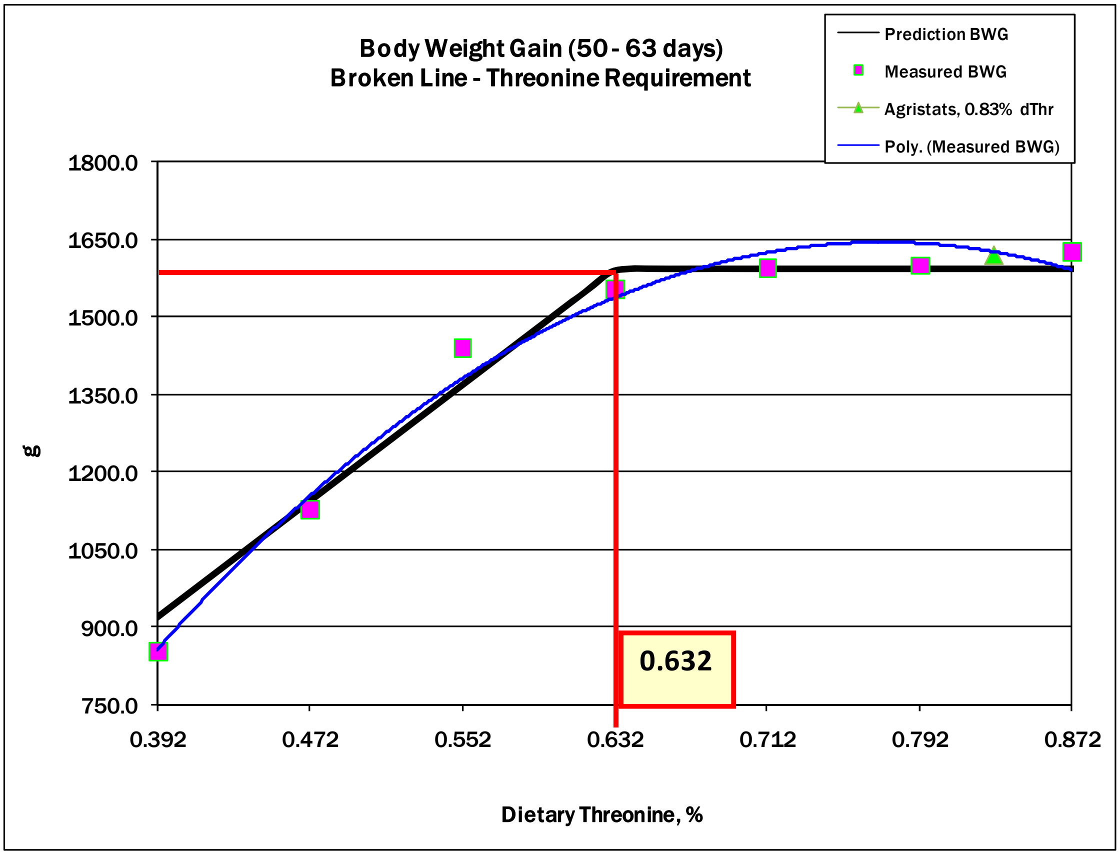


Figure 5.1. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible threonine (dThr) from 50 to 63 days of age[1].

[1]Broken-line response ($P < 0.0001$).

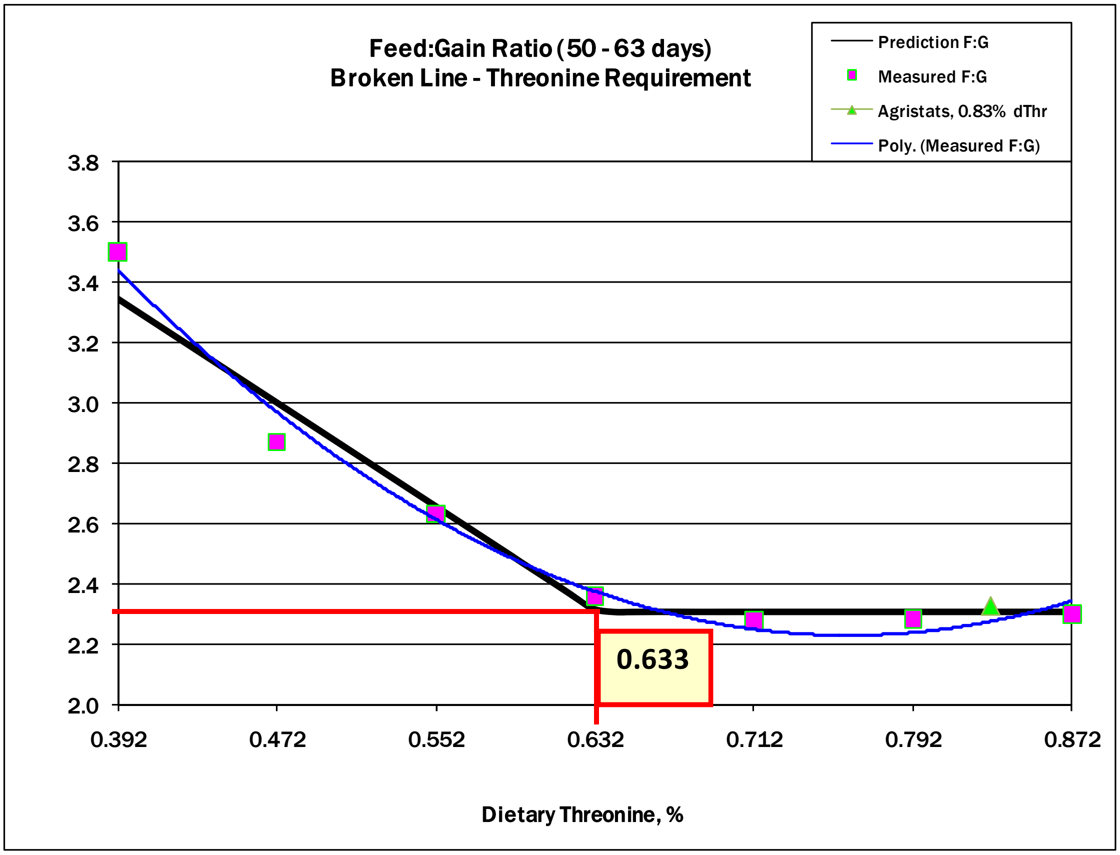


Figure 5.2. Broken-line analyses on feed to gain ratio of male turkeys fed graded levels of digestible threonine (dThr) from 50 to 63 days of age[1].

[1]Broken-line response ($P < 0.0001$).

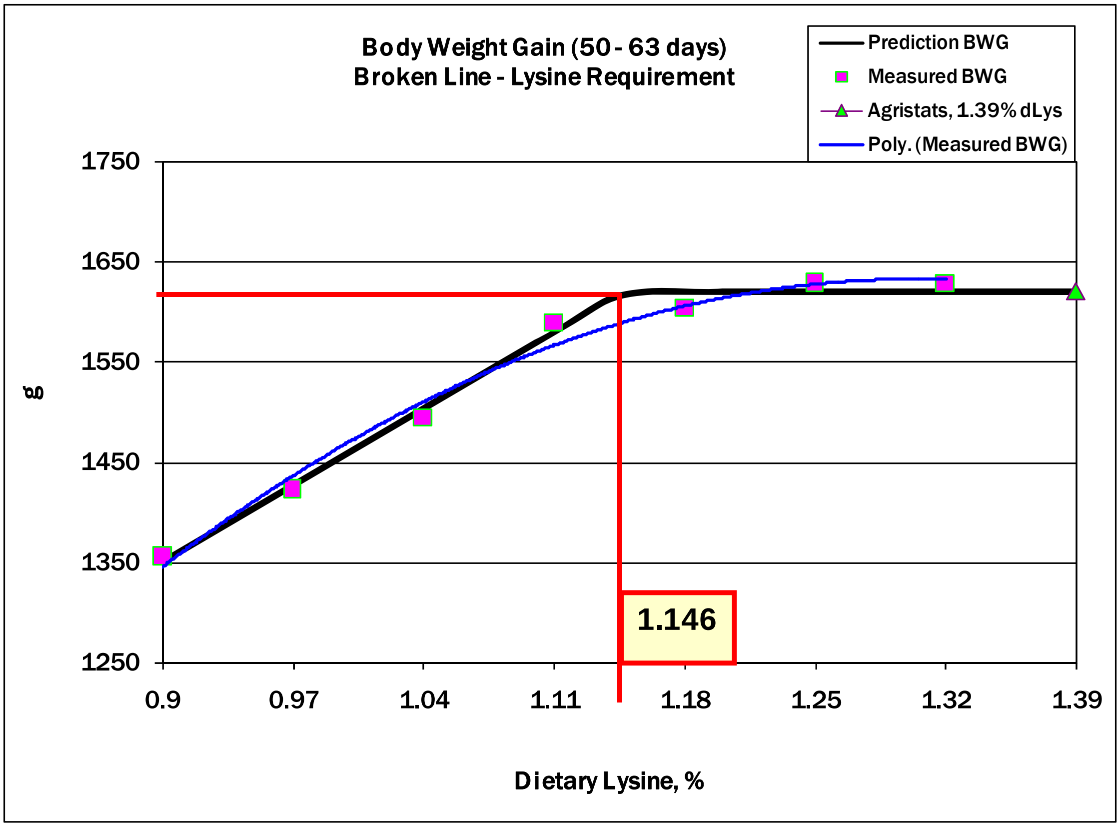


Figure 5.3. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible lysine (dLys) from 50 to 63 days of age[1].

[1]Broken-line response ($P < 0.0001$).

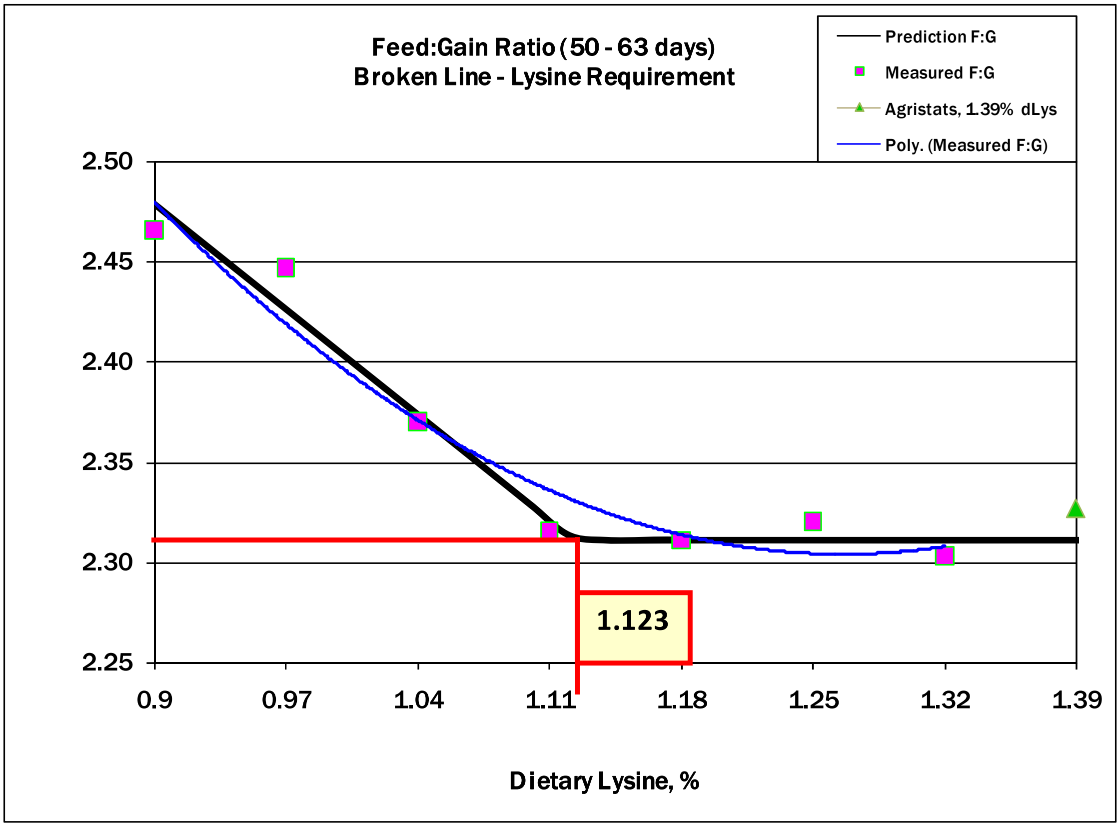


Figure 5.4. Broken-line analyses of feed to gain ratio of male turkeys fed graded levels of digestible lysine (dLys) from 50 to 63 days of age[1].

[1]Broken-line response ($P < 0.0001$).

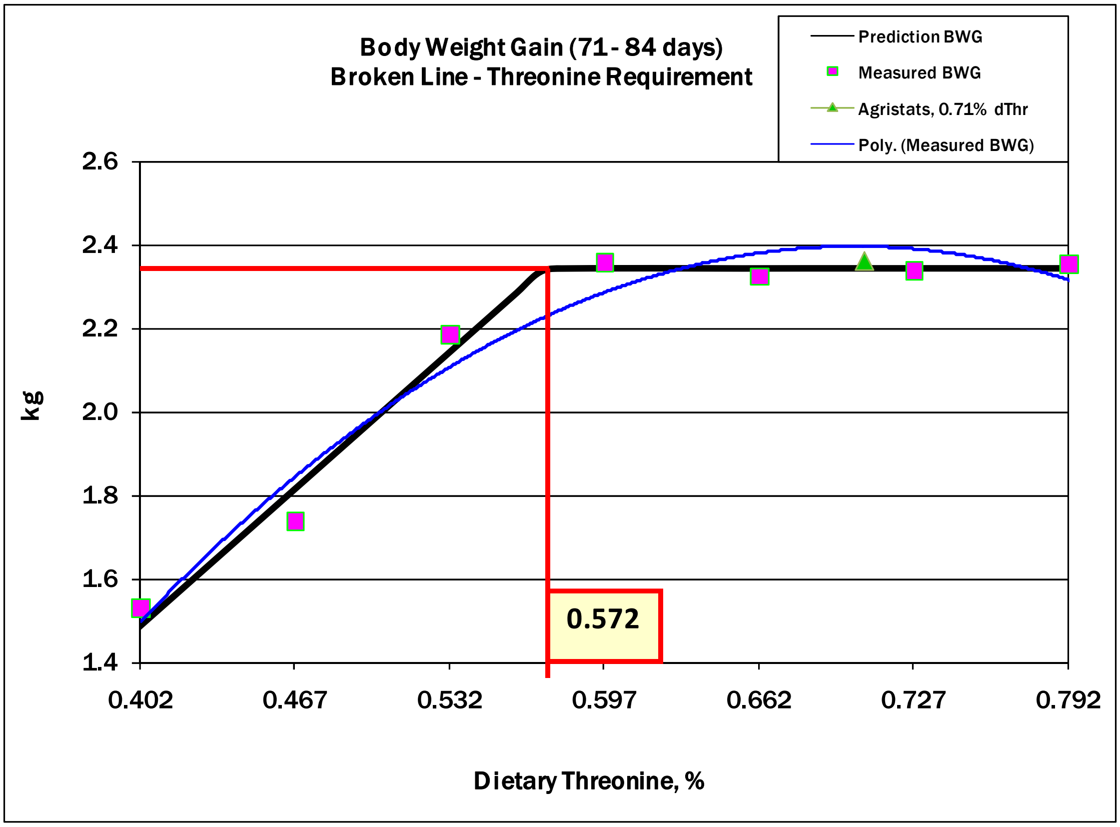


Figure 5.5. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible threonine (dThr) from 71 to 84 days of age[1].

[1]Broken-line response ($P < 0.0001$).

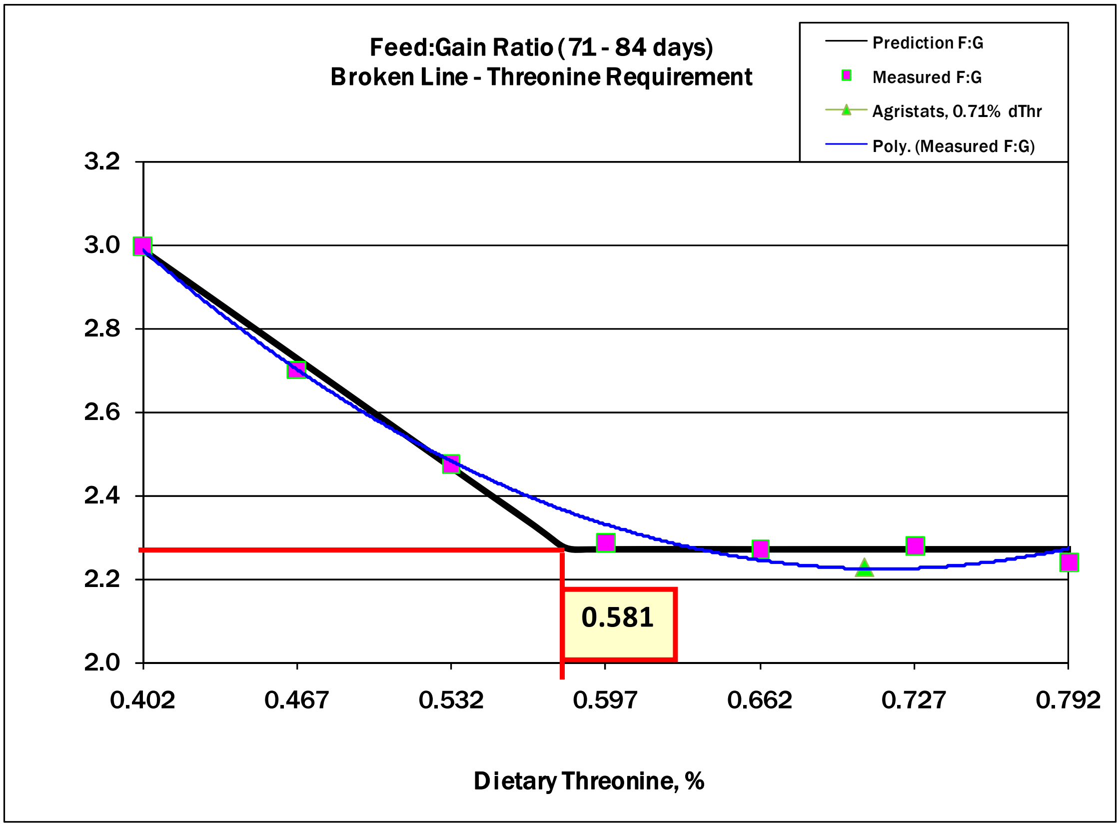


Figure 5.6. Broken-line analyses of feed to gain ratio of male turkeys fed graded levels of digestible threonine (dThr) from 71 to 84 days of age[1].

[1]Broken-line response ($P < 0.0001$).

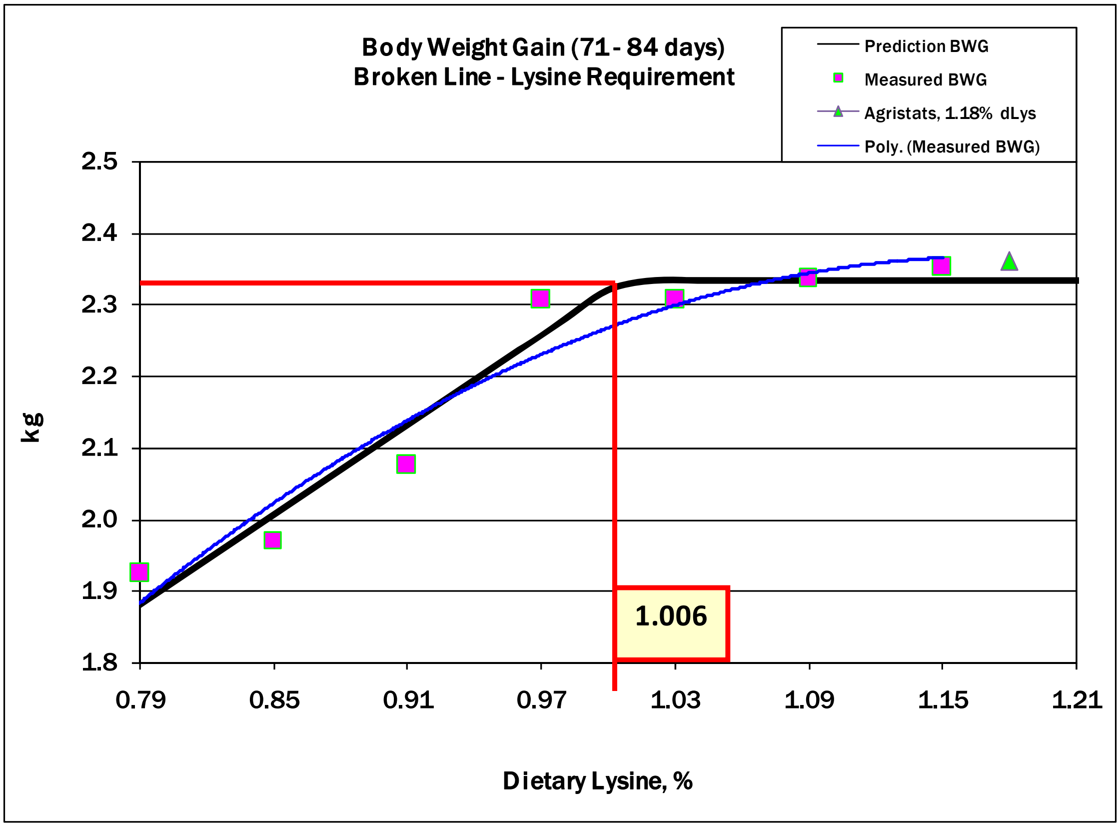


Figure 5.7. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible lysine (dLys) from 71 to 84 days of age[1].

[1]Broken-line response ($P < 0.0001$).

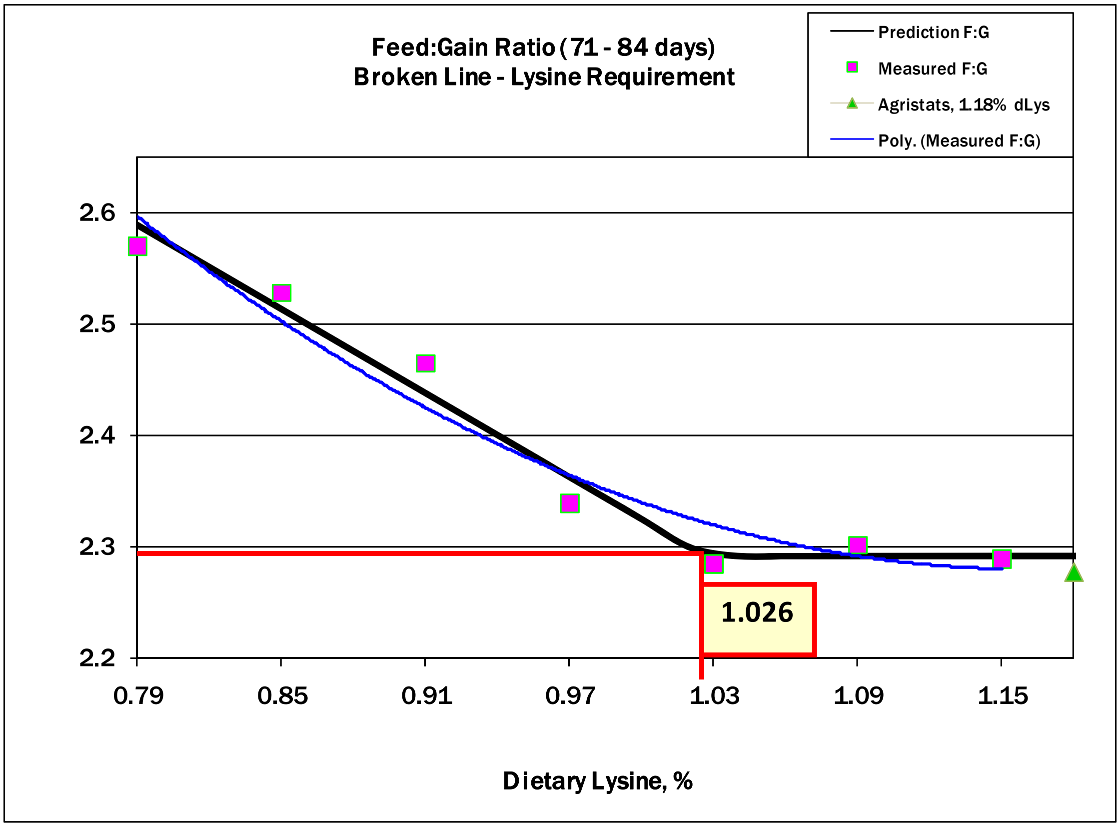


Figure 5.8. Broken-line analyses of feed to gain ratio of male turkeys fed graded levels of digestible lysine from 71 to 84 days of age[1].

[1]Broken-line response ($P < 0.0001$).

CHAPTER VI

DIGESTIBLE LYSINE AND THREONINE REQUIREMENTS OF MALE TURKEYS FROM DAYS 92 TO 105, DAYS 113 TO 126, AND DAYS 134 TO 147

SUMMARY

Three experiments were conducted to determine the digestible lysine (dLys) and digestible threonine (dThr) requirements of Nicholas White male turkeys from days 92 to 105 (Phase V), days 113 to 126 (Phase VI), and days 134 to 147 (Phase VII). In the three phases, birds were randomized to floor pens with 12 treatments and seven replicates per treatment, plus an additional two treatments with six replicates. A total of 576 birds were used in Phase V (six birds/pen), and 480 birds were used in Phases VI and VII (five birds/pen). In Phase V, a reduced low crude protein (16% CP, and 3,300 kcal/kg ME) corn-soybean meal (SBM)-peanut meal (PNM) basal diet supplied 0.62% dLys and 0.316% dThr. To determine the requirement for dThr, the level of dLys was kept at 0.98%, and the seven dietary dThr treatment levels ranged from 0.316 to 0.646%, in 0.055% increments. To determine dLys requirement, the level of dThr was kept at 0.646%, and the seven dietary dLys treatment levels ranged from 0.62 to 0.98%, in 0.06% increments. The positive control (PC) diet was an industry average diet containing 19.7% CP. The broken-line analyses of SAS was used to estimate the requirement for dLys in Phase V which was determined to be 0.81%

for BWG and 0.80% for F:G ratio, and the requirement for dThr to be 0.498% for BWG and 0.483% for F:G ratio. Using the highest requirement for both AA, the ratio of dThr to dLys is 0.62. In Phase VI, a reduced CP (14% CP, and 3,330 kcal/kg ME) corn-SBM-PNM basal diet supplied 0.53% dLys and 0.311% dThr. To determine the requirement for dThr, the level of dLys was kept at 0.83%, and the seven dietary dThr treatment levels ranged from 0.311 to 0.581%, in 0.045% increments. To determine dLys requirement, the level of dThr was kept at 0.581%, and the seven dietary dLys treatment levels ranged from 0.53 to 0.83%, in 0.05% increments. The PC industry average diet had 17% CP. The broken-line analyses of SAS was used to estimate the requirements for dLys in Phase VI to be 0.68% for BWG and 0.70% for F:G ratio, and the requirement for dThr to be 0.45% for both BWG and F:G ratio. The ratio of dThr to dLys was calculated to be 0.64. In Phase VII, a reduced CP (13.2% CP, and 3,340 kcal/kg ME) corn-SBM-PNM basal diet supplied 0.40% dLys and 0.278% dThr. To determine the requirement for dThr, the level of dLys was kept at 0.70%, and the seven dietary dThr treatment levels ranged from 0.278% to 0.488%, in 0.035% increments. To determine dLys requirement, the level of dThr was kept at 0.488%, and the seven dietary dLys treatment levels ranged from 0.40% to 0.70%, in 0.05% increments. The PC industry average diet had 16.1% CP. The broken-line analyses of SAS was used to estimate the requirements for dLys in Phase VII to be 0.58% for BWG and 0.55% for F:G ratio, and the requirement for dThr to be 0.40% for BWG and 0.39% for F:G ratio. The ratio of dThr to dLys was calculated to be 0.69.

INTRODUCTION

Cost of feed during the growing-finishing phases constitutes the majority of costs associated with turkey production, because of constant feed intake increments. About 80% of the total feed intake of a male turkey from day one up to market weight is consumed in the period after 12 weeks of age. Much of the research on amino acids (AA) requirements of turkeys has been conducted during the starter period only, with extrapolation of the data from the starter period to subsequent older ages.

Precision feeding systems and equipment and the application of the ideal protein (IP) concept, feeding the exact balance of AA needed for growth and maintenance without excesses or deficiencies is very important to reducing production costs. The turkey industry lacks sufficient information on digestible AA requirements for turkeys to develop an AA profile to be able to determine the AA ideal ratio to dLys. After 12 weeks of age, only one study has been conducted to determine the digestible lysine (dLys) requirements (Baker et al., 2003b). Many studies have been conducted to determine dietary total lysine (tLys) requirements for turkeys after 12 weeks of age (Balloun and Phillips, 1957; Jensen et al., 1976; Potter et al., 1981; Noll and Weibel, 1989; Lehmann et al., 1996). However, no research has been conducted to determine the digestible threonine (dThr) requirements for turkeys after 3 weeks of age, and there are fewer studies on total Thr (tThr) requirement for turkeys older than 12 weeks (Lehmann et al., 1997).

The objective of this research was determine the dLys and dThr requirement of Nicholas White male turkeys from days 92 to 105, from days 113 to 126, and from days134 to 147, in order to recommend digestible levels of these AA in diets formulated for growing-finishing turkeys, using the IP concept.

MATERIAL AND METHODS

Experiment 5

Housing: A total of 800 92-day-old Nicholas White male turkeys were weighed individually, and after the sorting procedure, 576 turkeys were distributed to the 14 treatments, in 96 pens, with six birds per pen. Birds were fed experimental diets from day 92 to 105. Poults were housed and maintained using standard husbandry practices. Birds were housed in a curtain sided building with temperature controlled by circulating fans for ventilation and a heater for warming. Birds were maintained on a 24 hour constant-light schedule and allowed access to feed and water *ad libitum*. All procedures were conducted in accordance with the University of Missouri Animal Care and Use Guidelines and approved protocols.

Sorting procedures for Experiments 5, 6, and 7: The number of birds needed to be used in the two week experimental periods plus an additional 20% were weighed individually, and the lighter and heavier birds were not used. Then, the total of birds needed for the period were randomized to 96 pens according to their weight, using the Microsoft™ Excel randomization tool, to obtain similar average pen weights.

Dietary Treatments: There were seven titration levels of dLys and seven titration levels of dThr, totaling 13 treatments (the summit treatment was common for both dLys and dThr trials), plus an industry average Positive Control (PC). The reduced crude protein (16% CP, and 3,300 kcal/kg ME) corn-soybean meal (SBM)-peanut meal (PNM) basal diet (Table 6.1) supplied 0.62% dLys and 0.316% dThr. To determine the requirement for dThr, the level of dLys was kept at 0.98%, and the seven dietary dThr treatment levels ranged from 0.316 to 0.646%, in 0.055% increments. For the dLys requirement, the level of dThr was kept at 0.646%, and the seven dietary dLys treatment levels ranged from 0.62 to 0.98%, in 0.06% increments. The PC industry average diet had 19.7% CP and 3,300 kcal/kg ME (Agri Stats, 2006), based on corn-SBM-meat and bone meal (MBM) as presented in Table 6.1.

Dietary treatments included:

A. Basal diet with 16% CP, 0.98% dLys, and 0.316% dThr;

B. Basal diet with 16% CP, 0.98% dLys, and 0.371% dThr;

C. Basal diet with 16% CP, 0.98% dLys, and 0.426% dThr;

D. Basal diet with 16% CP, 0.98% dLys, and 0.481% dThr;

E. Basal diet with 16% CP, 0.98% dLys, and 0.536% dThr;

F. Basal diet with 16% CP, 0.98% dLys, and 0.591% dThr;

G. Basal diet with 16% CP, 0.98% dLys, and 0.646% dThr;

H. Basal diet with 16% CP, 0.92% dLys, and 0.646% dThr;

I. Basal diet with 16% CP, 0.86% dLys, and 0.646% dThr;

J. Basal diet with 16% CP, 0.80% dLys, and 0.646% dThr;

K. Basal diet with 16% CP, 0.74% dLys, and 0.646% dThr;

L. Basal diet with 16% CP, 0.68% dLys, and 0.646% dThr;

M. Basal diet with 16% CP, 0.62% dLys, and 0.646% dThr;

N. Complete diet with 19.7% CP, 1.07% dLys and 0.647% dThr.

Measurements for Experiments 5, 6, and 7: Mortality was recorded as it occurred. All birds were inspected daily and health related problems were recorded. Data were collected during the last two weeks of each three weeks period (for example, in phase V, data were collected during the 14^{th} and 15^{th} weeks). The birds were weighed by pen at the end of the last week of the period. The initial body weight was subtracted from the final body weight to determine body weight gain (BWG) of the birds in the two week period. Total feed intake (TFI) was determined by subtracting the feed left from the initial feed offered to the birds. Average feed intake (AFI) was adjusted for mortality to more accurately reflect the access of individual birds in a pen to feed during the testing period, by using the following equation:

AFI = (TFI / TBD) * D,

where:

TFI = Total Feed Intake (kg), TBD = Total Bird Days (d), D = Duration of test period (d)

TBD = (no. living birds/pen at the conclusion of the trial * D) + (no. days which dead bird(s) had access to feed)

Feed to gain ratio (F:G) was calculated by dividing the AFI by the BWG.

Statistical Analyses for Experiments 5, 6 and 7: The experimental design for the two studies was a completely randomized design with 14 treatments and pen designated as the experimental unit. Data were analyzed using the ANOVA procedure of SAS (2003). All statements of significance are based on the 0.05 level of probability using the 14 treatment means (treatments A to N). Then, the broken-line analyses procedure of SAS (2003) was used to estimate the requirements for dLys (treatments G to M) and for dThr (treatments A to G) in each phase using BWG and F:G ratio as dependent variables. The NRM.xls Microsoft™ Excel workbook was used as a tool to prepare charts fitting the segmented regression with linear segments of broken-line model ($y = L + U * (R – x) + V * (x – R)$, where $(R – x)$ is defined as zero at values of $x > R$, and $(x – R)$ is defined as zero when $x < R$) and the segmented regression with quadratic segments model ($y = L + U * (R – x)^2$), where L is the constant rate of the asymptote of the first segment, R is the abscissa of the inflection in the curve, U is the slope of the line for $x < R$, and V is the slope of the line at $x > R$ (Robbins et al., 2006, Vedenov and Pesti, 2008).

RESULTS

Digestible Threonine

Feed intake, body weight gain, and feed efficiency of turkeys from 92 to 105 days were affected by treatments ($P < 0.0001$) (Table 6.2). There was a gradual increase in FI and BWG of turkeys, and also a gradual improvement in F:G ratio of turkeys in response to an increase in dietary Thr from 0.316 to 0.481%. Beyond that level there was no significant change in FI, BWG or F:G ratio. Body weight gain and F:G ratio of the PC treatment did not differ significantly ($P > 0.05$) from the treatments containing a minimum of 0.481% dThr.

Broken-line analyses of the data for BWG and F:G ratio are presented in Figures 6.1 and 6.2, respectively. The dThr requirement for male turkeys from 92 to 105 days was determined to be 0.498% for BWG, and 0.483% for F:G ratio.

Digestible Lysine

Feed intake, body weight gain and feed efficiency of turkeys from 92 to 105 days were affected by treatments ($P < 0.0001$) (Table 6.3). There was an increase of the FI of turkeys as dLys increased from 0.62% to 0.68%. Beyond that level there was no significant change in FI. There was a gradual increase on BWG of turkeys in response to an increase in dietary Lys from 0.62 to 0.80%. Beyond that level there was no significant change in BWG. However, the F:G ratio of turkeys improved in response to an increase in dietary Lys from 0.62 to 0.74%. Beyond that level there was no significant change in F:G ratio. Body weight gain and F:G ratio of the PC treatment did not differ significantly ($P > 0.05$) from the treatments containing a minimum of 0.80% dLys.

Broken-line analyses of the data for BWG and F:G ratio are presented in Figures 6.3 and 6.4, respectively. The dLys requirement for male turkeys from 92 to 105 days was determined to be 0.813% for BWG, and 0.801% for F:G ratio. Using the highest determined requirement for both AA, the ratio of dThr to dLys is 0.62.

MATERIAL AND METHODS

Experiment 6

Housing: A total of 700 113-day-old Nicholas White male turkeys were weighed individually, and after the sorting procedure, 480 turkeys were distributed to the 14 treatments, in 96 pens, with five birds per pen. Birds were fed experimental diets from day 113 to 126.

Dietary Treatments: There were seven titration levels of dLys and seven titration levels of dThr, totaling 13 treatments (the summit treatment was common for both dLys and dThr trials), plus an industry average PC treatment. The reduced CP (14% CP, and 3,330 kcal/kg ME) corn-SBM-PNM basal diet supplied 0.53% dLys and 0.311% dThr (Table 6.4). To determine the requirement for dThr, the level of dLys was kept at 0.83%, and the 7 dietary dThr treatment levels ranged from 0.311 to 0.581%, in 0.045% increments. For the dLys requirement, the level of dThr was kept at 0.581%, and the 7 dietary dLys treatment levels ranged from 0.53 to 0.83%, in 0.05% increments. The PC industry average diet had 17% CP, and 3,330 kcal/kg ME (Agri Stats, 2006), based on corn-SBM-MBM as presented in Table 6.4.

Dietary treatments included:

A. Basal diet with 14% CP, 0.83% dLys, and 0.311% dThr;

B. Basal diet with 14% CP, 0.83% dLys, and 0.356% dThr;

C. Basal diet with 14% CP, 0.83% dLys, and 0.401% dThr;

D. Basal diet with 14% CP, 0.83% dLys, and 0.446% dThr;

E. Basal diet with 14% CP, 0.83% dLys, and 0.491% dThr;

F. Basal diet with 14% CP, 0.83% dLys, and 0.536% dThr;

G. Basal diet with 14% CP, 0.83% dLys, and 0.581% dThr;

H. Basal diet with 14% CP, 0.78% dLys, and 0.581% dThr;

I. Basal diet with 14% CP, 0.73% dLys, and 0.581% dThr;

J. Basal diet with 14% CP, 0.68% dLys, and 0.581% dThr;

K. Basal diet with 14% CP, 0.63% dLys, and 0.581% dThr;

L. Basal diet with 14% CP, 0.58% dLys, and 0.581% dThr;

M. Basal diet with 14% CP, 0.53% dLys, and 0.581% dThr;

N. Complete diet with 17% CP, 0.89% dLys and 0.546% dThr.

RESULTS

Digestible Threonine

Feed intake, body weight gain, and feed efficiency of turkeys from 113 to 126 days were affected by treatments ($P < 0.0001$) (Table 6.5). There was an increase in FI of turkeys in response to an increase in dietary Thr from 0.311 to 0.356%. Beyond that level there was no significant change in FI. There was a gradual improvement of the BWG and F:G ratio of turkeys in response to an increase in dietary Thr from 0.311 to 0.446%. Beyond those levels there was no significant change in BWG and F:G ratio. Body weight gain and F:G ratio of the PC treatment did not differ significantly ($P > 0.05$) from the treatments containing the minimum of 0.446% dThr.

Broken-line analyses of the data for BWG and F:G ratio are presented in Figures 6.5 and 6.6, respectively. The dThr requirement for male turkeys from 113 to 126 days was determined to be 0.450% for BWG, and 0.453% for F:G ratio.

Digestible Lysine

Feed intake, body weight gain and feed efficiency of turkeys from 113 to 126 days were affected by treatments ($P < 0.0001$) (Table 6.6). There was an increase in FI of turkeys in response to an increase in dietary Lys from 0.53 to 0.58%. Beyond that level there was no significant change in FI. There was a gradual improvement of the BWG and F:G ratio of turkeys in response to an increase in dietary Lys from 0.53 to

0.68%. Beyond that level there was no significant change in BWG and F:G ratio. Body weight gain and F:G ratio of the PC treatment did not differ significantly ($P > 0.05$) from the treatments containing the minimum of 0.68% dLys.

Broken-line analyses of the data for BWG and F:G ratio are presented in Figures 6.7 and 6.8, respectively. The dLys requirement for male turkeys from 113 to 126 days was determined to be 0.682% for BWG, and 0.702% for F:G ratio. Using the highest determined requirement value for both AA, the ratio of dThr to dLys is 0.64.

MATERIAL AND METHODS

Experiment 7

Housing: A total of 700 134-day-old Nicholas White male turkeys were weighed individually, and after the sorting procedure, 480 turkeys were distributed to the 14 treatments, in 96 pens, with five birds per pen. Birds were fed experimental diets from day 134 to 147.

Dietary Treatments: There were seven titration levels of dLys and seven titration levels of dThr, totaling 13 treatments (the summit treatment was common for both dLys and dThr trials), plus an industry average PC treatment. The reduced CP (13.2% CP, and 3,340 kcal /kg ME) corn-SBM-PNM basal diet supplied 0.40% dLys and 0.278% dThr (Table 6.7). To determine the requirement for dThr, the level of dLys was kept at 0.70%, and the seven dietary dThr treatment levels ranged from 0.278 to 0.488%, in 0.035% increments. For the dLys requirement, the level of dThr was kept at 0.488%, and the seven dietary dLys treatment levels ranged from 0.40 to 0.70%, in 0.05% increments. The PC diet was an industry average diet containing

16.1% CP, and 3,340 kcal/kg ME (Agri Stats, 2006), based on corn-SBM-MBM as presented in Table 6.7.

Dietary treatments included:

A. Basal diet with 13.2% CP, 0.70% dLys, and 0.278% dThr;

B. Basal diet with 13.2% CP, 0.70% dLys, and 0.313% dThr;

C. Basal diet with 13.2% CP, 0.70% dLys, and 0.348% dThr;

D. Basal diet with 13.2% CP, 0.70% dLys, and 0.383% dThr;

E. Basal diet with 13.2% CP, 0.70% dLys, and 0.418% dThr;

F. Basal diet with 13.2% CP, 0.70% dLys, and 0.453% dThr;

G. Basal diet with 13.2% CP, 0.70% dLys, and 0.488% dThr;

H. Basal diet with 13.2% CP, 0.65% dLys, and 0.488% dThr;

I. Basal diet with 13.2% CP, 0.60% dLys, and 0.488% dThr;

J. Basal diet with 13.2% CP, 0.55% dLys, and 0.488% dThr;

K. Basal diet with 13.2% CP, 0.50% dLys, and 0.488% dThr;

L. Basal diet with 13.2% CP, 0.45% dLys, and 0.488% dThr;

M. Basal diet with 13.2% CP, 0.40% dLys, and 0.488% dThr;

N. Complete diet with 16.1% CP, 0.84% dLys and 0.512% dThr.

RESULTS

Digestible Threonine

Feed intake, body weight gain and feed efficiency of turkeys from 134 to 147 days were affected by treatments ($P < 0.0001$) (Table 6.8). There was a gradual increase in FI of turkeys in response to an increase in dietary Thr from 0.278 to 0.348%. Beyond that level there was no significant change in FI. There was a gradual improvement in BWG and F:G ratio of turkeys in response to an increase in dietary dThr from 0.278 to 0.383%. Beyond that level there were no significant changes in BWG and F:G ratio. Body weight gain and F:G ratio of the PC treatment did not differ significantly ($P > 0.05$) from treatments containing the minimum of 0.383% dThr.

Broken-line analyses of the data for BWG and F:G ratio are presented in Figures 6.9 and 6.10, respectively. The dThr requirement for male turkeys from 134 to 147 days was determined to be 0.399% for BWG, and 0.392% for F:G ratio.

Digestible Lysine

Feed intake, body weight gain, and feed efficiency of turkeys from 134 to 147 days were affected by treatments ($P < 0.0001$) (Table 6.9). There was a gradual increase in FI of turkeys in response to an increase in dietary Lys from 0.40 to 0.60%. Beyond that level there was no significant change in FI. There was also a gradual increase on BWG of turkeys in response to an increase in dietary Lys from 0.40 to 0.55%. Beyond that level there was no significant change in BWG. There was also a gradual improvement in F:G ratio of turkeys in response to an increase in dietary Lys from 0.40 to 0.50%. Beyond that level there was no significant change in F:G ratio. The PC treatment did not differ significantly ($P > 0.05$) from the treatments containing the minimum of 0.55% dLys for BWG, and 0.50% for F:G ratio.

Broken-line analyses of the BWG and F:G ratio data are presented in Figures 6.11 and 6.12, respectively. The dLys requirement for male turkeys from 134 to 147 days was determined to be 0.577% for BWG, and 0.550% for F:G ratio. Using the highest determined requirement for both AA, the ratio of dThr to dLys is 0.70.

DISCUSSION

Feed intake and body weight gain responses to dietary Thr and Lys in the three experiments indicated that the basal diet was deficient in both AA. Supplementation of DL-Met, L-Lys-HCl, L-Thr, L-His, L-Ile, L-Trp, and L-Val was required so that the EAA met the ideal protein ratio compared to the summit dLys level. Supplementation of L-Glu was necessary for the dietary treatments reach the minimum CP level reported in Tables 6.1, 6.4, and 6.7.

Results of the Exp. 5 evaluated the dThr requirements for male turkeys from 92 to 105 days. Results indicated a requirement for dThr of 0.50% for BWG and 0.48% for F:G ratio (Figures 6.1, and 6.2). These data are consistent with a previous study by Firman and Guaiume (2006), who reported that 0.51% dThr gave the best performance when male turkeys were fed from 12 to 15 weeks. The current NRC (1994) recommends a level of 0.75% tThr to support adequate body weight gain and feed conversion ratio of turkeys fed dietary from 12 to 16 weeks of age.

The requirements for dLys determined in Exp. 5 were 0.81% using BWG (Figure 6.3) and 0.80% using feed conversion (Figure 6.4). Baker et al. (2003b) fed male Nicholas White turkeys experimental diets from 84 to 95 days, and the dLys requirement was determined to be 0.68% using maximum body weight gain, and 0.67% using feed conversion. Their requirement values are very low compared to the results of this trial for the same period. One possible explanation is the difference in ME content of the diets; while the diets in this trial contained 3,300 kcal/kg, the diets used by Baker et al. (2003b) contained 3,500 kcal/kg, which might have caused a decrease in the feed intake, leading an underestimation of the dLys requirement. Firman and Guaiume (2006) achieved best performance results when they fed 0.77% dLys diets to male turkeys from 12 to 15 weeks of age, results which are closer to the ones observed in this study. Jensen et al. (1976) suggested 3.11 g of Lys/Mcal of ME, which represents 0.95% tLys in male turkey diets for the period between 12 and 16 weeks. Applying a digestibility coefficient of 85% to the diet, tLys requirements determined by Jensen et al. (1976) are close to the results presented in this experiment. However, Potter et al. (1981) suggested levels of 1.15% dietary tLys for male turkeys for the same time period, which seems to be very high for this age period.

The dThr and dLys requirements for male turkeys from 113 to 126 days were determined in Exp. 6. Results indicated dThr requirements of 0.45% using both BWG and F:G ratio (Figures 6.5, and 6.6). This requirement value for dThr is identical to that reported by Firman and Guaiume (2006) to give the best growth performance of male turkeys fed dietary treatments from 15 to 18 weeks. Meanwhile, NRC (1994) recommends 0.60% dietary tThr to support adequate body weight gain and feed conversion ratio of turkeys from 16 to 20 weeks of age. For the same period, a dietary tThr level of 0.58% appeared to be adequate to obtain maximum body weight gain, whereas 0.64% dietary tThr was required for optimum breast meat deposition (Lehmann et al., 1997).

The requirement for dLys determined in Exp. 6 was 0.68% using BWG (Figure 6.7) and 0.70% using feed conversion (Figure 6.8). Baker et al. (2003b) fed Nicholas White male turkeys experimental diets from day 105 to 116, and the dLys requirement determined to be 0.53% for optimum body weight gain, and 0.54% using feed conversion, values which are very low compared to the results of this trial for the same period. One possible explanation is the difference in ME content of the diets; while the diets in this trial contained 3,300 kcal/kg, the diets of Baker et al. (2003b) contained 3,600 kcal/kg, which might have caused a decrease in feed intake, leading to an underestimation of the dLys requirement. Firman and Guaiume (2006) achieved best performance when they fed a minimum of 0.65% dLys diets to male turkeys from 15 to 18 weeks of age, results which are closer to the ones observed in this study. Potter et al. (1981) estimated the tLys requirement for the period of 16 to 20 weeks to be 0.97% for males and 0.87% for female turkeys. Jensen et al. (1976), however, reported the minimum requirement for tLys for male turkeys to be 0.73% for the same period, whereas Noll and Waibel (1989) concluded that the minimum requirement for tLys was 0.77% for the Nicholas White male turkeys. However, in a more recent study, Lehmann et al. (1996) concluded that the dietary tLys requirement of male BUT turkeys is 0.96% or higher. Waldroup et al. (1998c) reported that Nicholas White turkeys tend to grow rapidly in the starting phase, whereas BUT turkeys tend to increase their growth rate in the later phases. This might explain the higher requirements for BUT turkeys, compared to the Nicholas White turkeys during the finishing phases.

The dThr and dLys requirements for male turkeys from 134 to 147 days were determined in Exp.7. The data indicated dThr requirements of 0.40% using BWG, and 0.39% using F:G ratio (Figures 6.9, and 6.10). There is no reference in the literature to compare with the results of this trial other than NRC (1994), which recommends a dietary level of 0.60% tThr needed to support adequate body weight gain and feed conversion ratio of turkeys from 16 to 20 weeks of age, and a dietary level of 0.50% tThr from 20 to 24 weeks of age.

The requirement for dLys determined in Exp. 7 was 0.57% using BWG (Figure 6.11) and 0.55% using feed conversion (Figure 6.12). For the period between 20 and 23 weeks of age, Kratzer et al. (1956) recommended 0.60% tLys for Broad Breast Bronze turkeys. However, NRC (1994) recommends 0.65% tLys for turkeys from 20 to 24 weeks of age, which is closer to the results of this trial if the digestibility coefficient of 85% for Lys is applied to the diets.

It is noticeable that the requirements for dThr did not decrease in the same way as the requirements of dLys according to the age. Using the highest resulting requirement for both AA, the ratio of dThr to dLys, which was 0.62 in the period from 92 to 105 days, increased to 0.69 for the period between 134 and 147 days of age. A critical need for Thr may be to support Lys utilization, because Lys and Thr interact to optimize breast meat yield (Kidd, 2000) and decrease fat content (Çiftci and Ceylan, 2004) in broilers. Hahn and Baker (1995) reported that the ideal dietary ratio of Thr to Lys increases with the body weight of pigs as a result of the increased importance of Thr relative to Lys in the ideal pattern for maintenance, and the increased importance of maintenance of adult animals compared to young ones. Edwards III et al. (1997)

calculated that the maintenance requirement of broiler chickens represents 5.5% of the total dThr need during the period from hatching to 3 weeks, increasing to 7.4% during the 3 to 6 weeks growth period and to 9.4% during the 6 to 8 week growth period. The results of this study suggest the same trend of increasing in maintenance requirement of Thr in turkeys according to growth.

CONCLUSIONS

According to the results of these three experiments, the requirement for dLys from 92 to 105 days for male turkeys was estimated to be 0.81% using BWG and 0.80% using F:G ratio, while the requirement for dThr was estimated to be 0.50% using BWG and 0.48% using F:G ratio for the same period, with the ratio of dThr to dLys being 0.62. For the following phase, from 113 to 126 days, the requirement for dLys for male turkeys was estimated to be 0.68% using BWG and 0.70% using F:G ratio, and the requirement for dThr was estimated to be 0.45% using both BWG and F:G ratio as well for the same period, with the ratio of dThr to dLys being 0.64. From 134 to 147 days, the requirement for dLys for male turkeys was estimated to be 0.57% using BWG and 0.55% using F:G ratio, and the requirement for dThr was estimated to be 0.40% using BWG and 0.39% using F:G ratio for the same period, with the ratio of dThr to dLys established as 0.70.

Table 6.1. Composition of Negative Control Basal and Positive Control diets of turkeys from 92 to 105 days of age (%).

Ingredient	Negative Control Basal Diet	Positive Control Diet
Corn	72.066	65.540
Soybean meal	4.000	18.053
Peanut meal	10.122	-
Meat and bone meal	0.000	10.259
Dicalcium phosphate	2.272	0.000
Limestone	1.532	0.317
Salt	0.328	0.337
Soy oil	4.917	4.425
L-Lysine.HCl	0.784	0.355
DL-Methionine	0.307	0.246
L-Threonine	0.335	0.092
Choline Cl	0.169	0.070
Trace mineral premix[1]	0.100	0.100
Vitamin premix[2]	0.075	0.075
Selenium premix[3]	0.030	0.030
Copper sulfate	0.013	0.013
Sodium bicarbonate	0.438	0.000
Avatec® 20%[4]	0.038	0.038
BMD®-50[5]	0.050	0.050
L-Arginine	0.250	-
L-Glutamic acid	1.478	-

Table 6.1. (Continued)

Ingredient	Negative Control Basal Diet	Positive Control Diet
L-Histidine	0.074	-
L-Isoleucine	0.255	-
L-Tryptophan	0.093	-
L-Valine	0.275	-
Calculated Composition		
EM	3,300	3,300
CP	16.00	19.70
Digestible Lys	0.62	1.07
Digestible Thr	0.32	0.65
Analyzed Composition		
CP	16.59	20.13
Total Lys	0.76	1.22
Total Thr	0.44	0.75

[1]Trace mineral mix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_4.7H_2O$); I, 2.0 (ethylenediamine dihydroiodide).
[2]Vitamin mix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg.
[3]Selenium premix provided 0.3 mg/kg of Se (Na_2SeO_3).
[4]Avatec® 20% provided 75 mg/kg of lasalocid sodium.
[5]BMD®-50 provided 25 mg/kg of bacitracin methylene disalicylate.

Table 6.2. Growth performance of male turkeys fed graded levels of digestible threonine (dThr) from 92 to 105 days of age[1]

Treatment	dThr (%)	Feed Intake (kg)	Body Weight Gain (kg)	Feed to Gain (kg:kg)
A	0.316	6.810[c]	1.742[c]	3.918[c]
B	0.371	7.469[b]	2.311[b]	3.247[b]
C	0.426	7.442[b]	2.408[b]	3.097[b]
D	0.481	7.982[a]	2.838[a]	2.820[a]
E	0.536	8.012[a]	2.921[a]	2.741[a]
F	0.591	8.023[a]	2.919[a]	2.748[a]
G	0.646	8.114[a]	2.967[a]	2.737[a]
N	0.647	7.497[a]	2.907[a]	2.735[a]
Pooled SEM		0.461	0.158	0.178

[a-c]Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of six turkeys per pen, except treatment F with six replicate pens of six turkeys per pen.

Table 6.3. Growth performance of male turkeys fed graded levels of digestible lysine (dLys) from 92 to 105 days of age[1]

Treatment	dLys (%)	Feed Intake (kg)	Body Weight Gain (kg)	Feed to Gain (kg:kg)
M	0.62	7.497[b]	2.309[c]	3.266[c]
L	0.68	8.018[a]	2.694[b]	2.980[b]
K	0.74	7.782[ab]	2.701[b]	2.893[ab]
J	0.80	8.022[a]	2.910[a]	2.756[a]
I	0.86	8.068[a]	2.962[a]	2.729[a]
H	0.92	8.068[a]	2.967[a]	2.718[a]
G	0.98	8.114[a]	2.967[a]	2.737[a]
N	1.07	7.947[ab]	2.907[a]	2.735[a]
Pooled SEM		0.449	0.174	0.174

[a-c]Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of six turkeys per pen, except treatment H with six replicate pens of six turkeys per pen.

Table 6.4. Composition of Negative Control Basal and Positive Control diets of turkeys from 113 to 126 days of age (%).

Ingredient	Negative Control Basal Diet	Positive Control Diet
Corn	76.669	72.733
Soybean meal	4.000	13.159
Peanut meal	8.077	-
Meat and bone meal	0.000	8.452
Dicalcium phosphate	1.834	0.000
Limestone	1.245	0.311
Salt	0.250	0.450
Soy oil	4.477	3.844
L-Lysine.HCl	0.612	0.374
DL-Methionine	0.208	0.184
L-Threonine	0.274	0.092
Choline Cl	0.170	0.070
Trace mineral premix[1]	0.100	0.100
Vitamin premix[2]	0.075	0.075
Selenium premix[3]	0.060	0.030
Copper sulfate	0.013	0.013
Sodium bicarbonate	0.481	0.000
Avatec® 20%[4]	0.038	0.038
BMD®-50[5]	0.050	0.050
L-Arginine	0.058	-
L-Glutamic acid	0.859	-

Table 6.4. (Continued)

Ingredient	Negative Control Basal Diet	Positive Control Diet
L-Histidine	0.031	-
L-Isoleucine	0.176	-
L-Tryptophan	0.070	-
L-Valine	0.173	-
Calculated Composition		
EM	3300	3300
CP	14.00	17.00
Digestible Lys	0.53	0.89
Digestible Thr	0.31	0.55
Analyzed Composition		
CP	14.37	16.88
Total Lys	0.67	1.07
Total Thr	0.41	0.66

[1]Trace mineral mix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_4.7H_2O$); I, 2.0 (ethylenediamine dihydroiodide).
[2]Vitamin mix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg.
[3]Selenium premix provided 0.3 mg/kg of Se (Na_2SeO_3).
[4]Avatec® 20% provided 75 mg/kg of lasalocid sodium.
[5]BMD®-50 provided 25 mg/kg of bacitracin methylene disalicylate.

Table 6.5. Growth performance of male turkeys fed graded levels of digestible threonine (dThr) from113 to 126 days of age[1]

Treatment	dThr (%)	Feed Intake (kg)	Body Weight Gain (kg)	Feed to Gain (kg:kg)
A	0.311	6.626^{b}	1.803^{c}	3.761^{c}
B	0.356	7.585^{a}	2.393^{b}	3.204^{b}
C	0.401	7.784^{a}	2.590^{b}	3.005^{b}
D	0.446	7.830^{a}	2.811^{ab}	2.789^{ab}
E	0.491	7.650^{a}	2.851^{a}	2.683^{ab}
F	0.536	7.767^{a}	2.925^{a}	2.667^{ab}
G	0.581	7.867^{a}	2.950^{a}	2.674^{ab}
N	0.546	7.580^{a}	2.923^{a}	2.608^{a}
Pooled SEM		0.608	0.237	0.317

[a-c]Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of five turkeys per pen, except treatment F with six replicate pens of five turkeys per pen.

Table 6.6. Growth performance of male turkeys fed graded levels of digestible lysine (dLys) from 113 to 126 days of age[1]

Treatment	dLys (%)	Feed Intake (kg)	Body Weight Gain (kg)	Feed to Gain (kg:kg)
M	0.53	7.148[b]	2.128[c]	3.382[d]
L	0.58	7.281[ab]	2.382[b]	3.111[cd]
K	0.63	7.533[ab]	2.553[b]	2.964[bc]
J	0.68	7.715[ab]	2.857[a]	2.713[ab]
I	0.73	7.589[ab]	2.942[a]	2.585[a]
H	0.78	7.696[ab]	2.960[a]	2.613[a]
G	0.83	7.867[a]	2.950[a]	2.675[ab]
N	0.89	7.580[ab]	2.923[a]	2.608[a]
Pooled SEM		0.671	0.255	0.338

[a-d]Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of five turkeys per pen, except treatment H with six replicate pens of five turkeys per pen.

Table 6.7. Composition of Negative Control Basal and Positive Control diets of turkeys from 134 to 147 days of age (%).

Ingredient	Negative Control Basal Diet	Positive Control Diet
Corn	80.123	75.610
Soybean meal	3.000	10.965
Peanut meal	5.490	-
Meat and bone meal	0.000	8.289
Dicalcium phosphate	1.795	0.000
Limestone	1.047	0.103
Salt	0.273	0.453
Soy oil	4.100	3.584
L-Lysine.HCl	0.508	0.402
DL-Methionine	0.144	0.168
L-Threonine	0.213	0.089
Choline Cl	0.179	0.070
Trace mineral premix[1]	0.100	0.100
Vitamin premix[2]	0.075	0.075
Selenium premix[3]	0.060	0.030
Copper sulfate	0.013	0.013
Sodium bicarbonate	0.500	0.000
BMD®-50[4]	0.050	0.050
L-Arginine	0.153	-
L-Glutamic acid	1.855	-
L-Histidine	0.006	-

Table 6.7. (Continued).

Ingredient	Negative Control Basal Diet	Positive Control Diet
L-Isoleucine	0.139	-
L-Tryptophan	0.057	-
L-Valine	0.119	-
Calculated Composition		
EM	3340	3340
CP	13.20	16.10
Digestible Lys	0.40	0.84
Digestible Thr	0.28	0.52
Analyzed Composition		
CP	14.02	15.24
Total Lys	0.51	0.97
Total Thr	0.37	0.59

[1]Trace mineral mix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_4.7H_2O$); I, 2.0 (ethylenediamine dihydroiodide).
[2]Vitamin mix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg.
[3]Selenium premix provided 0.3 mg/kg of Se (Na_2SeO_3).
[4]BMD®-50 provided 25 mg/kg of bacitracin methylene disalicylate.

Table 6.8. Growth performance of male turkeys fed graded levels of digestible threonine (dThr) from 134 to 147 days of age[1]

Treatment	dThr (%)	Feed Intake (kg)	Body Weight Gain (kg)	Feed to Gain (kg:kg)
A	0.278	7.928^{c}	2.217^{d}	3.680^{c}
B	0.313	8.184^{bc}	2.403^{cd}	3.448^{bc}
C	0.348	8.584^{abc}	2.712^{bc}	3.199^{b}
D	0.383	8.769^{ab}	3.078^{ab}	2.866^{ab}
E	0.418	8.997^{a}	3.213^{a}	2.802^{a}
F	0.453	8.813^{ab}	3.111^{a}	2.840^{ab}
G	0.488	8.890^{ab}	3.166^{a}	2.845^{ab}
N	0.512	8.756^{ab}	2.997^{ab}	2.950^{a}
Pooled SEM		0.727	0.375	0.381

$^{a\text{-}d}$Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of five turkeys per pen, except treatment F with six replicate pens of five turkeys per pen.

Table 6.9. Growth performance of male turkeys fed graded levels of digestible lysine (dLys) from 134 to 147 days of age[1]

Treatment	dLys (%)	Feed Intake (kg)	Body Weight Gain (kg)	Feed to Gain (kg:kg)
M	0.40	6.519[e]	1.731[d]	3.921[c]
L	0.45	7.529[d]	2.209[c]	3.496[bc]
K	0.50	8.002[cd]	2.552[bc]	3.146[ab]
J	0.55	8.190[bc]	2.852[ab]	2.880[a]
I	0.60	8.337[abc]	2.948[a]	2.845[a]
H	0.65	8.641[ab]	3.157[a]	2.802[a]
G	0.70	8.890[a]	3.166[a]	2.845[a]
N	0.84	8.756[ab]	2.997[a]	2.950[a]
Pooled SEM		0.619	0.378	0.469

[a-d]Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of seven replicate pens of five turkeys per pen, except treatment H with six replicate pens of five turkeys per pen.

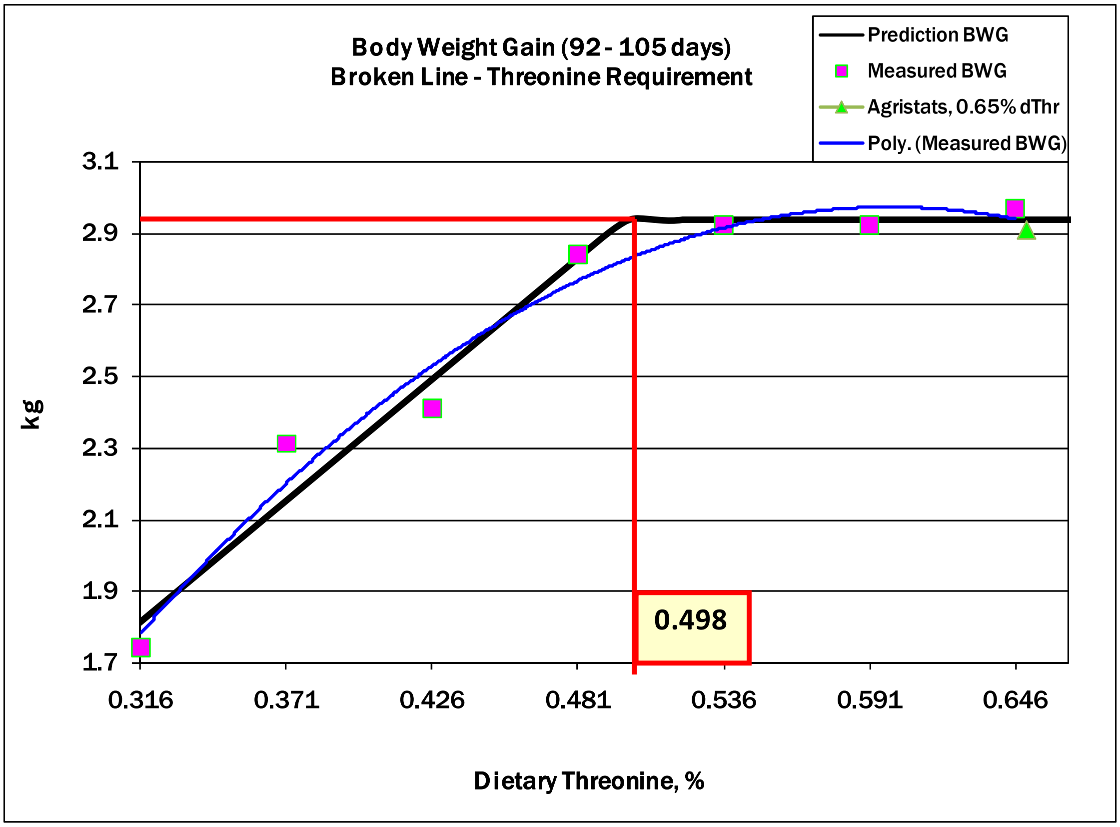


Figure 6.1. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible threonine (dThr) from 92 to 105 days of age[1].

[1]Broken-line response ($P < 0.0001$).

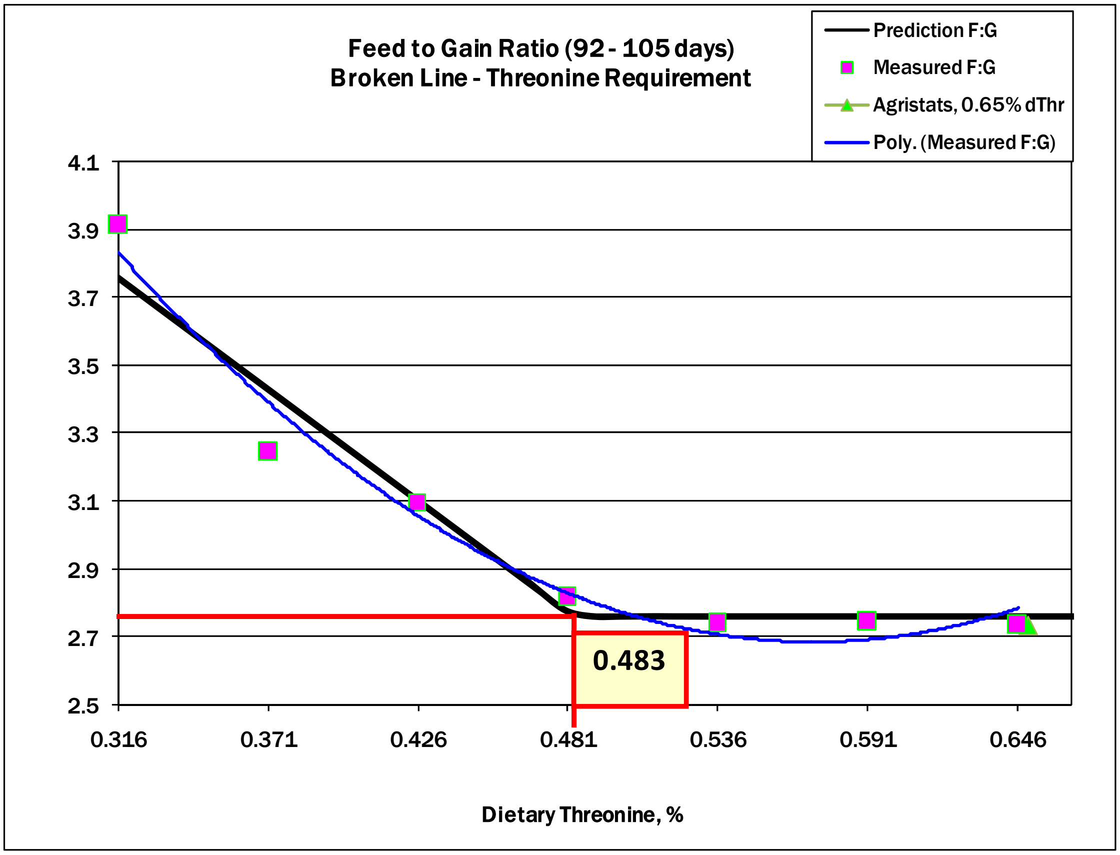


Figure 6.2. Broken-line analyses on feed to gain ratio of male turkeys fed graded levels of digestible threonine (dThr) from 92 to 105 days of age[1].

[1]Broken-line response ($P < 0.0001$).

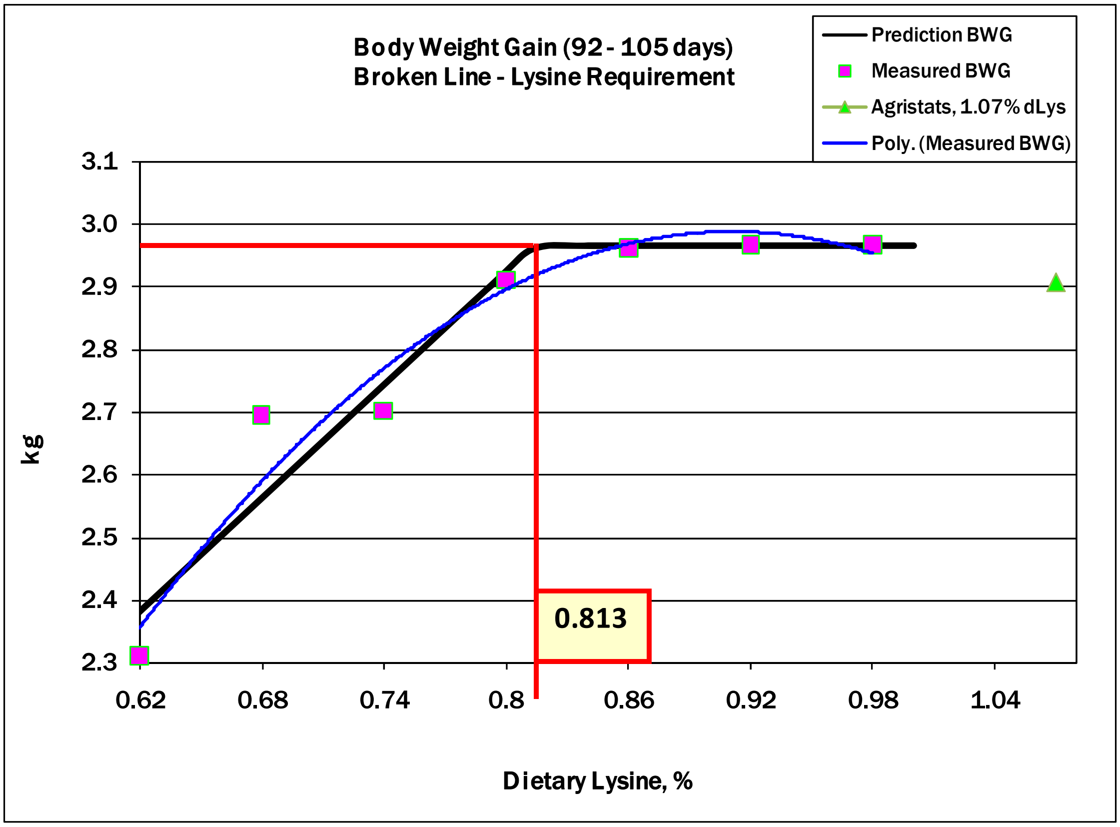


Figure 6.3. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible lysine (dLys) from 92 to 105 days of age[1].

[1]Broken-line response ($P < 0.0001$).

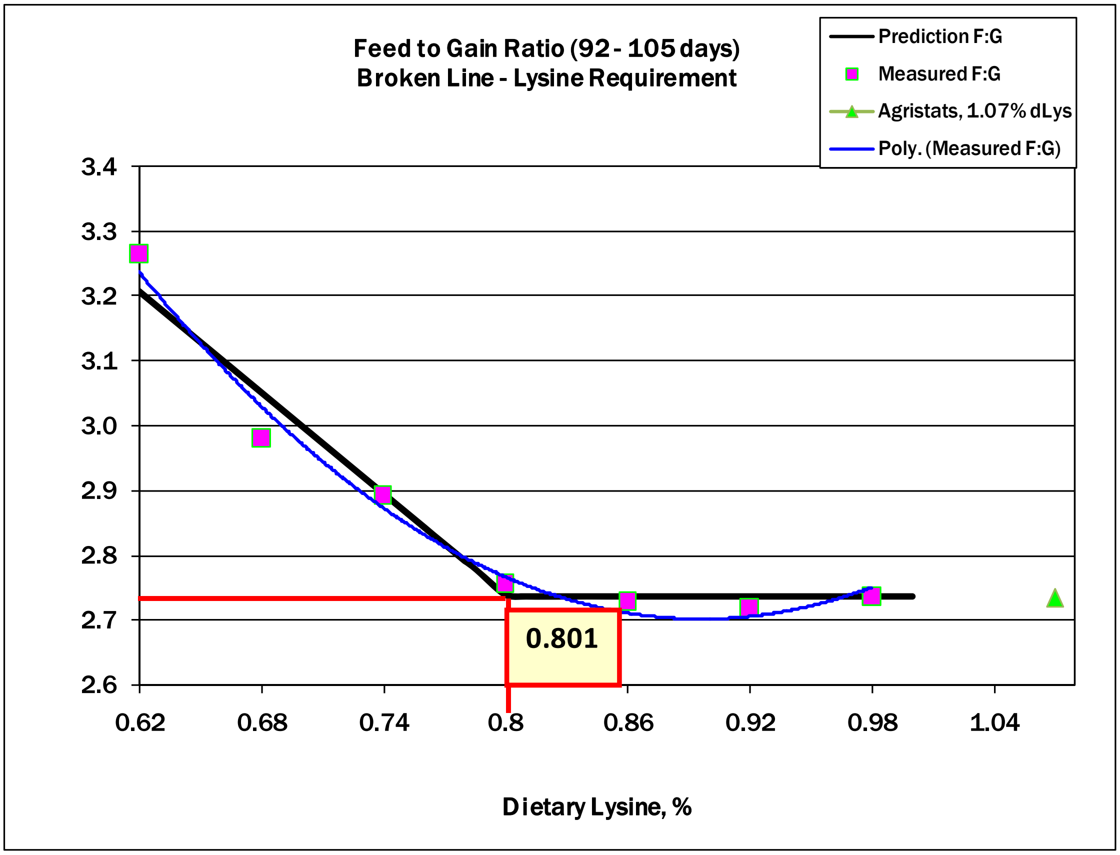


Figure 6.4. Broken-line analyses of feed to gain ratio of male turkeys fed graded levels of digestible lysine (dLys) from 92 to 105 days of age[1].

[1]Broken-line response ($P < 0.0001$).

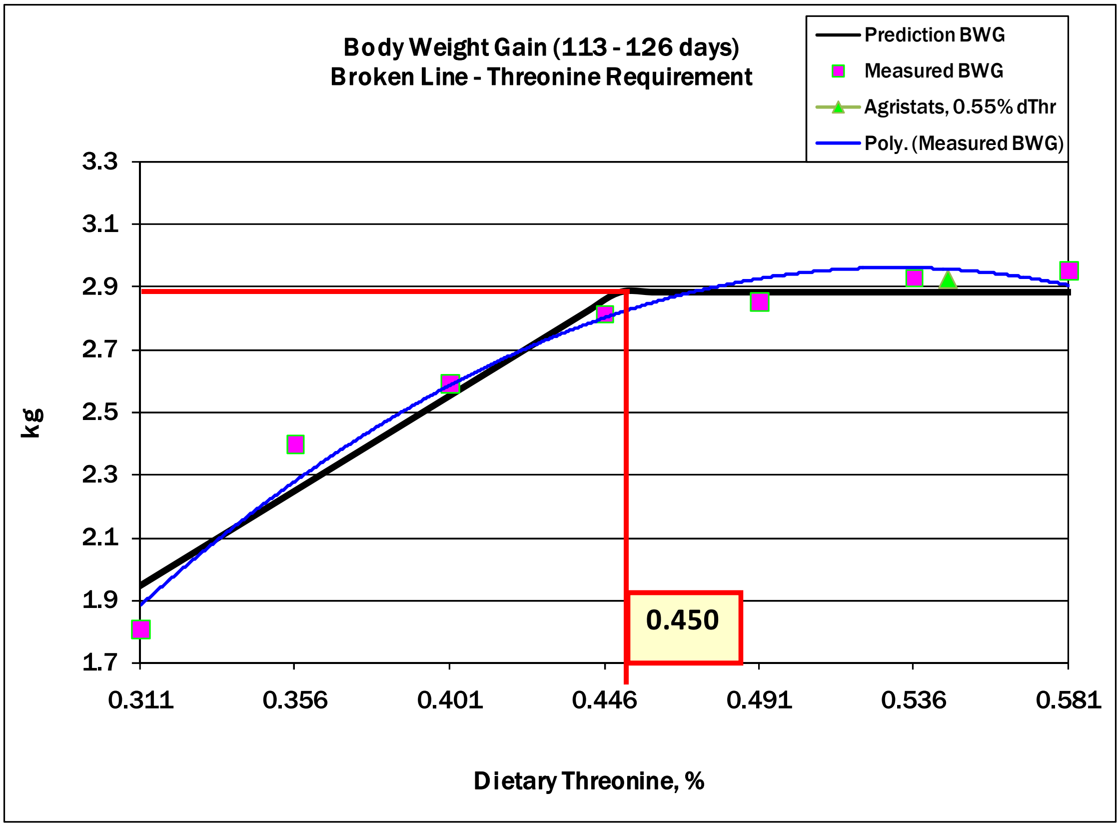


Figure 6.5. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible threonine (dThr) from 113 to 126 days of age[1].

[1]Broken-line response ($P < 0.0001$).

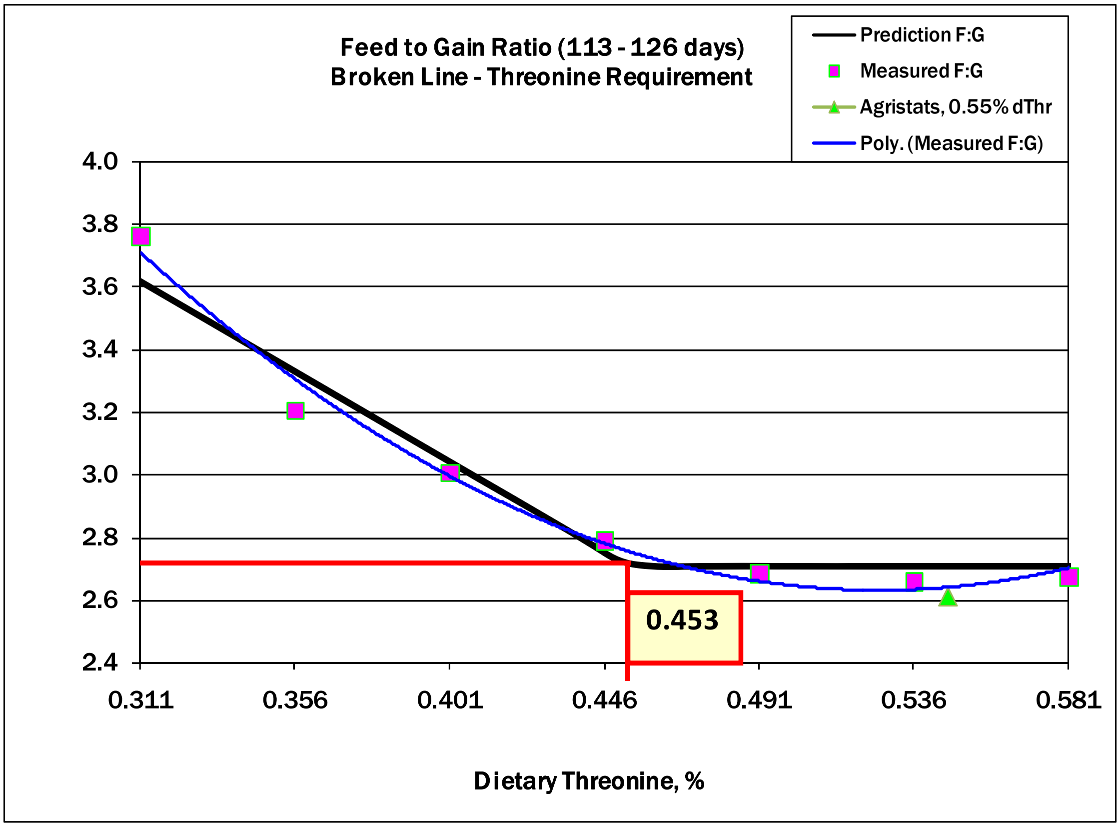


Figure 6.6. Broken-line analyses of feed to gain ratio of male turkeys fed graded levels of digestible threonine (dThr) from 113 to 126 days of age[1].

[1]Broken-line response (P < 0.0001).

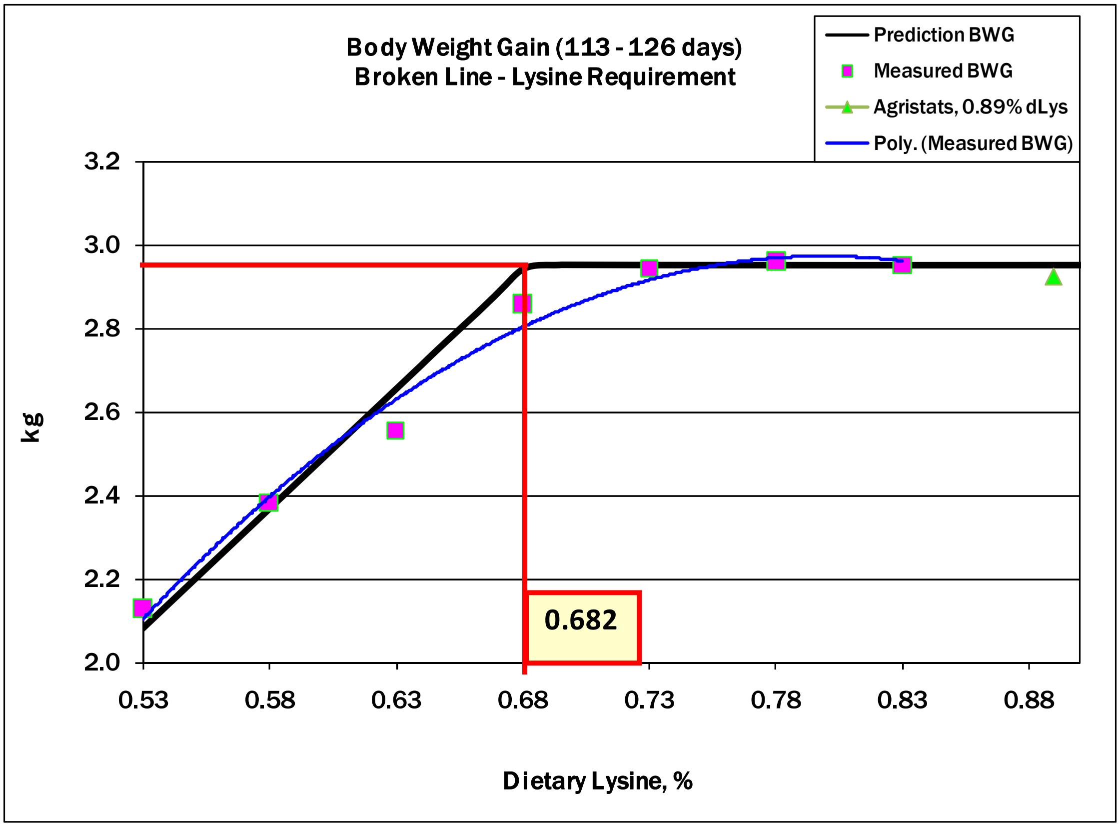


Figure 6.7. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible lysine (dLys) from 113 to 126 days of age[1].

[1]Broken-line response ($P < 0.0001$).

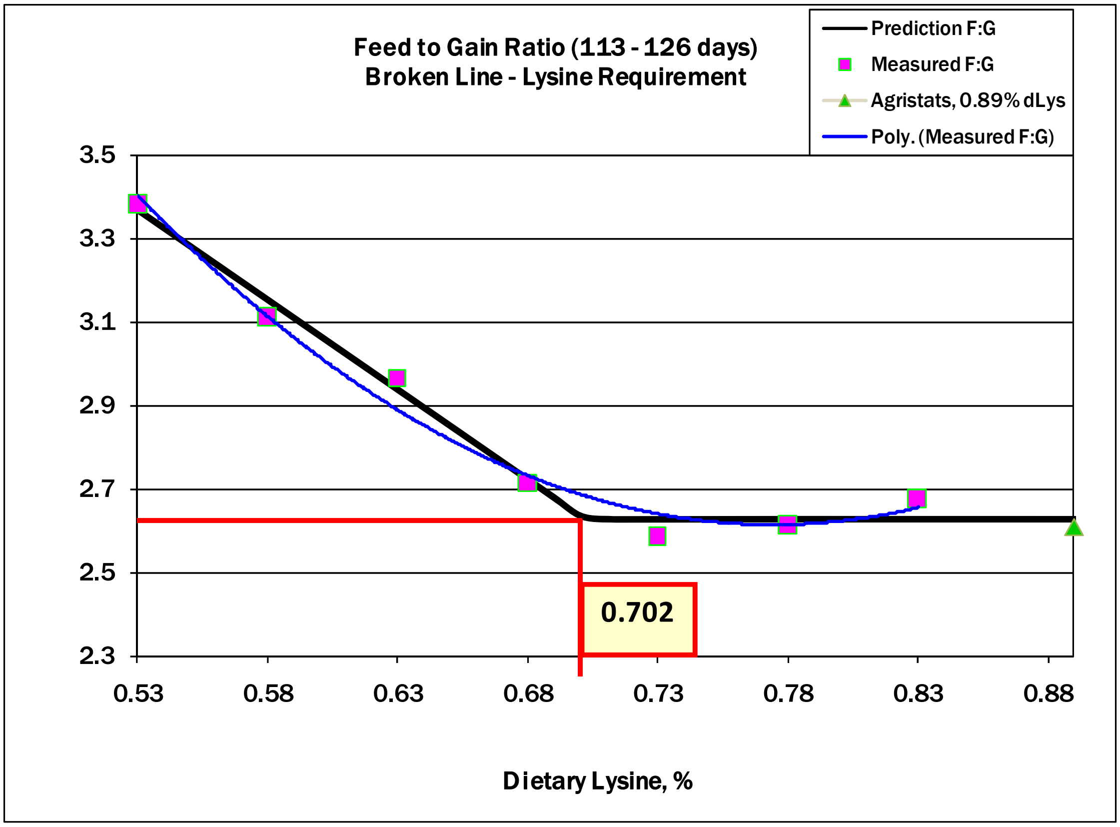


Figure 6.8. Broken-line analyses of feed to gain ratio of male turkeys fed graded levels of digestible lysine (dLys) from 113 to 126 days of age[1].

[1]Broken-line response ($P < 0.0001$).

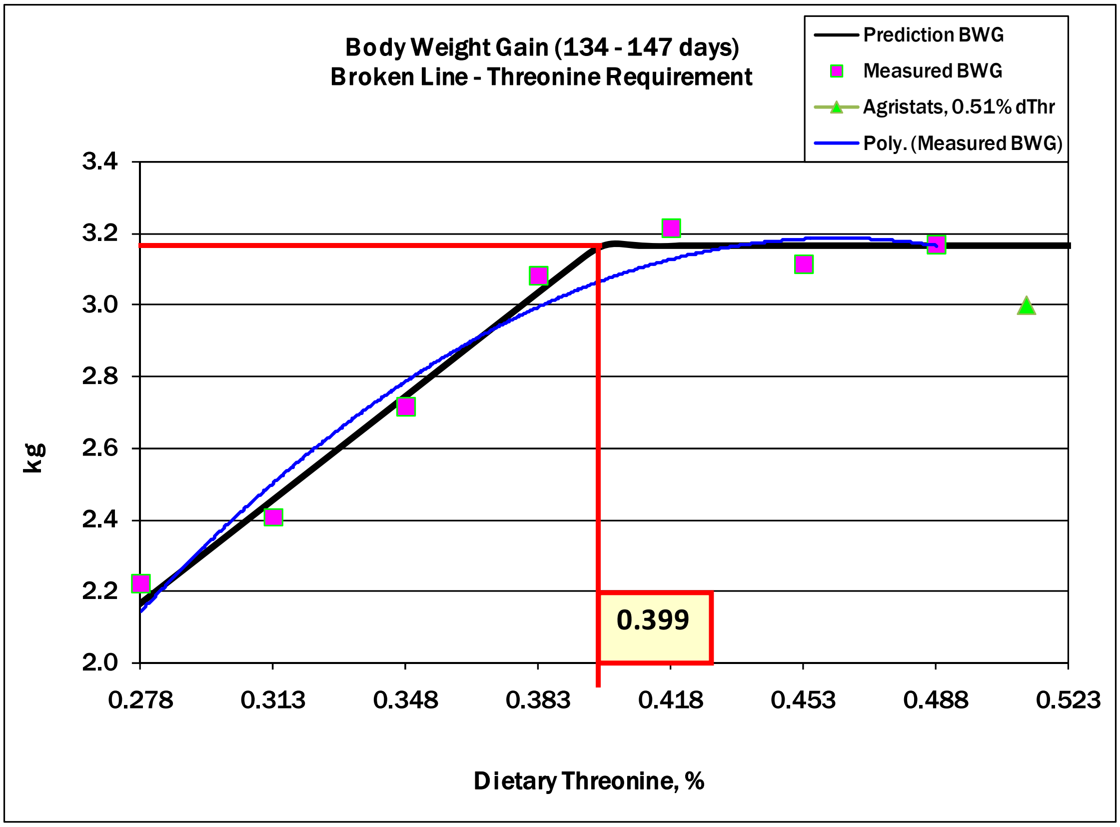


Figure 6.9. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible threonine (dThr) from 134 to 147 days of age[1].

[1]Broken-line response ($P < 0.0001$).

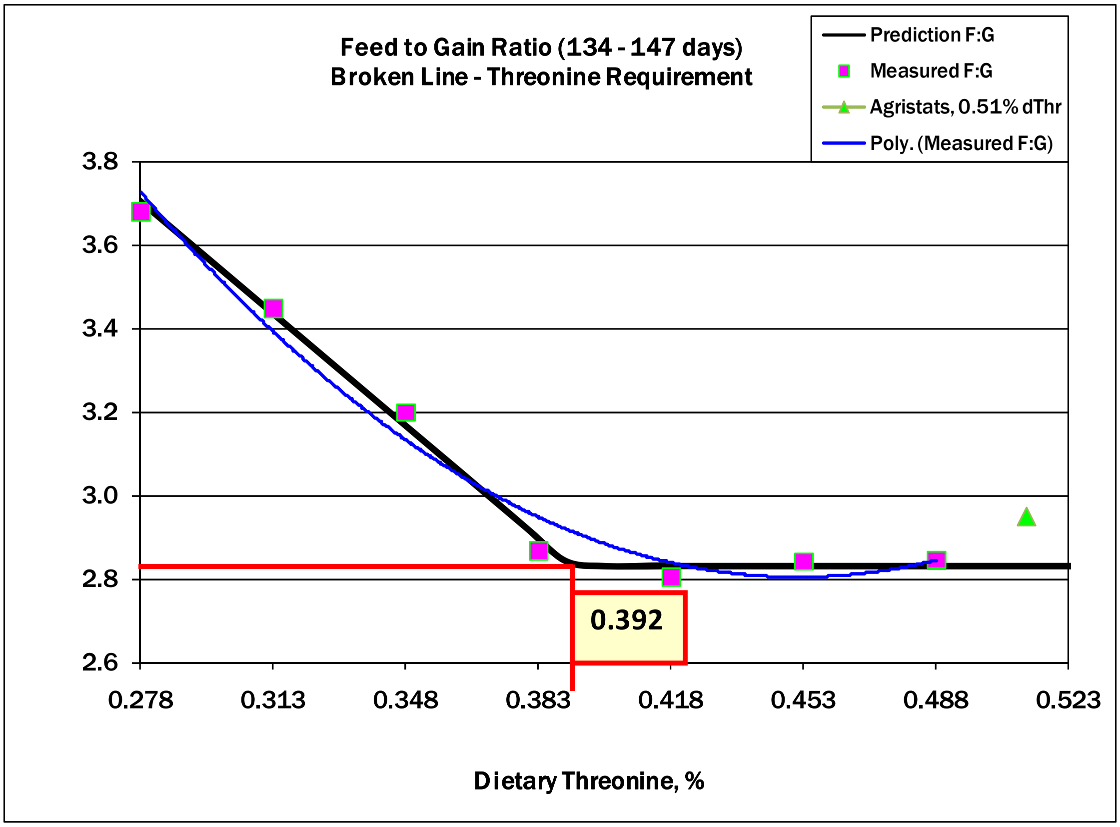


Figure 6.10. Broken-line analyses of feed to gain ratio of male turkeys fed graded levels of digestible threonine (dThr) from 134 to 147 days of age[1].

[1]Broken-line response ($P < 0.0001$).

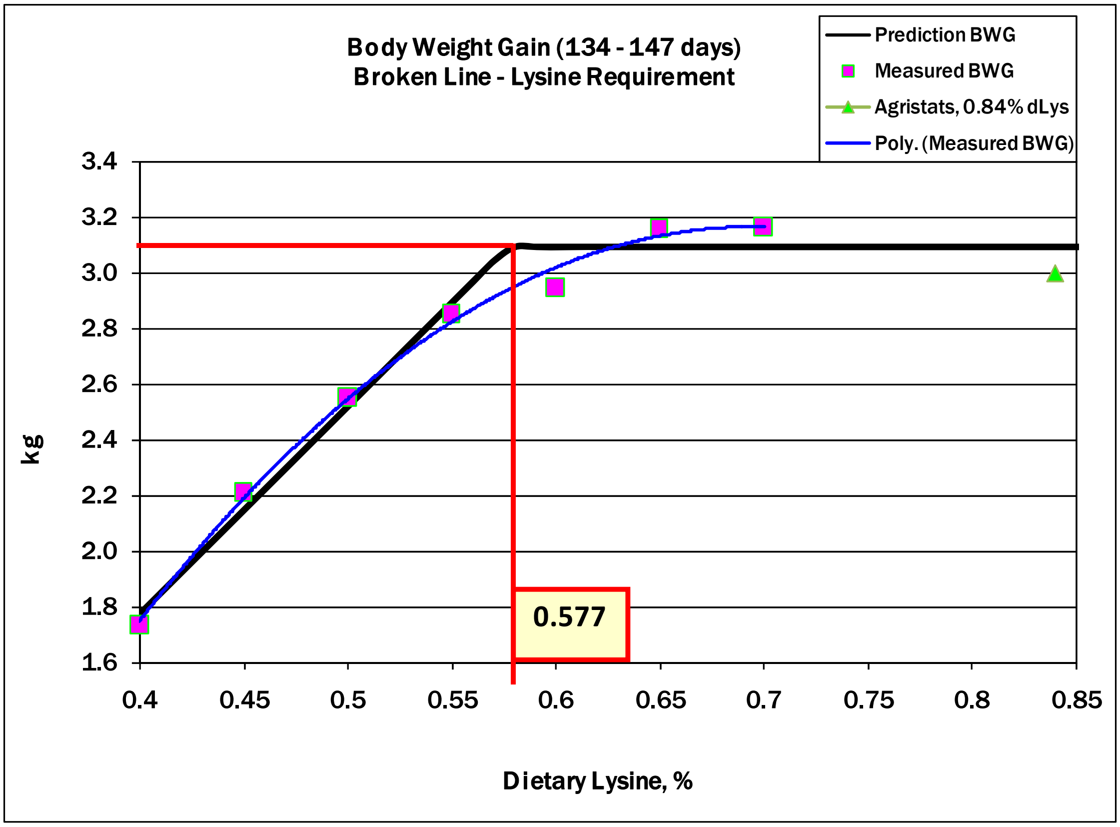


Figure 6.11. Broken-line analyses of body weight gain of male turkeys fed graded levels of digestible lysine (dLys) from 134 to 147 days of age[1].

[1]Broken-line response ($P < 0.0001$).

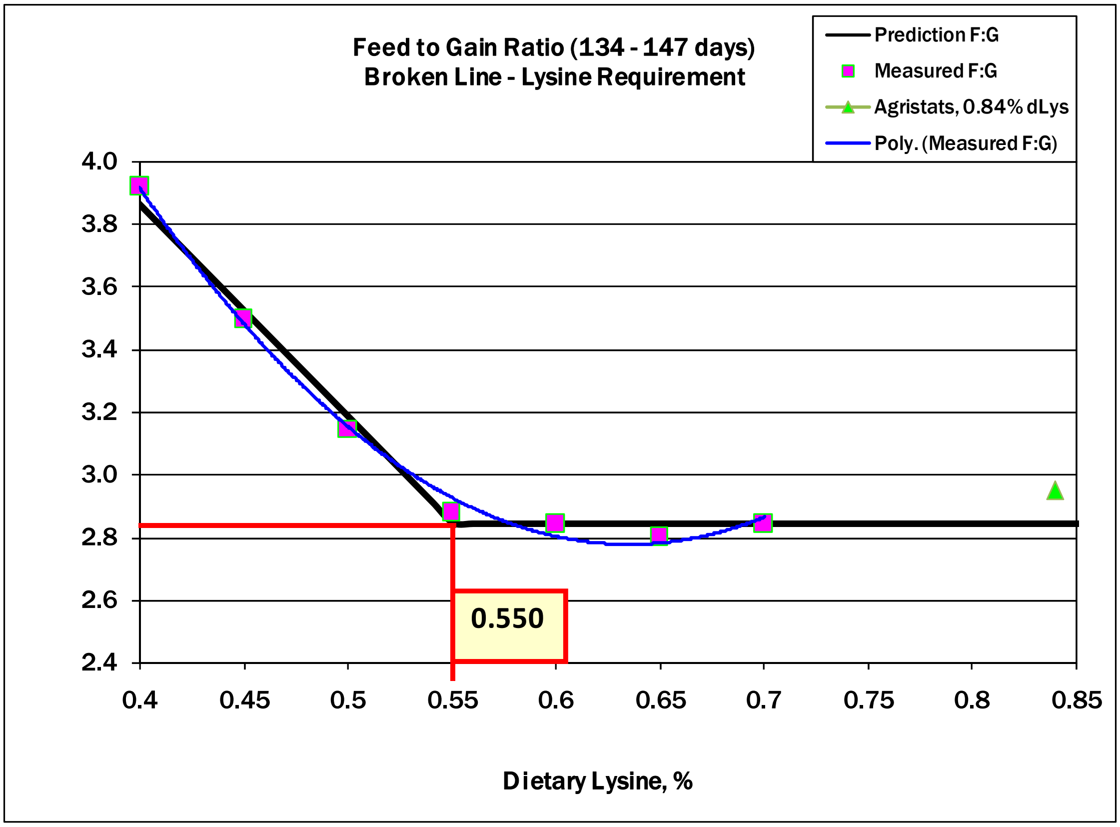


Figure 6.12. Broken-line analyses of feed to gain ratio of male turkeys fed graded levels of digestible lysine (dLys) from 134 to 147 days of age[1].

[1]Broken-line response ($P < 0.0001$).

CHAPTER VII

EFFECTS OF IDEAL PROTEIN PRACTICAL DIETS ON PRODUCTION AND ECONOMIC PERFORMANCE OF MALE TURKEYS FROM 1 TO 18 WEEKS OF AGE

SUMMARY

A study was conducted to determine the effects of diets formulated using the ideal protein (IP) concept on production and economic performance of BUT Big-9 male turkeys from 1 to 18 weeks of age. A total of 640 7-day male poults were placed in a curtain sided building and randomly assigned to four treatments with eight replicate pens containing 20 poults each. The positive control (PC) diets were industry average diets based on Agri Stats (2006) data. The PC diets were formulated by restricting the minimum level of crude protein (CP), and on a total amino acids (AA) basis. The experimental diets were formulated on a digestible AA basis using constraints based on previous results presented in this dissertation, with no minimum restriction on CP. In the IP formulation of the three experimental diets, the exact digestible AA requirements were used with 0, 5, or 10% AA safety factor. Diets were formulated to be isocaloric. Feed intake (FI) was recorded and birds were weighed on days 21, 42, 63, 84, 105, and 123, and body weight gain (BWG) and feed to gain ratio (F:G) were calculated for each period. At day 123, five birds per pen (40 birds/trt) were sacrificed to determine carcass and parts yield. Feed cost savings per live bird

was determined for each of the experimental dietary treatments comparing their costs to the PC diet cost. Profit of live bird, chilled carcass, and breast meat were determined for each of the experimental dietary treatments and compared to the PC diet cost. At day 123, dietary treatments had no effect ($P > 0.05$) on FI or F:G ratio. The BWG of birds fed the IP and IP + 10% AA diets were not significantly different ($P > 0.05$) from the PC. However, the BWG of the IP + 5% AA treatment was significantly lower ($P < 0.05$) than the PC. A mixing error during the preparation of the IP + 5% AA feed for the period between 42 to 63 days negatively affected the growth rate of the birds, resulting in the poor performance of birds fed this treatment. The chilled carcass, deboned thighs and drums, wings, and scapula meat yields were not significantly different ($P > 0.05$) among the treatments. Breast meat yield (BMY) of birds fed the IP + 10% AA diets were not significantly different ($P > 0.05$) from the PC. However, the BMY of the treatments IP and IP + 5% AA were significantly lower ($P < 0.05$) than the PC. Turkeys fed the PC diets presented the highest significant ($P < 0.05$) feed costs per live bird. The PC treatment presented the lowest significant ($P < 0.05$) profit on feed per live bird and per chilled carcass. The IP + 5% AA treatment presented the lowest significant ($P < 0.05$) profit on feed per breast meat. The IP + 10% AA presented the highest significant ($P < 0.05$) profit on feed per live bird, per chilled carcass, and per breast meat. The profit differences between the dietary treatments IP + 10% AA and PC were US$ 0.47/ live bird, US$ 0.49/ chilled carcass, and US$ 0.30/ breast meat. These results indicate that a low CP diet formulated with a 10% margin safety with respect to the minimum recommended levels of digestible

AA, did not affect performance, carcass, or meat yield, and resulted in significantly higher revenues as compared with an industry standard diet.

INTRODUCTION

In general, feed costs account for about two-thirds of the cost of poultry production, and minimizing these costs without impairing performance of the birds is a major goal for nutritionists. Currently, feeding male turkeys to market weight – 18 to 21 kg per bird – is very expensive because of high grain prices. However, least cost diets are not necessarily the most cost effective diets. A low cost diet that reduces turkey performance may reduce returns if performance or breast meat yield does not reach expected results.

The NRC (1994) recommends five different diets for turkeys from hatch to 20 weeks of age, feeding each diet for 4 weeks. Ideally, a turkey fed for 18 weeks should receive 126 different diets, a different diet for each day. The number of diets to be included in a feeding program is a practical decision depending on the ability of the feed mill and the turkey grower to manage the number of feeds that can be produced. An increase in the number of diets is one approach to reduce feed costs. With this approach birds are fed the exact nutrient needs for maintenance and muscle deposition thereby reducing the production cost. In order to provide the exact nutrient needs according to the age, it is necessary to determine the nutrient requirements for each phase.

Many studies have been conducted to determine nutrient requirements for turkeys, most of these were designed to determine the requirements for metabolizable energy (ME), crude protein (CP), total essential amino acids (AA), minerals, and vitamins. Typically, dietary ME increases with the age of birds, and dietary CP and AA concentrations decrease (NRC, 1994; Agri Stats, 2006). Metabolizable energy, CP and AA are major cost contributors to the diets, and must be supplied as the minimum necessary to optimize feed cost and efficient use of nutrients (Lemme et al., 2006).

Low CP diets supplemented with crystalline AA have been fed to turkeys. Some of these diets allowed birds to reach performance results similar to the high CP diets (Stas and Potter, 1982; Jackson et al., 1983; Jackson and Potter, 1987), whereas some of them did not (Klain et al., 1954; Ferguson, 1956; Leeson and Caston, 1991; Waldroup et al., 1997a,b). Corn and soybean meal (SBM) turkey diets with marginal levels of CP were fortified with commercially available supplements of Met and Lys: the most limiting AA in turkey feed (Waibel et al., 1995). Live performance and carcass yield of turkeys fed low CP diets may be compromised by marginal deficiencies of Val, Thr, Ile and Arg. However little research (Firman and Guaiume, 2006) has been conducted with diets formulated using the ideal protein (IP) concept, with minimum restriction based on digestible essential AA requirements, instead of on a CP basis.

The objective of this study was to evaluate the effects of diets formulated using the IP concept on production and economic performance of male turkeys fed from 1 to 18 weeks of age.

MATERIAL AND METHODS

General Procedures

Housing: A total of 700 1-day-old BUT Big-9 male poults were placed in a facility containing 32 floor pens on concrete with curtain-sided walls. The facility is located in Videira, SC, Brazil, and belongs to Perdigão Agroindustrial S/A, which generously supplied the poults, labor, and covered all other costs, except for the feed. Each floor pen measured 14 m^2, and contained one tube feeder, one bell waterer, and new soft-wood shavings. From day 1 to day 7, supplemental pan feeders were used in each pen to ensure good feed consumption at placement. Birds were maintained on a 23 hours constant-light schedule for the first week of age, decreasing to 12 hours daily up to 18 weeks of age. The facility was heated with one propane heater hood set in each pen. Birds were maintained in a ringed brooder area for two weeks and then allowed access to the remainder of the pen after that. All procedures were conducted in accordance with the University of Missouri Animal Care and Use Guidelines.

Trial Design: This 18 week trial was divided into six phases of three weeks each, except for the period between 7 and 21 days of age. The experiment was a complete randomized design with four treatments and pen designated as the experimental unit. At day 7, a total of 640 poults were randomized to four treatments with eight replicate pens per treatment, and each floor pen containing 20 poults.

Treatment Descriptions: The positive control (PC) diets were industry average diets based on Agri Stats (2006) data. The PC diets were formulated by restricting the minimum level of CP, and on a total AA basis. The experimental diets were formulated on a digestible AA basis using constraints based on previous results presented in this dissertation, with no minimum restriction on CP and using the ratio of the digestible AA to dLys (Table 7.1). In the IP formulation of the three experimental diets, the exact digestible AA requirements were used with 0, 5, or 10% AA safety factor (Table 7.2). Diets were formulated to be isocaloric and were based on corn, soybean meal, and poultry by-product meal (Tables 7.3 to 7.8). All digestibility values for the feed ingredients were obtained using an ileal digestibility procedure and young male poults (Chapter III in this dissertation), and data from Pierson et al., 1980, Parsons, 1982; Firman, 1992, Firman and Remus, 1993; NRC, 1994; Kluth and Rodehutscord, 2006; Adedokun et al., 2007.

Measurements: Feed intake (FI) was recorded and birds were weighed by pen at 21, 42, 63, 84, 105, and 123 days of age. The initial body weight was subtracted from the final body weight to determine body weight gain (BWG) of the birds in the three week periods, except for the period between days 7 and 21. Total feed intake (TFI) was determined by subtracting the feed left from the initial feed offered to the birds. Average feed intake (AFI) was adjusted for mortality to more accurately reflect the access of individual birds in a pen to feed during the testing period, using the following equation:

AFI = (TFI / TBD) * D,

where:

TFI = Total Feed Intake (kg), TBD = Total Bird Days (d), D = Duration of test period (d)

TBD = (# living birds/pen at the conclusion of the trial * D) + (# days which dead bird(s) had access to feed).

Feed to gain ratio (F:G) was calculated by dividing the AFI by the BWG.

At day 123, 8-hr fasted birds (five birds per pen – 40 birds/trt) were randomly selected, weighed, wing-banded, and transported to the Perdigão Agroindustrial S/A processing plant located in Carambeí, PR, Brazil. Birds were sacrificed to determine carcass and parts yield. After being bled, feathers removed, eviscerated and feet removed, each carcass was weighed. Because of the industrial processing, it was not possible to collect abdominal fat data. The carcasses were refrigerated in the chill air equalization tunnel for a period of 8 hours, and weighed again. The carcasses were then processed for parts collection and weights were recorded.

Parts collected were:

- breast: collected whole (*Pectoralis major* and *P. minor* together) with skin;
- thigh: collected and deboned, weighing the bone and the meat;
- drum: collected and deboned, weighing the bone and the meat;
- wings: collected whole (drummette, the middle, and end part of the wing);
- scapula meat (back meat on the base of the neck): collected whole;
- tail meat: cut from the carcass;
- neck: cut from the carcass;
- skeletal rack: weighed.

All carcass measurements were expressed as a percentage of the chilled carcass weight.

Economic Analyses. A Microsoft™ Excel program was designed to determine feed costs per metric ton (MT). The cumulative cost of feed per live bird was calculated by multiplying the average feed intake of each pen in each phase by the respective feed value. Feed cost savings (FCS) per live bird was determined for each of the experimental dietary treatments comparing their costs to the PC diet cost. Profit on feed per live bird was calculated by multiplying the pen average body weight of birds at day 123 by the market value of live bird then subtracting the cost of feed. Profit on feed per chilled carcass was calculated by multiplying the pen average body weight of birds at day 123 by the mean chilled carcass yield percentage – since there were no significant differences among dietary treatments – and multiplying the obtained value by the market value of chilled carcass then subtracting the cost of feed. Profit on feed per breast meat was calculated by multiplying the pen average chilled carcass by the percentage of breast meat yield of the respective treatment – because there were significant differences among dietary treatments – and multiplying the obtained value by the market value of breast meat then subtracting the cost of feed. Profit differences of live bird, chilled carcass, and breast meat were determined for each of the experimental dietary treatments comparing their costs to the PC diet cost. Grain feed ingredient prices were obtained from Agrolink (2008) in Paraná State (PR), Brazil, where the experimental diets were processed. The prices for other feed ingredients were obtained from Perdigão Agroindustrial S/A. feed mill. The prices were transformed to US$ using the exchange rate of Brazilian Reais R$ 1.70 to US$ 1.00 (July, 2008). Prices for market weight turkeys were obtained from Feedstuffs Market Watch (July, 2008). Live bird, carcass, and total breast meat (boneless) values were US$ 1.47, US$ 2.05 and US$ 3.79/kg, respectively.

Statistical Analyses. Data were analyzed as complete randomized design using the General Linear Models procedure of SAS (2003). All statements of significance are based on the 0.05 level of probability. For carcass data, bird served as the experimental unit, whereas pen was the experimental unit in the analyses of the performance and economic data.

RESULTS

Feed Intake

Feed intake of male turkeys fed PC, IP, IP + 5% AA, and IP + 10% AA diets from 1 to 18 weeks of age are presented in Table 7.9. From 1 to 3 weeks of age, FI of turkeys fed IP and IP + 5% AA diets were not significantly different from FI of turkeys fed the PC diet. However, FI of turkeys fed the IP + 10% AA diet was significantly higher than turkeys fed other treatment diets. From 1 to 6 weeks of age, FI of turkeys fed the PC diet was significantly higher than turkeys fed other treatment diets, whereas FI of turkeys fed the IP diet was significantly lower than turkeys fed the IP + 5% and IP + 10% AA. There was no significant difference in FI between turkeys fed the IP + 5% AA and IP + 10% AA diets.

From 1 to 9 weeks of age, FI of turkeys fed the PC diet was significantly higher than turkeys fed other treatment diets, and surprisingly FI of turkeys fed IP + 5% diet was significantly lower than turkeys fed other treatment diets. There were significant differences in FI between turkeys fed the IP and the IP + 10% AA with turkeys fed the IP + 10% AA diet consuming more feed that turkeys fed the IP diet. From 1 to 12 weeks of age, FI of turkeys fed the PC diet was significantly higher than turkeys fed the IP and IP + 5% AA diets, and FI of turkeys fed the IP + 5% diet was significantly lower than turkeys fed other treatment diets. There were no significant differences in FI between turkeys fed the IP and IP + 10% AA diets, and between PC and IP + 10%AA diets.

From 1 to 15 weeks of age, FI of turkeys fed the PC diet was significantly higher than turkeys fed the IP and IP + 5% AA diets, and FI of turkeys fed the IP + 5% AA diet was significantly lower than turkeys fed other treatment diets. There was no significant difference in FI between turkeys fed the PC and IP + 10% AA diets. However, from the period between 1 to 18 weeks of age, there were no significant differences among PC, IP and IP + 10% AA dietary treatments in cumulative FI. Feed intake of turkeys fed IP + 5% AA was significantly lower than turkeys fed other treatment diets.

Body Weight Gain

Body weight gain (BWG) of male turkeys fed PC, IP, IP + 5% AA, and IP + 10% AA diets from 1 to 18 weeks of age are presented in Table 7.10. From 1 to 3 weeks of age, BWG of turkeys fed the IP diet was not significantly different from BWG of turkeys fed the PC diet. However, BWG of turkeys fed IP + 10% AA was significantly higher than BWG of turkeys fed other treatment diets. From 1 to 6 weeks of age, BWG of turkeys fed the PC diet was significantly lower than BWG of turkeys fed the IP + 5% AA and IP + 10% AA diets, and BWG of turkeys fed the IP diet was significantly lower than turkeys fed other dietary treatments. There were no significant differences in BWG between turkeys fed the IP + 5% AA and IP + 10% AA diets.

From 1 to 9 weeks of age, there were no significant differences in BWG between turkeys fed the PC and IP + 10% AA diets, which presented the highest

BWG. However, BWG of turkeys fed IP was significantly lower than BWG of turkeys fed the PC and IP + 10% AA diets, and BWG of turkeys fed the IP + 5% diet was significantly lower than turkeys fed other treatment diets. From 1 to 12 weeks of age, BWG of turkeys fed the IP + 10% AA diet was significantly higher than turkeys fed other dietary treatment. However, BWG of turkeys fed the IP + 5% diet was significantly lower than turkeys fed other dietary treatments. There were no significant differences in BWG of turkeys fed the PC and IP diets.

From 1 to 15 weeks of age, there were no significant differences in BWG between turkeys fed the PC and IP + 10% AA diets, which presented the highest BWG. However, BWG of turkeys fed the IP diet was significantly lower than BWG of turkeys fed PC and IP + 10% AA diets, and BWG of turkeys fed IP + 5% diet was significantly lower than turkeys fed other dietary treatments. For the period between 1 to 18 weeks of age, there were no significant differences in BWG among turkeys fed the PC, IP, and IP + 10% AA diets. Body weight gain of turkeys fed the IP diet was not significantly different from BWG of turkeys fed the IP + 5% AA diet.

Feed to Gain Ratio

Feed to gain (F:G) ratio of male turkeys fed PC, IP, IP + 5% AA, and IP + 10% AA diets from 1 to 18 weeks of age are presented in Table 7.11. From 1 to 3 weeks of age, F:G ratio of turkeys fed the PC and the IP diets were not significantly different. There were no significant differences in F:G ratio of turkeys fed the IP + 5% AA and IP + 10% AA diets, and their F:G ratios were significantly lower than turkeys fed the other two dietary treatment. From 1 to 6 weeks of age, F:G ratio of turkeys fed the PC diet was significantly higher among all other dietary treatments, and F:G ratio of turkeys fed the IP diet was significantly higher than turkeys fed the other two IP treatments. There were no significant differences in F:G ratio of turkeys fed the IP + 5% AA and IP + 10% AA diets.

From 1 to 9 weeks of age, F:G ratio of turkeys fed the PC diet was significantly higher than turkeys fed the IP and IP + 10% AA. However, turkeys fed the IP + 5% AA diet had F:G ratio similar to that of turkeys fed the PC diet. There were no significant differences in F:G ratio of turkeys fed IP and IP + 10% AA diets. From 1 to 12 weeks of age, F:G ratio of turkeys fed the PC diet was significantly higher than that of turkeys fed other dietary treatments, and F:G ratio of turkeys fed the IP + 10% AA diet was the lowest among the dietary treatments. There was no significant difference in F:G ratio between turkeys fed the IP and IP + 5% AA diets.

From 1 to 15 weeks of age, turkeys fed the IP + 5% AA and IP + 10% AA diets had similar F:G ratio, and their F:G ratio were significantly lower than turkeys fed the PC diet. However, turkeys fed the IP diet had similar F:G ratio to that of turkeys fed the PC diet, and their F:G ratio was not significantly different from that of turkeys fed the IP + 10% AA diet. For the period between 1 to 18 weeks of age, there were no significant differences in F:G ratio of turkeys among dietary treatments.

Processing Measurements

Processing responses of male turkeys fed PC, IP, IP + 5% AA, and IP + 10% AA diets from 1 to 18 weeks of age are presented in Table 7.12. At 18 weeks of age, dietary treatments had no significant effect on chilled carcass yield, percentage of deboned thighs, deboned drums, wings, scapula meat, neck, and skeletal rack. However, there were treatment effects on breast meat yield (BMY) and percentage of tail. For BMY, there were no significant differences between PC and IP + 10% AA treatment diets. There were no significant differences in BMY between treatments IP and IP + 5% AA. However, these treatments gave the lowest BMY. Breast meat yield of turkeys fed the IP diet was not significant different from that of turkeys fed IP + 10% AA.

There were no significant differences in percentage of turkey tail among treatments PC, IP, and IP + 5%. However, percentage tail of turkeys fed IP + 10% was significantly lower among dietary treatments.

Economic Analyses

Feed costs of diets formulated on the IP concept were lower compared to the PC diet from 1 to 18 weeks of age, with the exception of the period between 6 and 9 weeks, where the price of the IP + 10% AA diet was higher than the PC diet (Figure 7.1).

Turkeys fed PC diets had the highest significant feed costs per live bird. The PC treatment presented the lowest significant profit on feed per live bird and per chilled carcass. The IP + 5% AA treatment presented the lowest significant profit on feed per breast meat. The IP + 10% AA presented the highest significant profit on feed per live bird, per chilled carcass, and per breast meat. The profit differences between the dietary treatments IP + 10% AA and PC were US$ 0.47/ live bird, US$ 0.49/ chilled carcass, and US$ 0.30/ breast meat (Table 7.13).

DISCUSSION

Total feed intake of turkeys fed either PC, IP, IP + 5% AA, or IP + 10% AA diets from 1 to 18 weeks were not different, averaging 39.21 kg/bird. This average feed intake is close to that observed in turkeys fed similar treatments by Firman and Guaiume (2006). The authors reported an average FI of 38.34 kg/bird from hatch to 18 weeks of age. Waldroup et al. (1997a) reported similar FI of turkeys fed 90% to 110% of NRC (1994) AA recommendations from hatch to 20 weeks of age. However, when turkeys were fed 90% to 115% of NRC (1994) AA recommendations from hatch to 18 weeks of age, Waldroup and England (2002) report an average FI of 34.74 kg/ bird. Havenstein et al. (2007) reported an average total FI of male turkeys of 40.44 kg/bird at 140 days of age, feeding seven dietary feeds for 2-week periods each from hatch to 98 days of age, and the finisher diet from day 99 to the end of the trial.

In the current study, turkeys fed the IP + 5% AA diet had much lower FI in the period between 6 and 9 weeks of age, because of a mistake during mixing of the feed. The diet was formulated to contain 24.86% CP, 1.21% dLys, 0.79% dTSAA, 0.76% dThr, and 0.89% dVal. However, the analyzed nutrient composition was actually 18.92% CP, 1.10% tLys, 0.74% tTSAA, 0.76% tThr, and 0.88% tVal. Unfortunately, the analyzed nutrient composition results were not available until after the feeding period was over. The mistake in the IP + 5% AA diet compromised the FI of turkeys for the period between 6 and 18 weeks. By the end of the study, the difference in total FI of birds fed PC and IP + 5% AA decreased, but they were still significantly different. A similar compensatory FI was observed by Auckland and Morris (1971), who fed low CP diets to turkeys from hatch to 6 weeks and thereafter fed recommended CP levels and reported a similar FI for turkeys fed the required CP levels at the end of the 20 week study period.

Body weight gain of the turkeys differed among the dietary treatments at 18 weeks of age. Turkeys fed the PC and IP + 10% AA diets had the highest BWG, averaging 16.94 kg/bird at day 123. Turkeys fed IP and IP + 5% AA diets had the lowest BWG, averaging 16.48 kg/bird at day 123, differing by 460 g from the average of the PC and IP + 10% AA diets. The average BWG of turkeys fed PC, IP, IP + 5%, and IP + 10% AA diets is close to that of turkeys fed similar treatments by Firman and Guaiume (2006). The authors reported average BWG of 15.79 kg/bird for the three top treatments from hatch to 18 weeks of age. In the current study, the genetic breed line was BUT Big-9, whereas in the Firman and Guaiume (2006) study, the genetic breed line was Nicholas White. Waldroup et al. (1997a) reported similar body weight (15.00 kg/bird) of turkeys fed 90% to 110% of NRC (1994) AA recommendations from hatch to 20 weeks of age. However, when turkeys were fed 95% to 115% of NRC (1994) AA recommendations from hatch to 18 weeks of age, Waldroup and England (2002) reported an average body weight of 14.02 kg/bird, feeding. More recently, Havenstein et al. (2007) fed seven dietary feeds for 2-week periods each from hatch to 98 days of age, and finisher diet from day 99 to the end of the trial and reported an average body weight of male turkeys of 15.54 kg/bird at 140 days of age,

Because of the feed mixing error during the IP + 5% AA diet preparation for the period between 6 and 9 weeks of age, there was a decrease in BWG of turkeys fed this dietary treatment. At 9 weeks of age, the difference between the IP + 5% and the average of the PC and IP + 10% AA diets was 684 g. After this period, differences from the top treatments were 845, 797, and 590 g at weeks 12, 15, and 18, respectively. The feed intake of turkeys fed the IP + 5% AA diet was 3.5% lower than birds fed the PC diet from 1 to 18 weeks, but they had a 4% depression in total BWG compared to birds fed other dietary treatments. Auckland and Morris (1971) reported that turkeys fed low CP diets from hatch to 6 weeks had the same FI of turkeys fed recommended CP levels, and the same body weight at 20 weeks of age. Clarke et al. (1993) reduced early growth in male turkeys by feeding different CP levels from days 8 to 56, and reported that only birds fed diets with 90% of the control CP diet had 123-day BW and F:G ratio values similar to those of control birds. In the current study, CP in the IP + 5% AA diet was only 76% of the formulated level for the period between 43 and 64 days of age.

Feed to gain ratio of turkeys fed PC, IP, IP + 5% AA, or IP + 10% AA diets from 1 to 18 weeks were not different, averaging 2.347. Firman and Guaiume (2006) fed male turkeys similar dietary treatments to those used in the current study and reported average FI and BWG similar to this study, and an average F:G ratio of 2.448. Waldroup et al. (1997a) reported similar F:G ratio (2.625) of turkeys fed 85% to 120% of NRC (1994) AA recommendations from hatch to 20 weeks of age. However, when Waldroup and England (2002) repeated a similar study, they reported an average F:G ratio of 2.493, feeding 90% to 115% NRC (1994) AA recommendations from hatch to 18 weeks of age. Havenstein et al. (2007) reported average F:G ratios of male turkeys of 2.314 and 2.638 at 112 and 140 days of age, respectively, feeding seven feeds for 2-

week periods each from hatch to 98 days of age, and a finisher diet from day 99 to the end of the study.

In the current trial, turkeys fed PC diets had the highest F:G ratio from hatch to 15 weeks of age, whereas turkeys fed IP + 10% AA diets had the lowest F:G ratio for the same period. Turkeys fed IP + 5% AA and IP + 10% AA diets had the lowest F:G ratio from hatch to 6 weeks of age. However, after 3 weeks of intake of a lower CP and AA diet, F:G ratio of turkeys fed IP + 5% AA worsened, only recovering at 15 weeks of age with compensatory growth (Auckland and Morris, 1971).

Comparing the performance results of Waldroup et al. (1997a) with the current study at same age, there is a noticeable increase in body weight of turkeys, and improvement in feed efficiency. This improvement in growth performance of turkeys compared to those in 1997 is most likely in part to improvements in genetics and nutrition.

There were no significant differences in chilled carcass yield among the treatments, and the average was 76.41%. Except for BMY and percentage of tail, there were no significant differences in other carcass parts yield among the treatments. Turkeys fed IP + 10% had similar BMY of turkeys fed the PC diet, and BMY of both treatments averaged 34.35%. However, BMY of turkeys fed IP and IP + 5% AA diets were lower (average of both treatments: 33.15%) compared to turkeys fed the PC diet. These results are in contrast to a previous report by Firman and Guaiume (2006) who reported no differences in part yields of turkeys fed diets similar to those used in the current study. However, a possible explanation for these contrasting results may be the depressed BWG of turkeys between 6 and 9 weeks of age.

Kidd et al. (1997) did not observe any differences in BMY at 18-weeks in male turkeys fed 100 or 92% NRC (1994) CP recommendations but supplemented with 105% NRC (1994) recommendations for TSAA, Lys, Thr, and Trp. However, 84 and 76% NRC (1994) CP treatments resulted in decreased BMY even though diets were supplemented with 0.1 and 0.2% L-Thr. Waldroup et al. (1997a,b) reported maximum BMY when turkeys were fed 105% of the NRC (1994) essential AA profile, and Waldroup et al. (1998b) reported increased BMY of turkeys fed 110 and 120% of the tLys (NRC, 1994) recommendations. Waldroup and England (2002) fed male turkeys 90 to 115% NRC (1994) AA recommendations, and observed maximum BMY of turkeys fed 105 to 115% NRC (1994) AA recommendations at 18 weeks of age. However, Rivas and Firman (1994) did not find significant differences in BMY of turkeys fed 100 or 115% NRC (1994) CP recommendations at 15 and 18 weeks of age. On the other hand, Weibel et al. (2000a) fed low CP diets to turkeys with adequate levels of Lys and Met and reported that 77 to 79% of NRC (1994) CP recommendations resulted in depressed body weight and BMY, and supplemental Thr provided a substantial improvement in body weight but not in BMY. In contrast, a combination of Thr, Ile, Val, Arg, and Trp completely prevent the depression in BW and partially improved BMY compared to 100% NRC (1994) CP recommendations. Lemme et al. (2004) fed low CP diets with constant AA levels to male turkeys from 14 to 140 days and reported that a reduction of 10% CP did not affected performance and carcass traits provided the diets contained the full range of essential AA.

In the formulation of IP, IP + 5%, and IP + 10% AA diets for turkeys from 1 to 18 weeks, valine (Val) was considered the third limiting AA to 12 weeks of age. The ratio of 0.74 dVal to dLys used was based on the values determined by Baker et al. (2002) for broiler chicken, even though Kamyab and Firman (1999) reported dVal requirement for female turkeys from 8 to 21 days to be 0.82%, which corresponds to a ratio of 0.61 dVal to dLys in their study. Threonine was considered the third limiting AA because of the increasing ratio of dThr to dLys after 12 weeks of age, probably because of an increase in maintenance requirement for Thr by turkeys (Ketelaars, 1987).

Feed cost savings occurred in all phases, but more significant cost savings occurred during the phases of high feed intake, for example, in the period between 15 and 18 weeks of age, the PC diet was US$ 8.20/MT more expensive than the IP + 10% AA diet. Firman and Guaiume (2006) reported cost savings of feed ranging from US$ 11.70 to US$ 18.73/MT using similar dietary treatments to those used in the current study.

Firman and Guaiume (2006) reported that turkeys fed an IP + 5% AA diet gave the best performance and economic returns compared to the other dietary treatments. In the current study, turkeys fed the IP + 10% AA diet had the best performance and economic returns when comparing profits on feed per live bird, feed per chilled carcass, and feed per breast meat. Applying these profits in a real situation of 26,000 poults housed, which is the average commercial flock size, profits can reach US$ 12,200/live flock, US$ 12,740/flock total chilled carcass, and US$ 7,800/flock total breast meat. However, if there had not been a significant reduction in BWG and BMY of turkeys fed treatment IP + 5% AA because of the feed mixing mistake between 6 and 9 weeks of age, it is possible that turkeys fed IP + 5% AA may have performed and had economic returns similar to that of the IP + 10% AA diet.

CONCLUSIONS

Overall, these results indicate that IP formulated diets based on digestible AA requirements are feasible for male turkeys fed from 1 to 18 weeks of age. The addition of a 10% safety margin on the essential AA achieved the best performance, resulting in significantly higher revenues, when compared to the standard industry formulated diet.

Table 7.1. Ideal protein amino acid ratios, compared to lysine, of formulated diets for male turkeys from 1 to 18 weeks of age (%).

AA	1 to 3 weeks	3 to 6 weeks	6 to 9 weeks	9 to 12 weeks	12 to 15 weeks	15 to 18 weeks
Lys	100	100	100	100	100	100
Met+Cis	66	66	66	66	66	66
Thr	60	60	60	60	62	64
Val	74	74	74	74	74	74
Arg	112	112	112	112	112	112
His	36	36	36	36	36	36
Ile	69	69	69	69	69	69
Leu	124	124	124	124	124	124
Phe+Tyr	105	105	105	105	105	105
Trp	16	16	16	16	16	16

Table 7.2. Amino acids constraints on Control and Ideal Protein (IP) based diets for male turkeys from 1 to 18 weeks of age (%).

1 to 3 weeks	Control (total)	IP (digestible)	IP+5% AA	IP+10% AA
Lysine	1.86	1.39	1.46	1.52
Met+Cys	1.23	0.92	0.96	1.00
Threonine	1.14	0.83	0.88	0.91
Valine	1.30	1.03	1.08	1.12
3 to 6 weeks	Control (total)	IP (digestible)	IP+5% AA	IP+10% AA
Lysine	1.77	1.29	1.35	1.42
Met+Cys	1.18	0.85	0.89	0.93
Threonine	1.09	0.77	0.81	0.85
Valine	1.25	0.95	1.00	1.05
6 to 9 weeks	Control (total)	IP (digestible)	IP+5% AA	IP+10% AA
Lysine	1.58	1.15	1.21	1.26
Met+Cys	1.10	0.76	0.79	0.83
Threonine	0.97	0.69	0.72	0.76
Valine	1.13	0.85	0.89	0.93
9 to 12 weeks	Control (total)	IP (digestible)	IP+5% AA	IP+10% AA
Lysine	1.34	1.05	1.10	1.16
Met+Cys	0.90	0.69	0.73	0.76
Threonine	0.84	0.63	0.66	0.69
Valine	0.99	0.78	0.81	0.85

Table 7.2. (Continued)

12 to 15 weeks	Control (total)	IP (digestible)	IP+5% AA	IP+10% AA
Met+Cys	0.83	0.54	0.56	0.59
Threonine	0.71	0.51	0.53	0.56
Valine	0.84	0.60	0.63	0.66
15 to 18 weeks	Control (total)	IP (digestible)	IP+5% AA	IP+10% AA
Lysine	1.01	0.70	0.74	0.77
Met+Cys	0.72	0.46	0.49	0.51
Threonine	0.65	0.45	0.47	0.49
Valine	0.72	0.52	0.55	0.57

Table 7.3. Composition of Positive Control (PC) and the Ideal Protein (IP) plus 0, 5, or 10% amino acids safety factor diets for male turkeys from 1 to 3 weeks of age[1].

Ingredients (%)	PC	IP	IP+5%	IP+10%
Corn	32.316	39.189	34.946	32.114
Soybean meal	53.125	47.993	51.635	54.137
Poultry by-prod. meal	3.000	3.000	3.000	3.000
Dicalcium phosphate	3.109	2.739	2.710	2.691
Limestone	1.390	1.423	1.408	1.398
Salt	0.475	0.500	0.500	0.500
Soybean oil	5.466	4.400	5.000	5.450
Lysine-HCl	0.303	0.073	0.060	0.062
DL-Methionine	0.355	0.290	0.344	0.251
L-Threonine	0.038	0.000	0.000	0.000
Choline chloride	0.070	0.070	0.070	0.070
Trace mineral premix[2]	0.100	0.100	0.100	0.100
Vitamin premix[3]	0.150	0.150	0.150	0.150
Sodium bicarbonate	0.101	0.074	0.076	0.077
Calculated composition				
ME (kcal/kg)	3,000	3,000	3,000	3,000
Crude protein (%)	29.76	28.55	30.00	30.95
Calcium (%)	1.49	1.40	1.40	1.40
Av. Phosphorus (%)	0.76	0.70	0.70	0.70
dLys (%)	1.86 (1.65)	1.39	1.46	1.52

Table 7.3. (Continued)

Ingredients (%)	PC	IP	IP+5%	IP+10%
dTSAA (%)	1.23 (1.09)	1.02	1.10	1.04
dThr (%)	1.14 (0.95)	0.88	0.92	0.96
dVal (%)	1.30 (1.12)	1.03	1.08	1.12
dArg (%)	1.92 (1.72)	1.70	1.80	1.86
dHis (%)	0.68 (0.60)	0.59	0.62	0.64
dIle (%)	1.16 (0.99)	1.00	1.06	1.10
dLeu (%)	2.14 (1.91)	1.87	1.94	2.00
dTAAA (%)	2.14 (1.87)	1.98	2.08	2.16
dTrp (%)	0.35 (0.29)	0.30	0.31	0.33
Analyzed composition				
Crude protein (%)	29.65	27.91	29.33	29.65
tLys (%)	1.77	1.57	1.59	1.77
tTSAA (%)	1.19	1.02	1.00	1.19
tThr (%)	1.13	1.01	1.01	1.13
tVal (%)	1.33	1.15	1.16	1.33
Cost (US$/MT)	360.45	341.74	350.04	353.06

[1]PC diet was formulated on total AA basis, and the digestibility coefficients were applied to the ingredients to calculate the digestible AA content in the diet, presented in the brackets.
[2]Trace mineral premix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_4.7H_2O$); Cu, 20 ($CuSO_4$); I, 2.0 (ethylenediamine dihydroiodide); Se, 0.4 (Na_2SeO_3).
[3]Vitamin premix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg; monensin sodium, 75 mg.

Table 7.4. Composition of Positive Control (PC) and the Ideal Protein (IP) plus 0, 5, or 10% amino acids safety factor diets for male turkeys from 3 to 6 weeks of age[1].

Ingredients (%)	PC	IP	IP+5%	IP+10%
Corn	36.365	46.215	42.841	38.956
Soybean meal	47.474	40.141	43.082	46.394
Poultry by-prod. meal	3.000	3.000	3.000	3.000
Dicalcium phosphate	2.715	2.605	2.511	2.555
Limestone	1.209	0.837	0.866	0.815
Salt	0.446	0.500	0.500	0.500
Soybean oil	6.250	4.714	5.189	5.767
Lysine-HCl	0.403	0.174	0.173	0.162
DL-Methionine	0.392	0.207	0.226	0.242
L-Threonine	0.081	0.002	0.003	0.000
Choline chloride	0.070	0.070	0.070	0.070
Trace mineral premix[2]	0.100	0.100	0.100	0.100
Vitamin premix[3]	0.150	0.150	0.150	0.150
Pellet binder	1.250	1.250	1.250	1.250
Sodium bicarbonate	0.095	0.036	0.038	0.039
Calculated analysis				
ME (kcal/kg)	3,100	3,100	3,100	3,100
Crude protein (%)	27.50	24.46	25.57	26.79
Calcium (%)	1.39	1.20	1.20	1.20
Av. Phosphorus (%)	0.68	0.65	0.65	0.65

Table 7.4. (Continued)

Ingredients (%)	PC	IP	IP+5%	IP+10%
dLys (%)	1.78 (1.59)	1.29	1.35	1.42
dTSAA (%)	1.18 (1.05)	0.85	0.89	0.93
dThr (%)	1.09 (0.91)	0.77	0.81	0.85
dVal (%)	1.25 (1.07)	0.95	1.00	1.05
dArg (%)	1.87 (1.67)	1.52	1.60	1.69
dHis (%)	0.72 (0.64)	0.58	0.60	0.63
dIle (%)	1.13 (0.97)	0.90	0.95	1.00
dLeu (%)	2.12 (1.89)	1.76	1.82	1.88
dTAAA (%)	1.95 (1.71)	1.74	1.83	1.92
dTrp (%)	0.32 (0.27)	0.24	0.26	0.27
Analyzed composition				
Crude protein (%)	29.01	23.82	25.61	26.21
tLys (%)	1.71	1.41	1.50	1.55
tTSAA (%)	1.11	0.92	0.99	0.94
tThr (%)	1.04	0.92	0.98	0.98
tVal (%)	1.14	1.10	1.17	1.17
Cost (US$/MT)	369.76	343.39	349.29	356.52

[1]PC diet was formulated on total AA basis, and the digestibility coefficients were applied to the ingredients to calculate the digestible AA content in the diet, presented in the brackets.
[2]Trace mineral premix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_4.7H_2O$); Cu, 20 ($CuSO_4$); I, 2.0 (ethylenediamine dihydroiodide); Se, 0.4 (Na_2SeO_3).
[3]Vitamin premix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg; monensin sodium, 75 mg.

Table 7.5. Composition of Positive Control (PC) and the Ideal Protein (IP) plus 0, 5, or 10% amino acids safety factor diets for male turkeys from 6 to 9 weeks of age[1].

Ingredients (%)	PC	IP	IP+5%	IP+10%
Corn	45.858	49.657	46.295	43.032
Soybean meal	37.131	36.376	39.281	42.095
Poultry by-prod. meal	6.000	3.000	3.000	3.000
Dicalcium phosphate	1.934	2.637	2.614	2.591
Limestone	1.232	0.986	0.975	0.964
Salt	0.444	0.500	0.500	0.500
Soybean oil	5.098	5.067	5.556	6.030
Lysine-HCl	0.332	0.107	0.096	0.089
DL-Methionine	0.364	0.135	0.147	0.161
L-Threonine	0.057	0.000	0.000	0.000
Choline chloride	0.050	0.050	0.050	0.050
Trace mineral premix[2]	0.100	0.100	0.100	0.100
Vitamin premix[3]	0.100	0.100	0.100	0.100
Pellet binder	1.250	1.250	1.250	1.250
Sodium bicarbonate	0.050	0.035	0.036	0.038
Calculated analysis				
Crude protein (%)	25.25	23.71	24.86	25.98
ME (kcal/kg)	3,150	3,150	3,150	3,150
Calcium (%)	1.20	1.20	1.20	1.20
Av. Phosphorus (%)	0.62	0.65	0.65	0.65

Table 7.5. (Continued)

Ingredients (%)	PC	IP	IP+5%	IP+10%
dLys (%)	1.58 (1.39)	1.15	1.21	1.26
dTSAA (%)	1.10 (0.97)	0.76	0.79	0.83
dThr (%)	0.97 (0.80)	0.72	0.76	0.79
dVal (%)	1.13 (0.95)	0.85	0.89	0.93
dArg (%)	1.68 (1.49)	1.38	1.46	1.53
dHis (%)	0.64 (0.57)	0.49	0.51	0.53
dIle (%)	1.01 (0.87)	0.81	0.86	0.90
dLeu (%)	1.97 (1.77)	1.60	1.66	1.72
dTAAA (%)	1.71 (1.50)	1.63	1.71	1.79
dTrp (%)	0.28 (0.23)	0.24	0.25	0.26
Analyzed composition				
Crude protein (%)	26.29	23.06	18.92	25.29
tLys (%)	1.50	1.37	1.10	1.31
tTSAA (%)	0.87	0.87	0.74	0.85
tThr (%)	0.98	0.90	0.76	0.87
tVal (%)	1.13	0.95	0.88	1.01
Cost (US$/MT)	360.57	351.43	356.77	362.05

[1]PC diet was formulated on total AA basis, and the digestibility coefficients were applied to the ingredients to calculate the digestible AA content in the diet, presented in the brackets.
[2]Trace mineral premix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_4.7H_2O$); Cu, 20 ($CuSO_4$); I, 2.0 (ethylenediamine dihydroiodide); Se, 0.4 (Na_2SeO_3).
[3]Vitamin premix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg; monensin sodium, 75 mg.

Table 7.6. Composition of Positive Control (PC) and the Ideal Protein (IP) plus 0, 5, or 10% amino acids safety factor diets for male turkeys from 9 to 12 weeks of age[1].

Ingredients (%)	PC	IP	IP+5%	IP+10%
Corn	51.612	58.313	55.436	52.387
Soybean meal	34.113	28.815	31.292	33.922
Poultry by-prod. meal	3.000	3.000	3.000	3.000
Dicalcium phosphate	2.099	2.085	2.066	2.045
Limestone	1.258	1.074	1.064	1.054
Salt	0.497	0.514	0.515	0.517
Soybean oil	5.386	4.349	4.766	5.208
Lysine-HCl	0.247	0.192	0.189	0.183
DL-Methionine	0.232	0.142	0.158	0.172
L-Threonine	0.028	0.007	0.007	0.005
Choline chloride	0.040	0.040	0.040	0.040
Trace mineral premix[2]	0.100	0.100	0.100	0.100
Vitamin premix[3]	0.100	0.100	0.100	0.100
Pellet binder	1.250	1.250	1.250	1.250
Sodium bicarbonate	0.038	0.017	0.018	0.017
Calculated analysis				
ME (kcal/kg)	3,200	3,200	3,200	3,200
Crude protein (%)	22.21	20.15	21.08	22.05
Calcium (%)	1.19	1.10	1.10	1.10
Av. Phosphorus (%)	0.56	0.55	0.55	0.55

Table 7.6. (Continued)

Ingredients (%)	PC	IP	IP+5%	IP+10%
dLys (%)	1.34 (1.18)	1.05	1.10	1.15
dTSAA (%)	0.90 (0.79)	0.69	0.73	0.76
dThr (%)	0.84 (0.69)	0.63	0.66	0.69
dVal (%)	1.01 (0.86)	0.78	0.81	0.85
dArg (%)	1.47 (1.31)	1.21	1.28	1.35
dHis (%)	0.59 (0.52)	0.48	0.50	0.52
dIle (%)	0.91 (0.78)	0.72	0.76	0.80
dLeu (%)	1.82 (1.64)	1.53	1.58	1.63
dTAAA (%)	1.56 (1.36)	1.41	1.48	1.56
dTrp (%)	0.25 (0.21)	0.19	0.20	0.22
Analyzed composition				
Crude protein (%)	21.68	20.43	20.91	21.37
tLys (%)	1.28	1.21	1.22	1.23
tTSAA (%)	0.84	0.77	0.81	0.82
tThr (%)	0.81	0.80	0.80	0.82
tVal (%)	0.93	0.84	0.95	0.94
Cost (US$/MT)	339.56	321.08	327.84	334.88

[1]PC diet was formulated on total AA basis, and the digestibility coefficients were applied to the ingredients to calculate the digestible AA content in the diet, presented in the brackets.
[2]Trace mineral premix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_4.7H_2O$); Cu, 20 ($CuSO_4$); I, 2.0 (ethylenediamine dihydroiodide); Se, 0.4 (Na_2SeO_3).
[3]Vitamin premix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg; monensin sodium, 75 mg.

Table 7.7. Composition of Positive Control (PC) and the Ideal Protein (IP) plus 0, 5, or 10% amino acids safety factor diets for male turkeys from 12 to 15 weeks of age[1].

Ingredients (%)	PC	IP	IP+5%	IP+10%
Corn	63.794	70.832	68.902	66.813
Soybean meal	24.493	17.941	19.583	21.376
Poultry by-prod. meal	3.000	3.000	3.000	3.000
Dicalcium phosphate	1.713	1.900	1.888	1.873
Limestone	1.069	0.999	0.992	0.985
Salt	0.481	0.500	0.511	0.511
Soybean oil	3.327	3.027	3.300	3.600
Lysine-HCl	0.298	0.186	0.204	0.205
DL-Methionine	0.240	0.072	0.087	0.100
L-Threonine	0.037	0.015	0.017	0.019
Choline chloride	0.050	0.050	0.050	0.050
Trace mineral premix[2]	0.100	0.100	0.100	0.100
Vitamin premix[3]	0.100	0.100	0.100	0.100
Pellet binder	1.250	1.250	1.250	1.250
Sodium bicarbonate	0.049	0.027	0.016	0.018
Calculated analysis				
ME (kcal/kg)	3,240	3,240	3,240	3,240
Crude protein (%)	18.80	16.06	16.70	17.87
Calcium (%)	1.01	1.00	1.00	1.00
Av. Phosphorus (%)	0.48	0.50	0.50	0.50

Table 7.7. (Continued)

Ingredients (%)	PC	IP	IP+5%	IP+10%
dLys (%)	1.16 (1.02)	0.81	0.86	0.90
dTSAA (%)	0.83 (0.73)	0.54	0.56	0.59
dThr (%)	0.71 (0.59)	0.51	0.53	0.56
dVal (%)	0.84 (0.71)	0.61	0.64	0.66
dArg (%)	1.19 (1.06)	0.91	0.96	1.01
dHis (%)	0.50 (0.44)	0.37	0.40	0.41
dIle (%)	0.75 (0.64)	0.55	0.58	0.61
dLeu (%)	1.62 (1.46)	1.36	1.35	1.39
dTAAA (%)	1.28 (1.12)	1.09	1.14	1.19
dTrp (%)	0.20 (0.16)	0.14	0.15	0.16
Analyzed composition				
Crude protein (%)	18.53	15.29	17.06	16.87
tLys (%)	1.12	0.85	0.92	0.88
tTSAA (%)	0.84	0.56	0.60	0.62
tThr (%)	0.72	0.59	0.63	0.64
tVal (%)	0.81	0.52	0.54	0.55
Cost (US$/MT)	309.20	295.62	300.35	305.27

[1]PC diet was formulated on total AA basis, and the digestibility coefficients were applied to the ingredients to calculate the digestible AA content in the diet, presented in the brackets.
[2]Trace mineral premix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_4.7H_2O$); Cu, 20 ($CuSO_4$); I, 2.0 (ethylenediamine dihydroiodide); Se, 0.4 (Na_2SeO_3).
[3]Vitamin premix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg.

Table 7.8. Composition of Positive Control (PC) and the Ideal Protein (IP) plus 0, 5, or 10% amino acids safety factor diets for male turkeys from 15 to 18 weeks of age[1].

Ingredients (%)	PC	IP	IP+5%	IP+10%
Corn	68.672	75.554	73.849	72.152
Soybean meal	19.085	13.351	14.810	16.261
Poultry by-prod. meal	3.000	3.000	3.000	3.000
Dicalcium phosphate	1.623	1.667	1.656	1.645
Limestone	0.874	0.897	0.891	0.885
Salt	0.487	0.518	0.517	0.500
Soybean oil	4.113	3.180	3.424	3.667
Lysine-HCl	0.282	0.186	0.190	0.194
DL-Methionine	0.187	0.038	0.049	0.061
L-Threonine	0.061	0.026	0.030	0.034
Choline chloride	0.050	0.050	0.050	0.050
Trace mineral premix[2]	0.100	0.100	0.100	0.100
Vitamin premix[3]	0.100	0.100	0.100	0.100
Pellet binder	1.250	1.250	1.250	1.250
Sodium bicarbonate	0.116	0.082	0.084	0.101
Calculated analysis				
ME (kcal/kg)	3,300	3,300	3,300	3,300
Crude protein (%)	16.65	14.29	14.85	15.40
Calcium (%)	0.90	0.90	0.90	0.87
Av. Phosphorus (%)	0.45	0.45	0.45	0.63

Table 7.8. (Continued)

Ingredients (%)	PC	IP	IP+5%	IP+10%
dLys (%)	1.01 (0.89)	0.70	0.74	0.22
dTSAA (%)	0.72 (0.63)	0.46	0.49	0.40
dThr (%)	0.65 (0.54)	0.45	0.47	0.58
dVal (%)	0.74 (0.63)	0.54	0.56	0.63
dArg (%)	1.02 (0.91)	0.79	0.83	0.61
dHis (%)	0.45 (0.39)	0.35	0.36	1.28
dIle (%)	0.65 (0.56)	0.48	0.51	0.77
dLeu (%)	1.48 (1.34)	1.22	1.25	0.29
dTAAA (%)	1.12 (0.98)	0.96	1.00	1.04
dTrp (%)	0.17 (0.14)	0.12	0.13	0.87
Analyzed composition				
Crude protein (%)	15.51	13.83	15.29	14.84
tLys (%)	0.84	0.79	0.77	0.85
tTSAA (%)	0.59	0.50	0.51	0.56
tThr (%)	0.57	0.54	0.59	0.61
tVal (%)	0.61	0.61	0.50	0.69
Cost (US$/MT)	306.53	290.07	294.18	298.33

[1]PC diet was formulated on total AA basis, and the digestibility coefficients were applied to the ingredients to calculate the digestible AA content in the diet, presented in the brackets.
[2]Trace mineral premix provided (mg/kg diet): Mn, 110 (MnO_2); Zn, 110 ($ZnSO_4$); Fe, 60 ($FeSO_4.7H_2O$); Cu, 20 ($CuSO_4$); I, 2.0 (ethylenediamine dihydroiodide); Se, 0.4 (Na_2SeO_3).
[3]Vitamin premix supplied (UI or mg/kg feed):vitamin A (retinyl acetate), 13,200 IU; cholecalciferol, 5,775 IU; vitamin E (dl-α-tocoferyl acetate), 21 IU; niacin, 82.5 mg; calcium panthotenate, 25 mg; riboflavin, 10 mg; pyridoxine, 3.3 mg; menadione sodium bisulfite, 2.5 mg; folic acid, 2.1 mg; thiamin mononitrate, 1.7 mg; biotin, 0.33 mg; cyanocobalamin, 20 µg; and ethoxyquin, 83 mg.

Table 7.9. Feed intake (kg) of male turkeys fed Positive Control (PC) and the Ideal Protein (IP) plus 0, 5, or 10% amino acids safety factor diets from 1 to 18 weeks of age[1].

	3 weeks	6 weeks	9 weeks	12 weeks	15 weeks	18 weeks
PC	0.668^{b}	3.669^{a}	9.715^{a}	18.402^{a}	28.918^{a}	39.765^{a}
IP	0.667^{b}	3.194^{c}	8.789^{c}	17.691^{b}	27.835^{b}	39.331^{a}
IP + 5%	0.669^{b}	3.406^{b}	8.456^{d}	16.655^{c}	26.639^{c}	38.181^{b}
IP + 10%	0.680^{a}	3.404^{b}	9.130^{b}	18.042^{ab}	28.485^{a}	39.553^{a}
SEM	0.004	0.028	0.093	0.160	0.214	0.293

[a-d]Values in columns with no common superscript differ significantly (P < 0.05).
[1]Data are means of eight replicate pens of 20 turkeys per pen.

Table 7.10. Body weight gain (kg) of male turkeys fed Positive Control (PC) and the Ideal Protein (IP) plus 0, 5, or 10% amino acids safety factor diets from 1 to 18 weeks of age[1].

	3 weeks	6 weeks	9 weeks	12 weeks	15 weeks	18 weeks
PC	0.538^{c}	2.324^{b}	5.743^{a}	9.708^{b}	13.470^{a}	16.874^{ab}
IP	0.540^{c}	2.220^{c}	5.489^{b}	9.597^{b}	13.075^{b}	16.621^{bc}
IP + 5%	0.550^{b}	2.399^{a}	5.070^{c}	8.996^{c}	12.724^{c}	16.345^{c}
IP + 10%	0.562^{a}	2.402^{a}	5.765^{a}	9.974^{a}	13.571^{a}	16.996^{a}
SEM	0.003	0.024	0.070	0.077	0.112	0.129

$^{a\text{-}c}$Values in columns with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of eight replicate pens of 20 turkeys per pen.

Table 7.11. Feed to gain ratio (kg:kg) adjusted for mortality of male turkeys fed Positive Control (PC) and the Ideal Protein (IP) plus 0, 5, or 10% amino acids safety factor diets from 1 to 18 weeks of age[1].

	3 weeks weight	6 weeks weight	9 weeks weight	12 weeks weight	15 weeks weight	18 weeks weight
PC	1.242[b]	1.579[c]	1.692[b]	1.896[c]	2.147[c]	2.356
IP	1.236[b]	1.439[b]	1.601[a]	1.844[b]	2.130[bc]	2.367
IP + 5%	1.216[a]	1.420[a]	1.670[b]	1.851[b]	2.094[a]	2.336
IP + 10%	1.210[a]	1.417[a]	1.584[a]	1.809[a]	2.100[ab]	2.328
SEM	0.005	0.006	0.012	0.008	0.011	0.014

[a-c]Values in columns with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of eight replicate pens of 20 turkeys per pen.

Table 7.12. Relative processing yields (%) of male turkeys fed Positive Control (PC) and the Ideal Protein (IP) plus 0, 5, or 10% amino acids safety factor diets from 1 to 18 weeks of age[1].

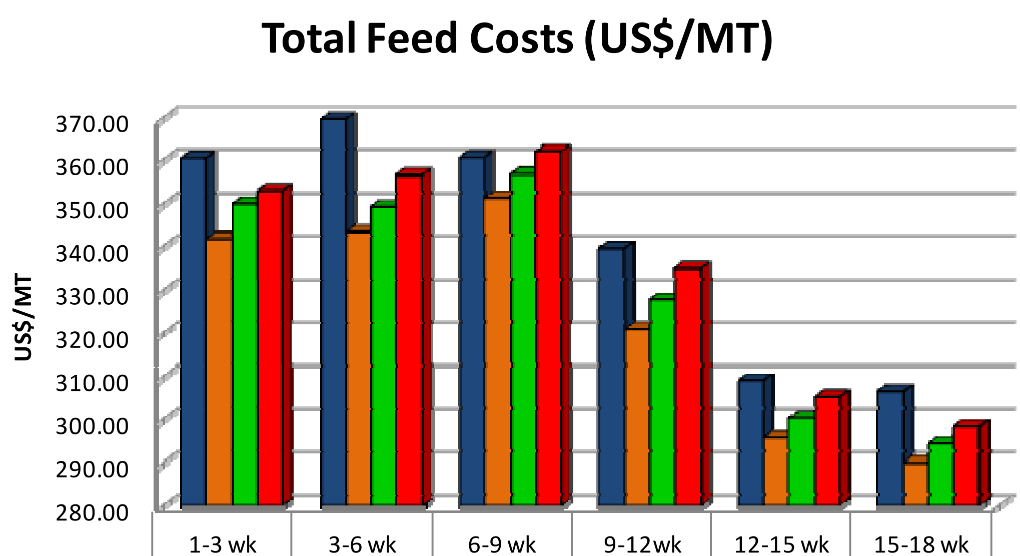
	PC	IP	IP+5%	IP+10%	SEM
Chilled carcass	76.51	76.41	76.07	76.63	0.083
Breast meat	34.36[a]	33.50[bc]	32.79[c]	34.13[ab]	0.117
Deboned thighs	15.92	16.33	16.39	16.04	0.077
Deboned drums	9.67	9.74	10.10	9.84	0.065
Wings	10.56	10.67	10.74	10.75	0.039
Scapula meat	2.94	3.07	2.96	2.89	0.031
Neck	5.07	4.97	4.98	4.95	0.056
Tail	1.94[a]	1.95[a]	1.93[a]	1.84[b]	0.018
Skeletal rack	15.59	15.83	15.93	15.48	0.073

[a-c]Values in rows with no common superscript differ significantly ($P < 0.05$).
[1]Data are means of 40 carcasses per treatment.

Table 7.13. Effects of Ideal Protein (IP) formulation diets on economic performance of male turkeys from 1 to 18 weeks of age[1].

Economic values, US$[2]	PC	IP	IP+5%	IP+10%
Feed cost/ live bird	13.05[a]	12.25[c]	12.07[c]	12.76[b]
Feed cost savings/ live bird[3]		0.80	0.98	0.29
Profit on feed/ live bird	11.95[b]	12.38[a]	12.15[ab]	12.42[a]
Profit differences/ live bird[3]		0.43	0.20	0.47
Profit on feed/ chilled carcass	13.59[b]	13.99[ab]	13.74[ab]	14.07[a]
Profit differences/ chilled carcass[3]		0.40	0.15	0.49
Profit on feed/ breast meat	3.87[b]	4.00[ab]	3.57[c]	4.17[a]
Profit differences/ breast meat[3]		0.13	-0.30	0.30

[1]Average BW at 18 weeks = 16.84 kg; average carcass yield = 76.41%; average BMY relative to chilled carcass = 33.72%;
[2]Economic values: 18 wk live male turkey = US$ 1.47/kg; carcass = US$ 2.05/kg; breast meat = US$ 3.79/kg (Feedstuffs, July 07th, 2008). Feed ingredient costs according to the Brazilian market adjusted every each production batch.
[3]Feed cost savings and profits relative to PC treatment.



	1-3 wk	3-6 wk	6-9 wk	9-12wk	12-15 wk	15-18 wk
PC	360.45	369.76	360.57	339.56	309.20	306.53
IP	341.74	343.39	351.43	321.08	295.62	290.07
IP+5%	350.04	349.29	356.77	327.84	300.35	294.18
IP+10%	353.06	356.52	362.05	334.88	305.27	298.33

Figure 7.1. Total feed costs of male turkeys fed Positive Control (PC) and Ideal Protein (IP) diets plus 0%, 5%, or 10% amino acids safety factor from 1 to 18 weeks of age[1].

[1]Grain feed ingredient prices were obtained from Agrolink (2008) in Paraná State (PR), Brazil. Prices for other feed ingredients were obtained from Perdigão Agroindustrial S/A feed mill. Prices were transformed to US$ using the exchange rate of Brazilian Reais R$ 1.70 to US$ 1.00 (July, 2008).

CHAPTER VIII

SUMMARY AND CONCLUSIONS

A study was conducted to determine the digestible lysine (dLys) and digestible threonine (dThr) requirements of male turkeys fed dietary treatments from 1 to 21 weeks. The study was divided into seven experiments each of three weeks duration, with data collected during the last two weeks of each period. Body weight gain and feed to gain were the response variables used to determine the requirements. Using digestibility coefficients of 85% for total Lys and 82% for total Thr on NRC (1994), the dLys and dThr requirements determined in this study are similar to NRC (1994) recommendations, as summarized in Table 8.1.

Table 8.1. Digestible lysine (dLys) and threonine (dThr) requirements, NRC (1994) recommendations adjusted for digestibility, and ratios of dThr to dLys for male turkeys from 8 to 147 days of age.

AA	8 to 21 days	29 to 42 days	50 to 63 days	71 to 84 days	92 to 105 days	113 to 126 days	134 to 147 days
	115 g	900 g	3.0 kg	6.0 kg	10 kg	14 kg	17 kg
dLys	1.39	1.29	1.15	1.03	0.81	0.70	0.58
NRC[1]	1.36	1.28	1.10	0.85	0.85	0.68	0.55
dThr	0.81	0.76	0.63	0.58	0.50	0.45	0.40
NRC[2]	0.82	0.78	0.65	0.62	0.62	0.49	0.41
dThr/ dLys ratio	0.58	0.59	0.55	0.56	0.62	0.64	0.69

[1]NRC (1994) recommendations for dLys using a digestibility coefficient of 85%.
[2]NRC (1994) recommendations for dThr using a digestibility coefficient of 82%.

A second study was then conducted to validate the determined digestible amino acids (AA) requirements. Diets were formulated using dLys and dThr requirements and the ideal protein (IP) concept. The dietary treatments included: an industry standard diet; a low crude protein (CP) diets that was formulated to meet minimum requirements for dLys and dThr; and the low CP diet plus additional safety margins of 5 and 10% above the minimum AA requirements.

Performance of turkeys fed the minimum requirements using the IP concept and a 5% safety margin was not similar to the turkeys fed the industry standard diet. However, turkeys fed the diet with a 10% safety margin over the minimum requirements performed as well as the birds fed industry standard diets. The cost of the 10% safety margin diet was significantly lower than the industry standard diet resulting in significantly higher revenues. In addition, the 10% safety margin diet resulted in a significant reduction in nitrogen excretion by birds fed this diet. The failure of the 5% safety margin to perform as well as the industry standard diet was most likely due to the feed mixing error that occurred during the 6 – 9 week period. Future studies will determine if a 5% safety margin diet will perform as well as an industry standard diets.

The major difference between the IP and the industry standard diet was the restriction placed on the minimum percentage of CP in the formulation. This study proves that well balanced turkey diets do not have be based solely on a CP basis, but can also be based on the balance of the digestible AA profile.

The minimum requirements for dLys and dThr determined in this study will provide invaluable data for application of the IP concept in the turkey industry.

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VITA

The author of this dissertation, Leonardo Bretas Linares, was born in Pratápolis, Minas Gerais, Brazil. He obtained his Bachelor's degree in Animal Sciences at Universidade Estadual Paulista – UNESP – Botucatu campus in December 1993. In May 1994, he was hired by Perdigão Agroindustrial S/A. as a feed mill quality controller. In 1996, he assumed the supervision of one of the company's breeder farms. In January 2001, the author was accepted as a Master student under the supervision of Dr. David Ledoux at the University of Missouri, Columbia, USA, where he obtained his Master's degree in Animal Sciences in December 2002. During his Master's program, Leonardo worked with low phytic acid grains for broiler chicken, and in several other projects including enzymes for poultry, toxicity of mycotoxins. In February 2003, he assumed the position of poultry nutritionist of breeders, broilers, and turkeys for Perdigão Agroindustrial S/A. In January 2006, the author was accepted as a PhD student under the supervision of Dr. David Ledoux at the University of Missouri, Columbia, USA, where he obtained his PhD degree in Animal Sciences in December 2008. During his PhD, Leonardo worked with amino acid nutrition for turkeys, and in several other projects including toxicity of mycotoxins.