EFFECTS OF REDUCED PROTEIN, AMINO ACID SUPPLEMENTED DIETS ON PRODUCTION AND ECONOMIC PERFORMANCE OF COMMERCIAL BROILERS FED FROM HATCH TO MARKET AGE

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Doctor of Philosophy

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by
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EFFECTS OF REDUCED PROTEIN, AMINO ACID SUPPLEMENTED DIETS ON PRODUCTION AND ECONOMIC PERFORMANCE OF COMMERCIAL BROILERS FED FROM HATCH TO MARKET AGE

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DEDICATION

This dissertation is dedicated to my parents, José Guaiume and Joanita Ferreira Guaiume, for their unconditional love and support.

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EFFECTS OF REDUCED PROTEIN, AMINO ACID SUPPLEMENTED DIETS ON PRODUCTION AND ECONOMIC PERFORMANCE OF COMMERCIAL BROILERS FED FROM HATCH TO MARKET AGE

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ABSTRACT

Five studies were conducted to determine the effects of reduced crude protein (CP) of commercial boilers. In experiments (EXP) 1, 2, and 3, birds were fed diets with up to 1.5% reduction in CP. Performance and meat yield were not affected by the decrease in CP, but abdominal pat pad yield increased as CP decreased. In EXP 3 and 4, birds were fed diets with up to 2.1% decrease in CP. To EXP 4, the lowest CP-diet received supplementation of arginine (Arg), valine (Val), isoleucine (Ile), leucine (Leu), or a mixture with these four amino acids (All). In EXP 4, a decrease in breast meat yield was observed when CT-2.1% was fed whereas in EXP 5 there was no effect on breast meat yield, which may have been due to the fewer replicates utilized for EXP 2. In EXP 4, carcass yield decreased and supplementation with Ile/All recovered carcass yield.

CHAPTER I

INTRODUCTION

Feed costs accounts for 75% of the cost associated with meat production. Therefore, many attempts have been done to decreased the cost of feed and therefore increase the profit of a company. Although many papers have been published to investigate the effects of low crude protein diets on performance and meat yield, only a few papers described the effect of amino acid addition followed by a slight decrease of crude protein diets on broiler performance.

Methionine, lysine, and threonine are the first three limiting amino acids in corn-soybean formulations for broilers. Synthetic methionine sources and crystalline lysine and threonine sources are now commercially available and reasonably priced. The addition of supplemental amino acids allows a decrease in crude protein without affecting performance. However, if crude protein levels decrease considerably, caution should be taken so the “less” limiting amino acids isoleucine, valine, arginine, and tryptophan do not decrease to marginal levels; therefore minimum values for these amino acids should be included in the feed formulation to serve as constraints to crude protein. Crude protein will decrease up to these levels and this decrease in intact protein will be at the expense of supplemental amino acids.

At what expense intact crude protein can be replaced by supplemental amino acids it not known, but it there is agreement that if crude protein falls beyond threonine supplementation, isoleucine and valine will become deficient and therefore hinder performance.

A series of experiments was realized to determine the effects of reduced crude protein, amino acid supplemented diets in three strains of broilers (Cobb 500, Ross 308, and Ross 708) fed to market age.

CHAPTER II

LITERATURE REVIEW

Introduction:

The U.S. poultry industry is the world's largest producer and second largest exporter of poultry meat. U.S. consumption of poultry meat (broilers, other chicken, and turkey) is considerably higher than beef or pork, but less than total red meat consumption. The United States is also a major egg producer. The poultry and egg industry is a major feed grain user, accounting for approximately 80 billion pounds of feed yearly (www.ers.usda.gov).

Poultry rations constitute about 51% of the feed that is annually mixed in the United States. The cost of feed represents approximately 75% of the cost of live poultry production. Moreover, the cost of feed is by far the most important factor in the competitiveness of a particular country, region, or chicken company (Aho, 2002). Therefore, there is considerable interest to effectively formulate poultry feeds (Roush, 2002).

Besides energy, crude protein (CP) or amino acids (AA) is the most important factor determining feed costs in the poultry industry (Wijtten *et al.*, 2004a). Meeting AA needs represents a large portion of diet costs, and over formulating is costly whereas under formulating may negate economic returns due to suboptimal growth and meat yields (Kidd *et al.*, 2005). Thus, the profitability of broiler production enterprises can also be affected by changes in dietary CP (Eits *et al.*, 2005).

Today, at the poultry industry grows worldwide and competition among different countries or region becomes steeper, there have been several attempts to decrease the cost of production. In addition, as there may be a regulation to decrease nitrogen excretion in the next decade, reduction of nitrogen and phosphorus in animal wastes will be one of the primary considerations in the diet formulation in the near future (Si *et al.*, 2004). As a result, the poultry industry is seeking methods to eliminate, reduce, or control potential pollutants (Summers, 1993).

Poultry manure and its nitrogenous compounds can be a potential pollutant causing eutrophication, nitrate or nitrite contamination of water, ammonia volatilization, and acid deposition in the air (Summers, 1993; Moore, 1996). Therefore, for the poultry industry, low CP diets may have two different impacts. The first is the effect on profit; that is, on feed costs and the second impact will be on the environment (Firman and Boling, 1998).

Several dietary strategies can be used to reduce nitrogen in poultry manure, including the supplementation of synthetic AA to low CP diets, the utilization of hydroxyl-analogues or keto acids of AA to supplement low CP diets, or the concept of a dietary ideal protein ratio. The ideal protein ratio concept has been previously reviewed in detail (Emmert and Baker, 1997; Baker, 2003).

Ideal Protein:

The NRC (1984) comments on that dietary requirement for CP are actually requirements for the AA contained in the dietary protein. Nevertheless, for many years, formulation of diets for poultry and swine were based on the concept that there was a requirement for crude protein (CP); that is, the amount of nitrogen multiplied by the factor 6.25. Moreover, individual AA was not taken into consideration (Costa *et al.*, 2001). As a result, diets had AA content much higher than the levels required by the animal.

More recently, diets have been formulated based on ideal protein as a means to formulated diets to meet amino acid proportional requirements of animals for protein accretion and maintenance and simultaneously avoiding deficiencies and excesses (Emmert and Baker, 1997; Baker, 2003). Utilization of ideal protein ratios as minimum AA requirement in diet formulation will help reduce diet costs and limit environmental pollution caused by excess nitrogen excretion (Firman and Boling, 1998).

The concept of ideal protein was first introduced by the Agricultural Research Council in 1981 (Heugten and Kempen, 1999) and it is based on the concept that all AA are exactly in the right proportions for maintenance and lean tissue accretion. Moreover, each AA is equally limiting and excretion of nitrogen is minimized.

Attempts were made to establish the ideal pattern using body composition data with limited success (Williams *et al.*, 1954; Summers and Fisher, 1961; Robel and Menge, 1973; ARC, 1981). Growth assays have since been used to establish ideal AA profiles for the pig (Wang and Fuller, 1989; Chung and Baker, 1992a), the chick (Sasse and Baker, 1973; Baker and Han, 1994), and the turkey (Firman and Boling, 1998).

In practice, ideal AA ratios for poultry diets are formulated with lysine as the reference amino acid and the quantities of all indispensable amino acids as a percentage of lysine (Baker and Han; 1994; Emmert and Baker, 1997; Baker *et al.*, 2002; Baker, 2003). Requirements of all essential AA are expressed as percentage of lysine. The practicality behind this concept is that for every change in lysine, a quick adjustment of the other AA requirements can be made (Heugten and Kempen, 1999).

Lysine was chosen as the reference AA for several reasons, it is generally second-limiting in poultry rations, there is a relatively large amount of requirement data available, and lysine is primarily used for protein accretion (Baker and Han, 1994). Because of lysine's role as the reference AA, its requirement must be determined as accurately as possible to avoid errors being transferred to other amino acid requirements (Baker *et al.*, 1994).

Firman and Boling (1998) reported that the concept of ideal protein is not new and that as early as 1946, Mitchell and Block discussed the concept of a perfect balance of AA. A variety of attempts have been made to determine ideal AA pattern through carcass composition (Price *et al.*, 1953; Williams *et al.*, 1954; Summers and Fisher, 1961; Robel and Menge, 1973). However, Firman and Boling (1998) observed that carcass composition may be used as a starting point for an ideal ratio, but it does not take into account the dynamics of the live animal such as maintenance costs. Dean and Scott (1965) were the first to use dietary testing to begin determination of ideal proteins. Since then, a number of studies have sought to determine the ideal ratio for both the chick and the pig (Fuller *et al.*, 1989; Wang and Fuller, 1989; Chung and Baker, 1992; Baker and Chung, 1992; Baker and Han, 1994; Brown, 1994).

Mendonza *et al.* (1999) designed an experiment comparing diets formulated using the ideal protein concept with diets based on crude protein. For the ideal protein diet, the authors utilized the levels recommended by Han and Baker (1994) and for the CP diet, NRC (1994) recommendation. The authors observed that performance was better in chicks fed diets based on ideal protein diet than intact CP. Based on the ideal protein concept, it is possible to reduce CP levels in broiler diets and fulfill the amino acids requirements with the addition of synthetic amino acids (Faria Filho *et al.*, 2005).

Digestible amino acid formulation:

An important feature of protein quality for the feed industry is the knowledge of the availability of AA in feedstuffs. The supply of protein and AA in poultry diets represents a significant cost of production. Traditionally, AA requirements have been expressed on a total basis (NRC, 1994). These values indicate the total amount of AA present in the feed and do not take into consideration the AA bioavailability in the bird.

In order to know the quality of the AA in the feed or ingredients, determination of ileal amino acid digestibility is considered a reasonable method of estimating availability (Bryden and Li, 2004)

Reliable digestible AA values for the different feedstuffs will permit more efficient formulation of diets. AA availability is defined as the proportion of dietary AA that is in a form suitable for digestion, absorption, and utilization. Many attempts have been made to determine AA availability using *in vitro* (enzymatic and chemical assays), indirect (microbiological or plasma amino acids) or direct (growth and digestibility assays) methods (Ravindran and Bryden, 1999a).

Using digestible formulation will allow for more accurate pricing of ingredients and more flexibility in the feed formulation matrix because comparisons between feedstuffs could be made on a basis of AA availability and more ingredients could be effectively used (Parsons, 1991; Firman *et al.*, 1999). Digestible requirements would also reduce the overfeeding of AA which must be deaminated and excreted in an inefficient process (Murray *et al.*, 1993).

The excess of protein (essential and non-essential AA) is catabolized and excreted as uric acid. Assuming that the metabolic cost to incorporate one single AA in the protein chain is of 4 mol of ATP, the cost to excrete one AA is estimated to be from 6 to 18 mol of ATP, depending on the number of nitrogen molecules the AA contains (Costa *et al.*, 2001). Therefore, excreting excess AA represents that the energy consumed will be partitioned into 2 pathways: for the excretion of nitrogen and for growth.

As previously mentioned, for the poultry industry, low CP diets may have two different impacts (Firman and Boling, 1998): on feed costs and on the environment. However, although there is an agreement in the literature that a decrease in CP levels will be followed by a decrease in nitrogen excretion, this same agreement does not exist with respect to performance and breast meat yield. While some authors have reported that decreases in CP protein does not affect these traits, others oppose these findings. The difference among these experiments may lie on the fact that CP levels were decreased up to the point of causing deficiency of amino acids which synthetic sources are not yet available.

Low crude protein diets: Previous and present studies

Previous studies:

For many years, researchers have attempted to use low CP diets to clearly define AA interactions or imbalances, the limiting AA and their order of limitation in corn and soybean meal mixtures (Sxhwartz and Bray, 1975; Uzu, 1982; Edmonds *et al.*, 1985; Han *et al.*, 1992).

Amino acid imbalances or interactions:

Harper (1958) reported that AA imbalance can occur when a low CP diet that is first-limiting in an indispensable AA is supplemented with a mixture of AA lacking the first limiting AA. Diets with imbalanced AA can affect feed intake, body weight gain, feed efficiency (Sugahara *et al.*, 1969; Allen *et al.*, 1972; Tews *et al.*, 1980; Davis and Austic, 1982a, 1982b; Cieslak and Benevenga, 1984a, 1984b, 1986), and enzyme activities (Wang *et al.*, 1973).

Tews *et al.* (1980) studied the effects of low CP diets with imbalanced AA in rats. The authors determined that feeding diets with AA imbalances can change AA patterns of plasma and other tissues. The authors also reported negative effects in growth and food intake. The modifications in AA patterns included decreased concentrations of the limiting AA, especially in plasma and brain, along with increased levels of the AA added to create the imbalances.

By definition, the growth depression that occurs is considered to be the result of an imbalance only if a simultaneous supplement of the first limiting AA prevents the depression (Park and Austic, 2000). Commonly, mixtures of all indispensable AA lacking the first-limiting AA have been used in models of threonine, isoleucine, or histidine imbalance in the rat (Leung *et al.*, 1968; Leung and Rogers, 1971; Peng *et al.*, 1972). In the rat and chick, certain small neutral AA also have been effective in producing conditions similar to those related to AA imbalance (Tews *et al.*, 1979, 1980; Davis and Austic, 1982a; 1994).

For broilers, the lysine-arginine interaction (O'Dell and Savage, 1966; Austic and Scott, 1975) has been well documented and reviewed elsewhere (Balnave and Brake, 2002). This interaction was first identified and investigated in the 1950's and 1960's (Balnave and Brake, 2002). Austic and Scott (1975), reported that the most important metabolic interactions between lysine and arginine are that lysine competes with arginine for reabsorption in renal tubules, reducing the efficiency of arginine retention and that excess lysine causes marked increases in renal arginase activity and degradation of arginine to ornithine and urea (Austic and Scott, 1975). The lysine-arginine interaction for broilers has also been evidenced by other authors (Edmonds *et al.*, 1982; Allen *et al.,* 1972; Wang *et al.,* 1973; and Dean and Scott; 1965).

The second amino acid antagonism described in chicken is between the branched chain amino acids. In the case of excess leucine, there was an increase in the requirements of chicks and rats for isoleucine and valine. In chicks, this interaction is not due to reduced feed intake only, but to increased muscle catabolism of branched-chain amino acids by increasing muscle branched-chain aminotransferase activity

Order of limitation of amino acids:

In most broiler diets, methionine is the first limiting AA and lysine is the second (Schwartz and Bray, 1975; Han *et al.*, 1992). However, research by Fernandez *et al.* (1974) reported that lysine was first limiting and threonine was second. O'Dell and

Savage (1966) determined that in casein based diet, the requirements for arginine for the growing chicks was higher compared to a corn soybean meal based diet due to the lysine-arginine interaction. This discovery represented the starting point for other authors to develop low CP diets to determine the order of limitation of other amino acids in diets with different ingredients.

As early as 1985, Edmonds *et al.* (1985) reports that because of the increase in commercial bioavailability of synthetic AA, the determination of limiting indispensable AA in low CP corn-soybean meal diets became the major importance to the poultry industry. Amino acid deletion and addition were the two most common methods used to assess limiting AA in diets (Edmonds *et al.*, 1985).

Amino acid addition studies involve adding AA individually and in combination to a low CP or AA deficient diet. In AA deletion studies, individual AA are deleted sequentially from a low CP diet containing a full complement of supplemental AA.

Authors noticed that the order of limitation of amino acids would change based on the ingredients utilized. For instance, if a corn soybean meal was fed, deficiencies of both methionine and lysine would cause the lowest growth and feed intake, but if the diet was casein based diet; then arginine deficiency was more relevant because casein is one of the few ingredients in which lysine is in great excess of arginine.

In addition, Warnick and Anderson (1968) also used a deletion study in which chicks were fed semi-purified diets containing 14% CP from soybean meal. The authors found methionine to be first limiting with threonine, valine, and lysine next limiting in soybean meal. Deletion of individual AA from an AA-fortified 12% CP diet caused reductions in chick growth of 46, 42, 31, 24, 16, and 16% for methionine, valine, threonine, lysine, isoleucine, and arginine, respectively (Schwartz and Bray, 1975). In 1982, Uzu *et al.* reported that the addition of methionine (first limiting) and lysine to a 16% CP corn-soybean meal diet for 4- to 7-week-old broilers, produced growth similar to that obtained from a 20% CP diet (Edmonds *et al.*, 1985). Further work with turkeys by Stas and Potter (1982) indicated that the deletion of valine, lysine, threonine, and isoleucine from a methionine-supplemented 22% CP corn-soybean meal diet resulted in 9, 8, 6, and 4% reductions in gain of young turkeys (Edmonds *et al.*, 1985).

Present studies:

Unlike previous studies, when attempts to decrease CP levels were unsuccessful, in this present study even though CP level were decreased, the minimum digestible amino acid requirements were kept constant across the four dietary treatments and minimum digestible values were included to arginine, valine, isoleucine, leucine, and tryptophan because these amino acids are not yet available commercially. Therefore, these amino acids determined how low the CP level could be reduced without provoking any known amino acid deficiency. Hackenhaar and Lemme (2005) reported that to reduce CP levels in broilers' diets some precautions should be taken such as amino acid content and digestibility of the ingredient utilized as well as minimum requirements for the amino acids methionine, lysine, threonine, valine, arginine, isoleucine, and tryptophan.

In previous studies, the loss of performance may have been attributed to the fact that CP levels were decreased beyond practical levels and without proper amino acid supplementation even when CP levels ranged from 4 to 7% below NRC requirements (Edmonds *et al.*, 1985; Mendonça and Jensen, 1989). Low crude protein diets can negatively affect feed intake and feed efficiency because it does not supply the necessary levels of non-essential amino acids (Sklan and Plavnik, 2002) for which a requirement is not yet known.

Today, as the poultry industry grew world-wide and the market became divided into internal and external consumption, competition among countries and companies became steeper. In addition, as chicken meat became a commodity, an increase in profit raises from a decrease in the cost of production per kg of meat produced. As feed costs account for 60 to 70% of the cost of production, a reduction in feed costs can cause an increase in profit.

Amino acid is one of the major cost components of diets for broilers and it has also a great effect on performance as well as overall cost of the finished product (Firman and Boling, 1998). Therefore, it is of considerable importance to continuously increase our knowledge of broiler requirements for AA (Wijtten *et al.*, 2004a). Several studies have been realized with the objective to establish more accurate digestible AA requirements, ratios of these amino acids to lysine, and adequate CP levels to current poultry genetics (to list a few: Corzo *et al.*, 2005; Wijjten *et al.*, 2004; Kidd *et al.*, 2005; Waldroup *et al.*, 2005; Si *et al.*, 2004; Emmert *et al.*, 2000; Sklan and Plavnik, 2002; Aletor *et al.*, 2000; Sklan and Noy, 2003; Eits *et al.*, 2003; Alleman *et al.*, 2000) among many others.

The first low CP studies basically looked at methionine and lysine supplementation. The authors found that supplementation of poultry diets with synthetic methionine and lysine improved the overall AA balance and enabled a reduction in CP level (Waldroup *et al.*, 2005). It has been consistently demonstrated that addition of lysine and methionine to broiler diets successfully reduces CP level in the diets to a point without adversely affecting the broiler performance (Waldroup *et al.*, 2005; Lipstein and Bornstein, 1975; Lipstein *et al.*, 1975; Waldroup *et al.*, 1976; Uzu, 1982; Uzu, 1983).

Due to technological advances, threonine has become economically available in recent years and there is a good possibility that others will be commercially available in the future (Keshavarz and Austic, 2004). In addition to the commercial availability of synthetic AA sources, recent emphasis has been given to decrease pollution of the environment by farm animals' waste which has revived the interest in the use of low CP diets for broilers and pigs.

The key for a successful reduction in CP in broiler's diet is to make sure that the minimum digestible levels for all essential AA, for instance, isoleucine, valine, arginine, and tryptophan (Kidd *et al.*, 2004) are met. Therefore, minimum values must be set in the dietary linear programming so that CP is allowed to fall to these minimum values (Kidd *et al.,* 2004). The reduction in CP will happen at the expense of supplemental AA sources. This is successfully obtained by addition of supplemental sources of AA, namely synthetic methionine sources and crystalline lysine and threonine sources (the first three limiting AA in corn-soybean meal formulations for broilers), in the linear programming.

As CP is decreased beyond methionine, lysine, and threonine (the first three limiting AA in corn-soybean meal formulations for broilers), AA such as isoleucine, valine, arginine, and leucine may become limiting. The order of limitation will depend on the feeding phase and the ingredients of a particular diet. Therefore, if the reduction in CP is too drastic, it is expected that performance will be inversely affected.

The former reduction in dietary CP typically may render isoleucine as the fourth limiting-critical amino acid in broiler diets containing L-threonine (Kidd *et al.*, 2004). The low amount of isoleucine in cereal grains (maize, sorghum, and wheat), soybean meal and poultry by-product indicate that this AA is likely to be the next limiting behind threonine (Kidd *et al.*, 2004). However, the inclusion of ingredients in the diet that is relatively lower in valine, tryptophan, and arginine than isoleucine may change the relative order of the less limiting AA (Kidd *et al.*, 2004). Therefore, it is always crucial to keep minimum values for these AA when formulating a low CP diet.

Keshavarz and Austic (2004) reported that for laying hens promising results can be obtained by the use of low CP, AA supplemented diets. However, in a majority of these low CP studies, performance still remained inferior to the control groups that were fed conventional levels of CP. In addition, the authors mention that this decrease in performance may have been caused by inadequate knowledge about essential AA requirements of laying hens, the essential AA content of feed ingredients, the digestibility and bioavailability of AA in feed ingredients, and the proper ratio among essential AA in the low CP diets.

For broilers, formulation of diets is usually carried out by stipulating a minimum for essential AA and for CP. The CP concentration is assumed to supply the needs of all other non-constrained AA (Sklan and Noy, 2003). As for laying hens, feeding low CP diets for broilers require adequate knowledge about EAA requirements. If the formulation is based on digestible AA, in addition to adequate knowledge about AA requirements, nutritionists need to be aware of the coefficient of digestibility of the AA for the different feed ingredients being utilized.

Previous studies involving reduction of CP in broiler's diets resulted in decreased performance and loss of breast meat yield. In the past, however, many factors may have contributed to this decrease in performance and meat yield:

1. CP levels decreased beyond practical levels without proper AA supplementation (reports vary from 4 to 8% below NRC requirements).
2. Utilization of purified diets or utilization of uncommon ingredients with the objective to provoke AA deficiency and/or imbalance.
3. Lack of knowledge about AA requirements and AA limitations. Different papers list different order of AA limitation.
4. Unlike today when low CP diet has a more commercial and therefore economic importance, the objective of early trials were to test AA antagonism and imbalances and very few to determine actual AA requirements.
5. Diets were formulated on a total basis and the nutrient content values were calculated; therefore, the lack of knowledge about digestibility of the different ingredients used may have led to diets deficient in one or more AA.
6. Lack of availability of synthetic or crystalline AA other than the essentials methionine and lysine making it difficult for researchers to formulate a balanced low CP diet.

It is beyond the scope of this review to explain details about each of the topics listed above, but a brief description of how and why low CP diets were formulated may be important to elucidate the reasons low CP diets may not have been successful in the past.

Therefore, all the factors listed above may tell us that low CP diets were not successful in the past because researchers did not have the tools available today, such as computer formulation, tables with digestible AA values for a wide variety of ingredients, synthetic/crystalline sources of AA commercially available and reasonably prices, etc. These tools allow formulation of balanced low CP diets.

Low CP diets formulated in early trials may have been deficient in AA, which resulted in loss of performance and meat yield. A starter diet formulated to contain 23% of CP already includes a synthetic source of methionine to fulfill methionine requirements for that phase; therefore, if the objective is to further decrease dietary CP, it is expected that other AA may need to be added into formulation. In a corn-soybean meal based diet, the order of limiting AA is methionine, lysine, and threonine, followed by valine, isoleucine, tryptophan, and arginine. The latter four AA may be used as constraints for CP when low CP diets are formulated as synthetic forms yet economically viable have not been developed.

However, even now with all the information available in terms of AA requirements and AA content and digestibility of AA, low CP diets have not been successful leading to loss of performance and breast meat yield. Corzo *et al.* (2005) reviewed that published reports involving the inclusion of AA other than methionine, lysine, and threonine whereby CP is reduced to the extent that numerous AA supplements are needed, vary in impact on broiler productivity. The authors exemplify that some research have shown that reduced CP, AA supplemented diets support good growth and feed consumption of broilers (Lipstein *et al.*, 1975; Schutte, 1987; Parr and Summers, 1991; Deschepper and Groote, 1995; Yamazaki *et al.*, 1998, 1996; Aletor *et al.*, 2000).

In contrast, other research papers evaluating the impact of low CP, AA supplemented diets have demonstrated negative effects on broiler productivity (Edmonds *et al.*, 1985; Fancher and Jensen, 1989; Holsheimer and Janssen, 1991; Jensen, 1991; Moran *et al.*, 1992; Bregendahl *et al.*, 2002 in Corzo *et al.*, 2005).

Corzo *et al.* (2005) also points out that the differences in CP level, AA fortification, dietary ingredients, amino acid requirements imposed, bird age, and bird strain may have contributed to the discrepancies in the former reports. Moreover, it may be that non-essential AA needs (Corzo *et al.*, 2005) or the lack of adequate less limiting AA (isoleucine, valine, arginine, and tryptophan) may have contributed to these discrepancies.

Aletor *et al.* (2000) reported that in all of these observations, there appear to be three points with conflicting interests:

1. The need to maintain optimal/economic poultry productivity.
2. The need to maintain desirable (from the consumer standpoint) carcass characteristics and composition (regarding fat content of the carcass. These same authors concluded that the most consistent observation in these low CP studies has been the increased in fat deposition).
3. The compelling need to protect the environment via decreased nitrogen excretion.

The harmonization of these three subjects will depend on regulations regarding nitrogen excretion, ingredient prices (energy versus protein sources), and consumer preference.

In a review about low CP for broilers, Aftab *et al.* (2006) described that many possibilities were suggested to explain the negative effect on performance of these low CP diets. These included:

1. Insufficiency of some essential AA (i.e. isoleucine, valine, arginine, leucine).
2. Insufficiency of the non-specific nitrogen for the synthetic non-essential AA. However, addition of glutamic acid to low CP diets as a source of nitrogen did not recover performance (Edmonds *et al.*, 1985).
3. Insufficient synthesis of non-essential AA (i.e. glycine).

   As the levels of CP are reduced, the protein sources are replaced by corn which may create a glycine deficiency because the level of glycine in corn is negligible when compared to the protein sources (total glycine content (%): corn, 0.33; poultry by-product, 3.95; and soybean meal, 2.05). Glycine is considered a semi-essential amino acid in young broiler chicks (Graber and Baker, 1973) since chicks can synthesize Gly, but there is still a considerable requirement for Gly to be supplied by the diet. Therefore, when low CP diets are formulated, special attention should be given not only to lysine, methionine, and threonine because for these synthetic forms are commercially available, but to the non-essential amino acids as well as to their ratios to lysine. In addition, ssupplementation with non essential glycine above current NRC recommendations alleviated these negative effects (Aftab *et al.*, 2006).
4. Altered essential to non-essential AA ratio.

The ratio between non essential and essential AA of 50:50 should be maintained (Aftab *et al.*, 2006).

5. Change in dietary potassium or the dietary electrolyte balance.

   As the potassium rich-soybean meal levels decrease in the low CP diet, potassium may fall below required levels. However, correcting potassium levels in the low CP diets did not restore performance and body fat to control levels (Han *et al.*, 1992; Si *et al.*, 2004).

6. Tendency of broilers to reduce voluntary feed intake on low CP diets.

   Depressed feed intake partially explains the negative effect of low CP diets (Aftab *et al.*, 2006). However, there is no agreement in the literature that a reduction in CP will reduce feed intake.

7. Efficiency of utilization of amino acids from a free source versus intact dietary protein for body protein accretion.

   Researchers have reported negative effects on performace associated with feeding too much crystalline AA (Han and Baker, 1993a; Waldroup *et al.*, 1976).

8. Lastly, the relationship between the dietary metabolizable energy and the net energy of low CP versus control or high CP diets.

   Increased net energy of the low CP diets seems to explain higher body fat accretion (Aftab *et al.*, 2006).

Increasing AA density:

Several researchers (Corzo *et al.,* 2006; Kidd *et al.*, 2004; Vieira *et al.*, 2004; Saleh *et al.*, 2004; Lemme *et al.*, 2003; Corzo *et al.*, 2002; Tesseraud *et al.*, 2001; Bartov and Plavnik, 1998; Kidd *et al.*, 1998) reported that an increase in AA density in the diets will have a positive effect in performance and, specially in breast meat yield.

Kidd *et al.* (2004) reported that there is a tendency for broiler integrators in the US to reduce dietary nutrient density to lower overall input costs of broiler production; however, numerous nutritionists and researchers from the supplier side of poultry production are arguing that the reduced dietary nutrient density regimen currently employed by some integrators is not an effective means of increasing profitability, especially when producing large, high-yield broilers for markets requiring saleable white meat (Kidd *et al.*, 1998).

The requirement for boneless, skinless white meat by the industry and market has driven the primary breeders to produce lines of birds that are extreme in their rates of growth and development of breast muscle (Howie, 1999). In a turkey deboning, further processing operation, more than 90% of the variation in the value of a turkey carcass is attributable to the mass of breast meat contained in that carcass. As a result, the processors aim to acquire turkeys that offer the highest yield of breast meat. Moreover, there is a benefit of feeding diets that help muscle development and fast growth. It is suggested that maximal muscle development can be achieved by feeding diets higher in protein, although a balance must be maintained between feed costs and carcass value (Howie, 1999).

When body weights and feed requirements of broilers from NRC (1984) and NRC (1994) are compared, males at 8 weeks of age had body weights approximately 500 g lighter than males at the same age listed on NRC (1994). However, cumulative feed consumption increased from 5.33 kg (NRC, 1984) to 6.43 kg (NRC, 1994). Moreover, lysine recommendation for 0 to 3 weeks was in fact decreased from 1.20% (NRC, 1984) to 1.10% (NRC, 1994), on a total basis. Therefore, an increase in AA density in the diet may increase diet costs and do not give the expect return of profits.

CHAPTER III

EFFECTS OF REDUCED PROTEIN DIETS ON PRODUCTION AND ECONOMIC PERFORMANCE OF COBB 500 BROILERS FED FROM HATCH TO SIX WEEKS OF AGE

ABSTRACT

A study was conducted to determine the effects of reduced dietary crude protein (CP) on performance and economics of Cobb 500 broilers from hatch to week 6. Fourteen hundred and forty straight-run broiler chicks were randomly assigned to four treatments with 12 replicate pens containing 30 birds each. Diets were formulated to be isocaloric and to have the same minimum digestible level for lysine and the same minimum ideal amino acid ratios to lysine for TSAA, threonine, valine, isoleucine, arginine, and tryptophan across the three feeding phases. An industry standard diet served as the control (CT). The remainder of the treatments (CT-0.5%, CT-1.0%, and CT-1.5%) had CP reduced in 0.5% increments. Treatments were: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.3%, CT-1.0%: 20.9%, and CT-1.5%: 20.6%]; [(Grower: 2 to 4wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6wks): CT:

17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%]. Feed intake was recorded and birds were weighed at 2, 4, and 6 weeks of age for feed to gain calculation. At week 6, four birds per pen (48 birds/trt; two males and two females) were humanely euthanized and had abdominal fat pad removed and carcass weighed for fat pad and carcass yield determination. Then, carcasses were let to chill for 2 hours prior to cut up for yield determination. Feed cost savings (FCS) per metric ton (MT) of live BW, FCS/MT carcass, and FCS/MT breast meat was calculated. At week 6, treatments had no effect ($P > 0.05$) on carcass yield, percentage of abdominal fat pad, breast meat yield, thigh, and wing. For BW, relative to CT, FCS were $1.99/MT when CT-1.5% was fed; for MT of carcass, $2.55/MT; and for MT of breast meat, $14.25. Overall, these results suggest that a decrease of CP by 1.5%, as compared with industry standards, did not affect performance, carcass, and meat yield, and resulted in significantly higher revenues.

INTRODUCTION

Feed constitutes the majority of costs associated with the production of poultry meat. Along with energy, amino acids are the most critical dietary factors in determining feed costs and performance in the poultry industry (Wijtten *et al.*, 2004a). Meeting amino acid needs represents a large portion of diet costs, and over formulating is costly whereas under formulating may negate economic returns due to suboptimal growth and meat yields (Kidd *et al.*, 2005). Thus, the profitability of broiler production enterprises can also be affected by changes in dietary crude protein (CP) (Eits *et al.*, 2005). Previous studies involving reduction of CP in broiler diets resulted in decreased performance and loss of breast meat yield. However, in these studies CP levels were decreased below practical levels without proper amino acid supplementation. Several studies reported decreases in CP varying from 4 to 7% below NRC requirements (Edmonds *et al.*, 1985; Mendonça and Jensen, 1989) with subsequent loss of performance.

Keshavarz and Austic (2004) reported that the decrease in performance observed when low CP diets were fed may have been caused by inadequate knowledge about essential amino acid requirements, amino acid content of feed ingredients, the digestibility and bioavailability of amino acids in feed ingredients, and the proper ratio among essential amino acids in the low CP diets. The other problem with previous experiments was that the diets were formulated on a total amino acid basis even when ingredients - other than corn and soybean meal - were utilized. Therefore, the differences in digestibility of amino acids among different feed ingredients were not taken into consideration.

Furthermore, unlike today when the use of low CP diets may be an approach to decrease feed costs, the objective of early studies was to test amino acid antagonisms and imbalances and very few studies were designed to determine actual amino acid requirements or the use of low CP in the industry. Currently, because of the commercial availability of synthetic amino acid at reasonable prices, it has become possible to formulate diets with low crude protein levels while maintaining adequate levels of amino acids to ensure ideal performance and meat yield.

The objective of this study was to determine if a 1.5% decrease in CP with adequate amino acid supplementation would affect performance and meat yield of Cobb 500 broilers fed from hatch to week 6.

MATERIAL AND METHODS

Experimental facility:

The experiment was conducted in a facility containing 48 floor pens on concrete with side wall curtains. Each floor pen measured 1.80 x 1.20 m (0.072 m^2/bird). Each pen contained one tube feeder, a nipple drinker line (five nipples per pen), and used soft-wood shavings. From day 1 to 7, supplemental pan feeders were used in each pen to ensure good feed consumption at placement. The facility was heated with electric heat lamps in each pen and propane heaters were placed in the center of the aisle.

Experimental design and animal husbandry:

Fourteen hundred and forty industry standard one-day-old straight-run Cobb 500 broiler chicks were purchased from a commercial hatchery after *in ovo* vaccination against Marek's disease and post hatch vaccination against Newscastle disease and infectious bronchitis. On day 1, birds were weighed and randomly assigned to fou treatments with 12 replicate pens containing 30 birds each.

Blocks were based on house location and treatments were randomly allotted within blocks with two replicates per block. Chicks were maintained on a 23-h constant light schedule and allowed food and water *ad libitum.* Birds were monitored daily for signs of morbidity and mortality. The animal care and use protocol was reviewed and approved by the University of Missouri-Columbia Animal Care and Use Committee.

Dietary treatments:

Dietary treatments included four different dietary levels of CP for each of the three feeding phases. Diets were least-cost formulated to be isocaloric and to have the same minimum digestible level for lysine (Lys), and the same minimum ideal amino acid ratios to lysine for TSAA, threonine (Thr), valine (Val), isoleucine (Ile), arginine (Arg), and tryptophan (Trp) across the three feeding phases [starter (0 to 2 weeks of age), grower (2 to 4 weeks), and finisher (4 to 6 weeks)]. The ratios to lysine were based on Baker's recommendation (Baker, 1994) (Table 3.1). The control diets (CT) contained the current CP levels fed by the industry (Agristats, 2005) for each feeding phase whereas the remainder of the treatments (CT-0.5%, CT-1.0%, and CT-1.5%) had CP levels reduced in 0.5% increments for all feeding phases. Therefore, CT had the highest level of crude protein and CT-1.5% the lowest level (Table 3.2). The levels of CP for each of the dietary treatments per feeding phase are listed on Table 3.3. To originate the dietary treatments, two diets were mixed (CT and CT-1.5%) and then blended together in different proportions to originate the intermediate treatments (CT-0.5% and CT-1.0). For CT-0.5%, 2/3 of the mix corresponded to diet CT and the remaining 1/3 to diet CT-1.5%

whereas for CT-1.0%, 1/3 of the mix corresponded to CT and 2/3 to CT-1.5%. This treatment regimen continued throughout the 6-week period.

Prior to diet formulation, samples of corn, soybean meal, and poultry by-product were sent to Degussa Corporation (Kennesaw, GA, USA) for CP and amino acid analyses and the coefficient of digestibility of amino acids was obtained from Ajinomoto Heartland, LLC (Chicago, IL, USA). Values were for corn: ME, 3,350 kcal/kg; CP, 6.70%; Lys, 0.23%; TSAA, 0.31%; Thr, 0.24%; Trp, 0.06%; Ile, 0.22%; and Val, 0.31%. For soybean meal: ME, 2,750 kcal/kg; CP, 47.05%; Lys, 2.94%; TSAA, 1.34%; Thr, 1.84%; Trp, 0.65%; Ile, 2.14%; and Val, 2.24%. Finally, for poultry by-product: ME, 2,950 kcal/kg; CP, 60.03%; Lys, 3.53%; TSAA, 1.62%; Thr, 2.15%; Trp, 0.50%; Ile, 2.12%; and Val, 2.65%.

Performance data:

Body weight gain and feed intake was recorded at weeks 2, 4, and 6 and used for feed to gain calculation. Mortality was also recorded on a pen basis and feed consumption data were adjusted. Mortality remained low and occurred randomly throughout the treatments. Therefore, mortality data were not analyzed statistically.

Carcass Measurements:

At the end of week 6, four birds (two males and two females) per pen (48 birds/trt) were randomly selected, weighed, wing-banded, and transported to the processing plant, where they remained without feed, but with access to water for 12 hours prior to processing. Birds were hung on shackles, stunned with electric shock, and bled for 5 minutes after severance of the jugular vein. Birds remained on shackles and were dipped in a hot water scalder for 45 seconds with the thermostat set at 60ºC. They were then transferred to an automated drum picker and defeathered for 60 seconds. After hocks and heads were removed, birds were eviscerated and washed manually. Therefore, carcass consisted of the whole bird without blood, feathers, hocks, heads, offal, and abdominal fat. Abdominal fat and carcasses were weighed to determine abdominal fat pad yield. Carcasses were then rewashed and chilled in an ice bath for a minimum of 2 hours. After 2 hours, breast muscles (*pectoralis major* and *pectoralis minor)*, thighs, legs, and wings were severed from the chilled carcasses on a manual deboning line, weighed, and recorded for determination of parts yield. All carcass measurements were expressed as percentage over live body weight at processing.

Economic Analysis:

A program was designed to determine feed costs per metric ton (MT) of live BW, carcass, and total breast meat. Feed cost savings (FCS)/MT of live BW, carcass, and breast meat were determined for each of the dietary treatments that had a decrease in CP by comparing their costs to the control diet cost of the correspondent feeding phase (Table 3.6). Because there were no statistical differences among the treatments, all the numbers obtained from the different treatments were averaged to determine FCS (average BW of 2.38 kg/bird; average carcass yield of 77.99%; and average total breast meat yield of 17.75%). Feed ingredient prices were obtained from Feedstuffs (June, 2007) and they were Kansas City prices. The prices for synthetic amino acids were obtained from the University of Missouri's Feed mill. The prices were, in US$/metric ton: corn (144.00);

soybean meal (245.00); poultry by product (335.00); DL-Methionine (2,200.00); Lysine.HCl (1,980.00); L-Threonine (2,494.80). Prices for broiler chicken items were obtained from USDA Market News (June, 2007). Carcass and total breast meat (boneless) values were US$ 1.76/kg and US$ 3.08/kg, respectively.

Statistical Analysis:

Pen was the experimental unit for all analyses. Performance data were analyzed as a completely randomized block design (CRBD) using the Mixed procedure (Proc Mixed) of SAS (SAS Institute, 2003) by the following model:

$$Y_{ijk} = \mu + B_i + T_j + B(T)_{i(j)} + \epsilon_{k(ij)}$$

Where μ is the common mean; B_i is the effect if the ith block; T_j is the effect of jth treatment; $B(T)_{i(j)}$ is the effect of the jth treatment within the ith block, and $\epsilon_{k(ij)}$ is the random error.

For the processing data, the effect of gender and the gender x treatment interactions were fitted in the statistical model. Processing data were also analyzed as a CRBD using Proc Mixed by the following model:

$$Y_{ijkl} = \mu + B_i + T_j + G_k + TG_{ik} + B(TxG)_{i(jk)} + \epsilon_{l(ijk)}$$

Where μ is the common mean; B_i is the effect if the ith block; T_j is the effect of jth treatment; G_k is the effect of the kth gender; TG_{ik} is the interaction between the effect of jth treatment and the effect of the kth gender; $B(TxG)_{i(jk)}$ is the interaction between the effect of jth treatment and the effect of the kth gender within the ith block, and $\epsilon_{k(ij)}$ is the random error.

Means showing significance in ANOVA were compared using Fisher's protected least significant difference procedure (Snedecor and Cochran, 1989). All statements of difference were based on a significance of $P < 0.05$. Linear and quadratic polynomial contrasts were performed using Proc Mixed of SAS (SAS Institute, 2003).

RESULTS

Performance:

Results for feed intake (FI), body weight gains (BWG), and feed to gain (FDGN) are demonstrated in Table 3.4. From 0 to 2 weeks of age, birds fed diet CT-1.5% showed a linear decrease ($P = 0.012$) in FI. Birds fed CT-1.5% also had lower BWG ($P = 0.006$) when compared to the remaining treatments. Treatments had no effect on FDGN ($P = 0.052$). For the 0 to 4-week-period, treatments did not affect FI; however, birds fed CT-1.5% were lighter ($P = 0.011$) than birds fed CT (CT: 1.33 kg/bird; CT-1.5%: 1.27 kg/bird). All treatments with reduced CP had worse FDGN when compared to CT ($P = 0.001$) for the 0 to 4 week period. When data were analyzed for the entire experimental period, from 0 to 6 weeks of age, treatments had no effect on the variables measured.

Processing measurements:

Processing responses are listed on Table 3.5. At week 6, treatments had no effect

(P > 0.05) on carcass yield, percentage of abdominal fat pad, leg, drum, wing, and breast meat yield. In addition, Table 3.6 lists the effect of gender on the processing responses. Females had higher (P < 0.05) percentage of fat pad and minor yield when compared to males (fat pad: females 2.13% and males 1.84%; minor yield: females: 4.08% and males: 3.78%). In contrast, males had higher percentage of leg yield when compared to females (males 11.20% and females 10.82%). Gender had no effect on carcass, thigh, wing, major, and total breast yield. No relevant gender by treatment interactions were observed, except for wing.

Economical Analysis:

Feed costs decreased as CP levels were decreased in the diets and this effect was consistent for each of the feeding phases (Figure 3.1). Therefore, as the levels of CP decreased, there was a decrease in feed costs. Moreover, as diet costs decreased, there was a reduction in feed costs/MT of BW, carcass, and total breast meat (Table 3.7) of up to US$ 1.99/MT of live BW, US$ 2.55/MT of carcass, and US$ 14.25/MT of breast meat when CT-1.5% was compared to CT.

DISCUSSION

The use of low crude protein , amino acid supplemented diets has been the subject of numerous investigations (Keshavarz and Austic, 2004) as a way to maintain adequate performance and breast meat yield while decreasing feed costs. The addition of synthetic amino acids to the diets allows for a reduction of crude protein while maintaining adequate levels of the essential amino acids. Broilers fed diets with reduced levels of crude protein but with adequate amino supplementation may support meat yield and performance and increase profitability. Therefore, an economic comparison was performed between the control diet (CT) and the diet with the lowest level of CP (CT-1.5%) using published feed ingredient prices (Feedstuffs, 2007) and chicken meat prices (USDA Market News, 2007) (Figure 3.1 and Table 3.7). The diet costs per metric ton (US$/1,000 kg of feed) are listed on Figure 3.1. As the level of crude protein decreased, there was a decrease in feed costs and this decrease was consistent across the four feeding phases.

The addition of synthetic amino acids results in an increase in the digestibility of the diet because less intact protein is needed to achieve the desired level of essential amino acids; as a result, there is a decrease in feed costs. However, with respect to the effects of low crude protein diets on performance and meat yield, reports found in the literature are rather controversial. Earlier studies showed that birds fed diets with decreased levels of crude protein also had decreased meat yield and poor performance when compared to the control group. Pesti and Fletcher (1984) fed male broilers diets containing 22% or 17.5% CP from 21 to 42 days of age and found that body weight gains and feed efficiency increased with increasing levels of CP. In addition, there was an increase in abdominal fat pad and total carcass fat when birds were fed the low CP diet. However, no effect on carcass yield was determined. When comparing the levels of lysine, methionine, and TSAA between the normal versus the low CP diets, lysine was 1.18 versus 0.88%, methionine, 0.46 versus 0.37%, and TSAA, 0.78 versus 0.64%, respectively. The NRC (1994) recommendations for total lysine, methionine, and TSAA from 21 to 42 days of age are 1.00, 0.38, and 0.72%, respectively. This implies that the low CP diets may have been deficient in lysine and TSAA and offered marginal levels of methionine. This may explain the decrease in feed efficiency and the increase in fat deposition with no effect on carcass yield observed when the low CP diet was supplied. In an attempt to achieve the requirement for the deficient amino acids, birds increased feed intake, which in turn, increased energy intake resulting in higher fat deposition. In contrast, Wijtten *et al.* (2004a) tested increasing ideal protein (IP) concentrations for broiler chicks fed from day 14 to 34 and reported linear increases in body weight gains and improvement in feed efficiency as the dietary IP increased from 0.91 to 1.44% digestible lysine. Even at 1.44% digestible lysine, birds had not reached the growth plateau. The different dietary IP concentrations were obtained through blending of a purified diet (23.8 % of corn starch and 9.7% of inert fillers) with a diet resembling a commercial type diet. Therefore, the increased response as the dietary IP increased may have been caused by the decreased levels of corn starch and fillers. Imbalance of amino acids may represent a problem when feeding a purified diet. In addition, Moran *et al.* (1992) fed broilers from 0 to 3 weeks of age, diets with either 20 to 17% CP and for the 3 to 6 week period, the levels of CP were lowered from 17 to 14%. The authors observed that live body weights were unaffected in both periods; however, 3 to 6 week feed conversion worsened, abdominal fat increased, and breast meat yield decreased. In this present study, a decrease of crude protein of up to 1.5% relative to the control decreased feed intake and body weight gains at week 2. At week 4, a decrease in CP worsened feed efficiency and decreased body weight gain.

However, at week 6, this negative effect disappeared and treatments were no longer different. In addition, as the level CP decreased there was no effect on carcass yield, abdominal fat pad, and parts yield. The diets from this experiment were formulated to have the same minimum digestible amino acids across the dietary treatments. Therefore, the diets had lower crude protein contents, but the levels of amino acids did not vary among treatments. The positive response obtained in this experiment in terms of performance and meat yield may have been due to the slight decrease in CP (up to 1.5%) and amino acid supplementation. Large decreases in CP levels may lead to deficiency of not only essential amino acids, but of non-essential amino acids (Alleman *et al.*, 2000). The decrease in performance observed in the earlier phases (at week 2 and 4) is in agreement with Wijtten *et al.* (2004b). The authors fed a low CP starter diet (0 to 14 days of age) containing 20.8% CP and 1.05% digestible lysine. They reported decreased body weight gain and poor feed efficiency when compared to the control diet. However, in their case, performance of the birds fed low CP diets was only partly compensated for in later phases of life. In the present study, treatments had no affect on body weight gain, feed intake, and feed efficiency at 6 weeks of age.

CONCLUSION

Overall, these results indicate that a decrease of CP by 1.5% but with adequate amino acid supplementation, as compared with industry standards, did not affect performance of Cobb 500 broiler and meat yield at 6 weeks of age, and resulted in significantly higher revenues.

Table 3.1: Minimum digestible lysine level and the ratios of essential amino acids to lysine utilized for the four dietary treatments for each feeding phase

	FEEDING PHASES[1]			
	Starter	Grower	Finisher	Ratios[2]
Lysine[3], %	1.09	0.97	0.84	100
Amino Acids, %				
Threonine	0.720	0.650	0.560	66
Methionine	0.495	0.440	0.380	45
TSAA	0.810	0.730	0.630	74
Tryptophan	0.170	0.150	0.130	15
Isoleucine	0.730	0.645	0.550	65
Valine	0.850	0.750	0.647	77
Arginine	1.123	1.000	0.870	102

[1] Starter diet was fed from 0 to 14 days of age; Grower from 14 to 28 days; and Finisher: 28 to 42 days.
[2] Ratios based on Baker's recommendation (Baker, 1994).
[3] Lysine and all amino acids are expressed in a digestible basis.

Table 3. 2: Diet composition of the control (CT) and the diet with the lowest level of crude protein (CT-1.5%)[1]

	TREATMENTS[2]			
	Starter		Grower	
Ingredients, %	CT	CT-1.5%	CT	CT-1.5%
Corn	57.69	62.25	63.00	67.93
Soybean meal	33.67	29.67	28.75	24.43
Poultry by-product	3.50	3.50	3.50	3.50
Animal & vegetal fat	2.15	1.35	2.04	1.18
Dicalcium phosphate	1.21	1.25	0.99	1.03
Limestone	0.86	0.85	0.86	0.85
DL Methionine	0.22	0.25	0.18	0.22
Lysine.HCl	0.00	0.11	0.00	0.13
L-Threonine	0.00	0.06	0.00	0.06
Others[3]	0.72	0.72	0.69	0.69
Diet cost, US$/MT[4]	205.15	204.05	198.98	197.73
Chemical composition (amino acids on a total basis[5]) as analyzed:				
ME, Kcal/kg	3,067	3,067	3,122	3,122
Crude Protein, %	22.00	20.61	20.00	18.50
Lysine, %	1.18	1.23	1.15	1.11
Arginine, %	1.39	1.35	1.36	1.25
Methionine, %	0.55	0.61	0.52	0.47
TSAA, %	0.91	0.93	0.86	0.77
Threonine, %	0.91	0.94	0.89	0.75
Isoleucine, %	0.92	0.88	0.90	0.78
Leucine, %	1.77	1.73	1.78	1.62
Valine, %	1.02	0.99	1.01	0.89
Tryptophan[5,6], %	0.25	0.23	0.24	0.22
Glycine, %	1.10	1.09	1.08	0.94
Serine, %	1.14	1.11	1.11	0.87

Table 3.2 *(cont)*:

	TREATMENTS[2]	
	Finisher	
Ingredients, %	CT	CT-1.5%
Corn	68.95	73.89
Soybean meal	22.65	18.31
Poultry by-product	3.50	3.50
Animal & vegetal fat	2.19	1.33
Dicalcium phosphate	1.06	1.10
Limestone	0.87	0.86
DL Methionine	0.13	0.17
Lysine.HCl	0.02	0.15
L-Threonine	0.00	0.06
Others[3]	0.64	0.64
Diet cost, US$/MT[4]	192.55	191.42
Chemical composition (amino acids on a total basis[5]) as analyzed:		
ME, Kcal/kg	3,190	3,190
Crude Protein, %	17.50	16.00
Lysine, %	0.94	1.04
Arginine, %	1.11	1.12
Methionine, %	0.46	0.44
TSAA, %	0.76	0.74
Threonine, %	0.77	0.71
Isoleucine, %	0.74	0.71
Leucine, %	1.57	1.54
Valine, %	0.85	0.82
Tryptophan[5,6], %	0.20	0.18
Glycine, %	0.93	0.86
Serine, %	0.97	0.83

[1] Crude Protein (CP) levels: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.3%, CT-1.0%: 20.9%, and CT-1.5%: 20.6%]; [(Grower: 2 to 4wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%].
[2] To originate the intermediate treatments CT-0.5% and CT-1.0%, CT and CT-1.5% diets were mixed and then blended together in different proportions. For CT-0.5%, 2/3 of the mix corresponded to diet CT and the remaining 1/3 to diet CT-1.5% whereas for CT-1.0%, 1/3 of the mix corresponded to CT and 2/3 to CT-1.5% for all feeding phases.
[3] Others = NaCl: Starter, 0.42%; Grower, 0.39%, and Finisher, 0.34%); Selenium premix, 0.025% supplying 0.15 mg Se/kg diet; copper sulfate pentahydrate, 0.012% or 30.25 mg Cu/kg diet; Mineral mix (0.10%) mg supplied per kg of diet: Ca, 25; Fe, 60; Mg, 26.8, Mn, 110; Zn, 110; I, 2; Vitamin mix (0.075%) supplied per kilogram of diet: vitamin D_3, 2,625 ICU; vitamin A, 6,000 IU; vitamin E, 9.4 IU; niacin, 37.5mg; D-pantothenic acid, 11.25 mg; riboflavin, 4.5 mg; pyridoxine, 1.5 mg; menadione, 1.13 mg; folic acid, 0.94 mg; thiamine, 0.75 mg; biotin, 0.15 mg; vitamin B12, 7.5 µg; Coccidiostatic, 0.075% (60% sodium monensin premix, Elanco Animal Health, Greenfield, IN).
[4] MT (metric ton) = 1,000 kg.
[5] Feed samples sent to Degussa Corp., Kennesaw, GA, USA for CP and AA analyses.
[6] Analyzed by Ajinomoto Heartland LLC, Chicago, IL, USA.

Table 3.3: Crude protein levels of the different dietary treatments per feeding phase.

	CRUDE PROTEIN LEVELS (%)[1]		
Feeding phases[2]:	Starter[2]	Grower	Finisher
Treatments:			
CT	22.0	20.0	17.5
CT-0.5%	21.3	19.5	17.0
CT-1.0%	20.9	19.0	16.5
CT-1.5%	20.6	18.5	16.0

[1] To originate CT-0.5% and CT-1.0%, CT and CT-1.5% diets were mixed and then blended together in different proportions. For CT-0.5%, 2/3 of the mix corresponded to diet CT and the remaining 1/3 to diet CT-1.5% whereas for CT-1.0%, 1/3 of the mix corresponded to CT and 2/3 to CT-1.5% for all feeding phases.
[2] Starter diet was fed from 0 to 14 days of age, Grower from 14 to 28 days, and Finisher: 28 to 42 days.

Table 3.4: Effect of decreasing crude protein levels on performance of Cobb 500 broilers fed from hatch to six weeks of age[1,2]

	Starter			Grower			Finisher		
Treatments[2]	FI (g)	BWG (g)	FDGN (g:g)	FI (Kg)	BWG (kg)	FDGN (kg:kg)	FI (kg)	BWG (kg)	FDGN (kg:kg)
CT	468^{a}	334^{a}	1.40^{b}	1.94	1.33^{a}	1.45^{b}	4.06	2.35	1.73
CT-0.5%	467^{a}	333^{a}	1.40^{b}	1.92	1.31^{ab}	1.47^{a}	4.07	2.34	1.74
CT-1.0%	467^{a}	325^{ab}	1.44^{a}	1.94	1.32^{a}	1.47^{a}	4.06	2.36	1.72
CT-1.5%	446^{b}	311^{b}	1.43^{ab}	1.89	1.27^{b}	1.49^{a}	4.01	2.30	1.74
SEM	*0.006*	*0.005*	*0.012*	*0.021*	*0.013*	*0.001*	*0.052*	*0.037*	*0.009*
					Probabilities				
ANOVA	0.024	0.006	0.050	0.379	0.011	0.001	0.828	0.737	0.547
Linear	0.012	0.174	0.912	0.421	0.441	0.805	0.513	0.497	0.827
Quadratic	0.098	0.187	0.889	0.429	0.462	0.770	0.518	0.502	0.830

[1] Data are averaged means of 12 replicates of 30 birds each.
[2] FI = feed intake; BWG = body weight gain; FDGN = feed to gain.
[3] Crude Protein (CP) levels: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.3%, CT-1.0%: 20.9%, and CT-1.5%: 20.6%]; [(Grower: 2 to 4wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.0%: 16.5%, CT-1.5%: 16.0%].
[a, b] Values within column with different superscripts differ significantly ($P < 0.05$).

Table 3.5: Effect of decreasing crude protein levels on processing responses, expressed as percentage over live body weight, of Cobb 500 broilers[1]

	CARCASS[2]	FAT PAD	LEG	THIGH	WING	MAJOR	MINOR	BREAST[3]
Treatments[4]	(%)							
CT	77.63	1.96	10.86	12.19	8.59	13.95	3.92	17.88
CT-0.5%	78.13	2.06	10.95	12.33	8.99	13.77	4.01	17.78
CT-1.0%	78.71	1.93	11.06	12.12	8.71	13.87	4.00	17.87
CT-1.5%	77.49	1.99	11.17	12.24	8.92	13.69	3.79	17.46
SEM	*0.145*	*0.691*	*0.122*	*0.202*	*0.146*	*0.210*	*0.113*	*0.264*
	Probabilities							
ANOVA	0.673	0.763	0.536	0.937	0.350	0.898	0.562	0.765
Linear	0.692	0.994	0.103	0.941	0.630	0.683	0.272	0.451
Quadratic	0.308	0.903	0.825	0.924	0.944	0.958	0.388	0.789

[1] Processing measurements are averaged means of 12 replicates of four birds each (two males and two females) with body weights close to pen average (2.38 kg) at 6 weeks of age.
[2] Carcass = Chilled carcass (without blood, feathers, head, hocks, offal, and abdominal fat pad).
[3] Breast = Major + Minor.
[4] Crude Protein (CP) levels: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.3%, CT-1.0%: 20.9%, and CT-1.5%: 20.6%]; [(Grower: 2 to 4wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%].

Table 3.6: Effect of decreasing crude protein levels[1] on processing responses, expressed as percentage over live body weight, of male and female Cobb 500 broilers[2,3]

	CARCASS[4]	FAT PAD	LEG	THIGH	WING	MAJOR	MINOR	BREAST[5]
Gender	(%)							
Female	78.25	2.13^a	10.82^b	12.28	8.88	13.88	4.08^a	17.96
Males	77.73	1.84^b	11.20^a	12.17	8.72	13.75	3.78^b	17.54
SEM	*0.145*	*0.691*	*0.122*	*0.202*	*0.146*	*0.210*	*0.113*	*0.264*
	Probabilities							
TRT	0.673	0.763	0.536	0.937	0.350	0.898	0.562	0.765
Gender	0.503	0.001	0.017	0.639	0.308	0.630	0.017	0.184
Gender X TRT	0.574	0.969	0.737	0.902	0.005	0.438	0.109	0.461

[1] Crude Protein (CP) levels: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.3%, CT-1.0%: 20.9%, and CT-1.5%: 20.6%]; [(Grower: 2 to 4wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%].

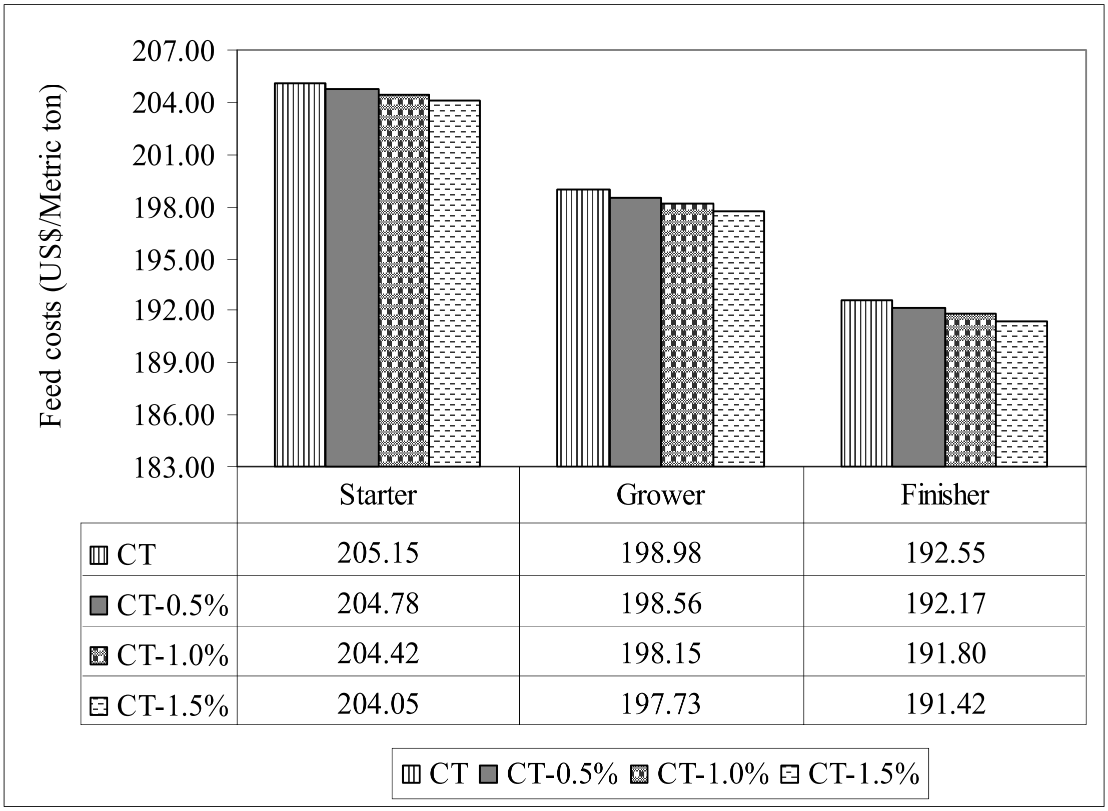
[2] Processing measurements are averaged means of 12 replicates of four birds each (two males and two females) with body weights close to pen average (2.38 kg) at 6 weeks of age.

[3] Because no relevant interactions were detected ($P > 0.05$), only the main effect means for gender are shown. For treatment effects, see table 5.

[4] Carcass = Chilled carcass (without blood, feathers, head, hocks, offal, and abdominal fat pad).

[5] Breast = Major + Minor.

[a, b] Values within column with different superscripts differ significantly ($P < 0.05$).



	Starter	Grower	Finisher
CT	205.15	198.98	192.55
CT-0.5%	204.78	198.56	192.17
CT-1.0%	204.42	198.15	191.80
CT-1.5%	204.05	197.73	191.42

Figure 3.1: Effect of up to 1.5% decrease in crude protein levels on feed costs of Cobb 500 broilers[1,2]

[1] Feedstuff prices (US$/1,000 kg): Corn, 144.00; Soybean meal, 245.00; Poultry by-product meal, 335.00; DL-Methionine, 2,200.00; Lysine.HCl, 1,980.00; L-Threonine, 2,494.80.

[2] Dietary Treatments: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.3%, CT-1.0%: 20.9%, and CT-1.5%: 20.6%]; [(Grower: 2 to 4wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%].

Table 3.7: Effect of decreasing crude protein levels on economics of Cobb 500 broiler[1]

Economic values, US$/MT[2,3]	CT	CT-0.5%	CT-1.0%	CT-1.5%
Feed costs/MT live BW	333.46	332.79	332.12	331.47
Feed cost savings/MT live BW[4]	----	0.66	1.32	1.99
Feed costs/MT carcass	427.56	426.71	425.86	425.01
Feed cost savings/MT carcass[4]	----	0.85	1.70	2.55
Feed costs/MT breast meat	2,391.29	2,386.54	2,381.79	2,377.04
Feed cost savings/MT breast meat[4]	----	4.75	9.50	14.25

[1] Average BW = 2.38 kg at 6 weeks of age; average carcass yield = 77.99%; average breast meat yield = 17.75%.
[1] MT (metric ton) = 1000 kg.
[2] Economic value for carcass, US$ 1.76/kg; breast meat, US$3.08/kg (USDA, June 2007). Prices for feedstuffs (Feedstuffs, 2007): corn (US$ 144.00/MT), soybean meal (US$ 245.00/MT), and poultry by-product meal (US$335.00/MT).
[3] Feed cost savings relative to CT.

CHAPTER IV

EFFECTS OF REDUCED PROTEIN DIETS ON PRODUCTION AND ECONOMIC PERFORMANCE OF ROSS 308 BROILERS FED FROM HATCH TO SEVEN WEEKS OF AGE

ABSTRACT

A study was conducted to determine the effects of reduced dietary crude protein (CP) on performance of Ross 308 broilers fed from hatch to week 7. Fourteen hundred and forty straight-run broiler chicks were randomly assigned to four treatments with 12 replicate pens containing 30 birds each. Diets were formulated to be isocaloric and to have the minimum digestible level for lysine (Lys), and the same minimum ideal amino acid ratios to lysine for TSAA, threonine (Thr), valine (Val), isoleucine (Ile), arginine (Arg), and tryptophan (Trp) across the four feeding phases [starter (0 to 2 wks), grower (2 to 4wks), finisher (4 to 6 wks), and withdraw (6 to 7 wks)]. An industry standard diet served as the control (CT). The remainder of the treatments (CT-0.5%, CT-1.0%, and CT-1.5%) had CP reduced in 0.5% increments. Diets were formulated to contain the following levels of CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.5%, CT-1.0%:

21.0%, and CT-1.5%: 20.5%]; [(Grower: 2 to 4wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%]; [(Withdraw: 6 to 7wks): CT: 16.5%, CT-0.5%: 16.0%, CT-1.0%, 15.5%, and CT-1.5%, 15.0%]. Feed and birds were weighed at 2, 4, 6, and 7 weeks of age for feed to gain calculation. At week 7, four birds per pen (48 birds/trt; two males and two females) were sacrificed and abdominal fat pad was removed and carcass weighed for fat pad and carcass yield determination. Then, carcasses were chilled for 2 hours and cut up for meat yield determination. Feed cost savings (FCS) per metric ton (MT) of live body weight (BW), FCS/MT carcass, FCS/MT breast meat were calculated. Treatments had no effect (P > 0.05) on performance throughout the 7-week period. At week 7, treatments had no effect (P > 0.05) on carcass, fat pad, and breast meat yields. For FCS, when CT-1.5% was compared to CT, FCS was of US$ 2.08/MT of live BW; US$ 2.65/MT carcass, and US$ 9.02/MT breast meat. To conclude, a decrease of CP by 1.5% did not affect performance and processing attributes at 7 weeks of age and resulted in significantly higher revenues.

INTRODUCTION

Dietary crude protein (CP) level, beside its determinant effect on weight gain and feed efficiency of broiler chicks, has a marked effect on the quality of their carcasses, such as yields of edible meat and fat content (Bartov and Plavnik, 1998). Diets with levels of CP levels lower than recommended result in reduction of yields of meat (Moran *et al.*, 1992) and increase in abdominal fat content (Moran *et al.,* 1992; Bartov, 1996). There are great discrepancies, however, in attempts that have been made to feed broiler chicks low CP diets that are supplemented with synthetic amino acids (Han *et al.*, 1992). While some authors have reported decreases in meat yield (Moran *et al.,* 1992) and performance (Edmonds *et al.*, 1985; Mendonça and Jensen, 1989) others report no effect on meat yield and performance (Parr and Summers, 1991; Deschepper and De Groote, 1995; Aletor *et al.,* 2000; Guaiume, unpublished data) when low CP diets supplemented with amino acids were fed.

The decrease in performance may be the result of reducing CP levels below recommendation without proper amino supplementation. Keshavarz and Austic (2004) reported that the decrease in performance observed when low CP diets were fed may have been caused by formulating diets with insufficient amino acid level as a result of inadequate knowledge about essential amino acid requirements, amino acid content of feed ingredients, the digestibility and bioavailability of amino acids in feed ingredients, and the proper ratio among essential amino acids in the low CP diets.

Recent advances in commercial production of crystalline amino acids such as the essential amino acids (EAA) lysine, methionine, and threonine make the inclusion of these amino acids more economically feasible for use in animal feeds (Han *et al.*, 1992). Addition of synthetic amino acids to diets permits a reduction of dietary CP content and at the same time provides the needs of essential amino acids.

Meeting amino acid needs represents a large portion of diet costs, and over formulating is costly whereas under formulating may negate economic returns due to suboptimal growth and meat yields (Kidd *et al.*, 2005). Thus, the profitability of broiler production enterprises can also be affected by changes in dietary crude protein (Eits *et al.*, 2005). In an earlier study performed at the University of Missouri – Columbia (Guaiume*,* unpublished data), Cobb 500 broilers were fed from hatch to 6 weeks of age diets with levels of crude protein reduced by 1.5% (compared to Agristats, 2005). No effect on meat yield, abdominal fat pad, and performance was observed throughout the 6-week period. In addition, as the levels of CP were decreased and the inclusion of synthetic amino acids increased, there was a decrease in feed costs. When the diet with 1.5% reduction of CP was compared to the control, feed cost savings were of US$ 1.99/metric ton of live BW produced, US$ 2.55/metric ton of carcass, and US$ 14.25/metric ton of breast meat.

Because birds from the Ross strain have higher percentage of breast meat yield and are raised until later ages than Cobb 500 broilers, the same diets (Table 4.2) were offered to Ross 308 broilers with the objective to determine if a 1.5% decrease in CP with adequate amino acid supplementation would affect performance and meat yield of broilers fed from hatch to week 7.

MATERIAL AND METHODS

Experimental facility:

The experiment was conducted in a facility containing 48 floor pens on concrete with side wall curtains. Each floor pen measured 1.80 x 1.20 m (0.072 m^2/bird) and contained one tube feeder, a nipple drinker line (five nipples per pen), and used litter. From day 1 to 7, supplemental pan feeders were used in each pen to ensure good feed consumption at placement. The facility was heated with electric heat lamps in each pen and propane heaters were placed in the center of the aisle.

Experimental Design and Animal Husbandry:

Fourteen hundred and forty industry standard one-day-old straight-run Ross 308 broiler chicks were purchased from a commercial hatchery (Townsend Inc., Baytesville, AR), weighed, and randomly assigned to four treatments with 12 replicate pens containing 30 birds each from day 1.

The 48 floor pen facility was divided into six blocks, based on house location, and treatments were randomly allotted within blocks with two replicates per block. Chicks were maintained on a 23-h constant light schedule and allowed food and water *ad libitum.* Birds were monitored daily for signs of morbidity and mortality. The animal care and use protocol was reviewed and approved by the University of Missouri-Columbia Animal Care and Use Committee.

Dietary treatments:

Diets were least-cost formulated to be isocaloric and to have the same minimum digestible level for lysine (Lys), and the same minimum ideal amino acid ratios to lysine for TSAA, threonine (Thr), valine (Val), isoleucine (Ile), arginine (Arg), and tryptophan (Trp) across the four feeding phases [starter (0 to 2 wks), grower (2 to 4 wks), finisher (4 to 6 wks), and withdraw (6 to 7 wks)] (Table 4.1). The ratios to lysine were based on Baker's recommendation (Baker, 1994) (Table 4.2). Dietary treatments included four different dietary levels of CP. The control diets (CT) contained the current CP levels fed by the industry (Agristats, 2005) for each feeding phase whereas the remainder of the treatments (CT-0.5%, CT-1.0%, and CT-1.5%) had CP levels reduced in 0.5% increments for all feeding phases (Table 4.3). Therefore, CT had the highest level of crude protein and CT-1.5% the lowest level. The levels of crude protein for each of the dietary treatments per feeding phase are listed on Table 4.2. To originate the dietary treatments, two diets were mixed (CT and CT-1.5%) and then blended together in different proportions to originate the intermediate treatments (CT-0.5% and CT-1.0). For CT-0.5%, 2/3 of the mix corresponded to diet CT and the remaining 1/3 to diet CT-1.5% whereas for CT-1.0%, 1/3 of the mix corresponded to CT and 2/3 to CT-1.5%. This treatment regimen continued throughout the 7-week period.

Feed samples were sent to Degussa Corporation (Kennesaw, GA, USA) for CP and amino acid analyses and the coefficient of digestibility of amino acids was obtained from Ajinomoto Heartland, LLC (Chicago, IL, USA).

Performance data:

Body weight gain and feed intake was recorded at weeks 2, 4, 6 1/2, and 7 and used for feed to gain calculation. Mortality was also recorded on a pen basis and feed consumption data were adjusted. Mortality remained low and occurred randomly throughout the treatments. Therefore, mortality data were not analyzed statistically.

Carcass Measurements:

At the end of week 7, four birds per pen (two males and two females), totaling 48 birds per treatment were randomly selected, weighed, wing-banded, and transported to the processing plant, where they remained without feed, but with access to water for 12 hours prior to processing. Birds were hung on shackles, stunned with electric shock, and bled for 5 minutes after severance of the jugular vein. Birds remained on shackles and were dipped in a hot water scalder for 45 seconds with the thermostat set at 60ºC. They were then transferred to an automated drum picker and defeathered for 60 seconds. After hocks and heads were removed, birds were eviscerated and washed manually. Therefore, carcass consisted of the whole bird without blood, feathers, hocks, heads, offal, and abdominal fat. Abdominal fat and carcasses were weighed to determine abdominal fat pad yield. Carcasses were then rewashed and chilled in an ice bath for a minimum of 2 hours. After 2 hours, breast muscles (*pectoralis major* and *pectoralis minor)*, thighs, legs, and wings were severed from the chilled carcasses on a manual deboning line, weighed, and recorded for determination of parts yield. All carcass measurements were expressed as percentage over live body weight at processing.

Economical Analysis:

A program was designed to determine feed costs per metric ton (MT) of live BW, carcass, and total breast meat. Feed cost savings (FCS)/MT of live BW, carcass, and breast meat were determined for each of the dietary treatments that had a decrease in crude protein by comparing their costs to the control diet cost of the correspondent feeding phase (Table 4.7). Because there were no statistical differences among the treatments, all the numbers obtained from the different treatments were averaged to determine FCS (average BW of 2.94 kg/bird; average carcass yield of 78.42%; and average total breast meat yield of 29.42%). Feed ingredient prices were obtained from Feedstuffs (June, 2007) and they were Kansas City prices. The prices for synthetic amino acids were obtained from the University of Missouri's Feed mill. The prices were, in US$/metric ton: corn (144.00); soybean meal (245.00); poultry by product (335.00); DL-Methionine (2,200.00); Lysine.HCl (1,980.00); L-Threonine (2,494.80). Prices for broiler chicken items were obtained from USDA Market News (June, 2007). Carcass and total breast meat (boneless) values were US$ 1.76/kg and US$ 3.08/kg, respectively.

Statistical Analysis:

Pen was the experimental unit for all analyses. Performance data were analyzed as a completely randomized block design (CRBD) using the Mixed procedure (Proc Mixed) of SAS (SAS Institute, 2003) by the following model:

$$Y_{ijk} = \mu + B_i + T_j + B(T)_{i(j)} + \epsilon_{k(ij)}$$

Where μ is the common mean; Bi is the effect if the ith block; Tj is the effect of jth treatment; $B(T)_{i(j)}$ is the effect of the jth treatment within the ith block, and $\epsilon_{k(ij)}$ is the random error.

For the processing data, the effect of gender and the gender x treatment interactions were fitted in the statistical model. Processing data were also analyzed as a CRBD using Proc Mixed by the following model:

$$Y_{ijkl} = \mu + B_i + T_j + G_k + TG_{ik} + B(TxG)_{i(jk)} + \epsilon_{l(ijk)}$$

Where μ is the common mean; Bi is the effect if the ith block; Tj is the effect of jth treatment; G_k is the effect of the kth gender; TG_{ik} is the interaction between the effect of jth treatment and the effect of the kth gender; $B(TxG)_{i(jk)}$ is the interaction between the effect of jth treatment and the effect of the kth gender within the ith block, and $\epsilon_{k(ij)}$ is the random error.

Means showing significance in ANOVA were compared using Fisher's protected least significant difference procedure (Snedecor and Cochran, 1989). All statements of difference were based on a significance of $P < 0.05$. Linear and quadratic polynomial contrasts were performed using Proc Mixed of SAS (SAS Institute, 2003).

RESULTS

Performance:

Results for feed intake (FI), body weight gains (BWG), and feed to gain (FDGN) are demonstrated in Table 4.4. From 0 to 14 d of age, birds fed diet CT-1.0% and CT-1.5% had worse FI when compared to CT and CT-0.5% ($P = 0.022$). Treatments had no effect ($P > 0.05$) on BWG and FGDN from 0 to 2 weeks. For the 0 to 28 d period, there was a linear worsening in FDGN as CP decreased ($P = 0.023$). However, CT-0.5% and CT-1.0% did not differ from CT. When the data were analyzed from 0 to 42 d and 0 to 49 d, treatments had no effect ($P > 0.05$) on any of the variables analyzed.

Processing measurements:

Processing attributes are listed on Table 4.5. At week 7, treatments had no effect ($P > 0.05$) on carcass yield, percentage of abdominal fat pad, leg, drum, wing, and breast meat yield. In addition, Table 4.6 lists the effect of gender on the processing attributes. Females had higher ($P > 0.05$) percentage of carcass yield, fat pad, leg, and minor yield when compared to males (carcass: females, 79.50%; males, 77.35%; fat pad: females, 3.04%; males, 2.44%; and minor: females, 5.43%; males, 5.09%). In contrast, males had higher percentage ($P < 0.0001$) of leg yield when compared to females (males 12.87% and females 12.21%). Gender had no effect on thigh, wing, major, and total breast yield. No gender by treatment interactions was observed.

Economical Analysis:

Feed costs decreased as CP levels were decreased in the diets and this effect was consistent for each of the feeding phases. Therefore, as the levels of CP decreased, there was a decrease in feed costs (Figure 4.1). Moreover, as diet costs decreased, there was a reduction in feed costs/MT of BW, carcass, and total breast meat (Table 4.7) of up to US$ 2.08/MT of live BW, US$ 2.65/MT of carcass, and US$ 9.02/MT of breast meat when CT-1.5% was compared to CT.

DISCUSSION

This study examined the effect of the reduction of CP in diets on performance and meat yield of broilers. Based on the ideal protein concept, it is possible to reduce CP levels in broiler diets and fulfill the amino acids requirements with the addition of synthetic amino acids (Faria Filho *et al.*, 2005). Guaiume (unpublished data) fed Cobb 500 broilers diets with CP levels decreased by 1.5% comparing to an industry type diet (Agristats, 2005) and supplemented the diets with synthetic methionine, lysine, and threonine. The authors found no difference in performance, carcass and breast meat yields at 6 weeks of age. Feed costs were also decreased as the levels of CP were reduced.

In this present study, Ross 308 broilers were also fed diets with CP levels reduced by 1.5% and supplemented with amino acids in order to maintain the same minimum amino requirements and ratios to lysine as the control diets. No negative effect was observed on performance, carcass, and breast meat yields at 7 weeks of age. Unlike previous studies, when attempts to decrease CP levels were unsuccessful, in this present study even though CP level were decreased, the minimum digestible amino acid requirements were kept constant across the four dietary treatments and minimum digestible values were included to arginine, valine, isoleucine, leucine, and tryptophan because these amino acids are not yet available commercially. Therefore, these amino acids determined how low the CP level could be reduced without provoking any known amino acid deficiency. Hackenhaar and Lemme (2005) reported that to reduce CP levels in broilers' diets some precautions should be taken such as amino acid content and digestibility of the ingredient utilized as well as minimum requirements for the amino acids methionine, lysine, threonine, valine, arginine, isoleucine, and tryptophan.

In previous studies, the loss of performance may have been attributed to the fact that CP levels were decreased beyond practical levels and without proper amino acid supplementation even when CP levels ranged from 4 to 7% below NRC requirements (Edmonds *et al.*, 1985; Mendonça and Jensen, 1989). Low crude protein diets can negatively affect feed intake and feed efficiency because it does not supply the necessary levels of non-essential amino acids (Sklan and Plavnik, 2002) for which a requirement is not yet known. In addition, as the levels of CP are reduced, the protein sources are replaced by corn which may create a glycine deficiency because (total glycine content (%): corn, 0.33; poultry by-product, 3.95; and soybean meal, 2.05). Glycine is considered a semi-essential amino acid in young broiler chicks (Graber and Baker, 1973) since chicks can synthesize Gly, but there is still a considerable requirement for Gly to be supplied by the diet. Therefore, when low CP diets are formulated, special attention should be given not only to lysine, methionine, and threonine because for these synthetic forms are commercially available, but to the non-essential amino acids as well as to their ratios to lysine.

With respect to the increased levels of abdominal pad, the results obtained in this experiment are in agreement with the literature where abdominal fat content increased with decreased levels of crude protein (Sklan and Plavnik, 2002; Alleman *et* al., 2000; Jackson et *al.,* 1982). The hypothesis is that as CP is reduced, there is an increase in the net energy of the diet because less energy will be spent to extreme the excess CP; therefore, more energy is available. However, it is beyond the scope of this report to accept or reject this hypothesis because the diets were formulated to be isocaloric.

CONCLUSION

Overall, these results indicate that a decrease of CP by 1.5% with adequate amino acid supplementation, as compared with industry standards, did not affect performance and meat yield of Ross 308 broilers at 7 weeks of age, and resulted in significantly higher revenues.

Table 4.1: Minimum digestible lysine level and the ratios of essential amino acids to lysine utilized for the four dietary treatments for each feeding phase

	FEEDING PHASES[1]				
	Starter	Grower	Finisher	Withdraw	Ratios[2]
Lysine[3], %	1.09	0.97	0.84	0.79	100
Amino Acids, %					
Threonine	0.720	0.650	0.560	0.525	66
Methionine	0.495	0.440	0.380	0.360	45
TSAA	0.810	0.730	0.630	0.600	74
Tryptophan	0.170	0.150	0.130	0.125	15
Isoleucine	0.730	0.645	0.550	0.530	65
Valine	0.850	0.750	0.647	0.620	77
Arginine	1.123	1.000	0.870	0.810	102

[1] Starter diet was fed from 0 to 14 days of age; Grower from 14 to 28 days; Finisher: 28 to 42 days; and Withdraw from 42 to 49 days of age.
[2] Ratios based on Baker's recommendation (Baker, 1994).
[3] Lysine and all amino acids are expressed in a digestible basis.

Table 4.2: Crude protein levels of the different dietary treatments per feeding phase.

	CRUDE PROTEIN LEVELS (%)[1,2]			
Feeding phases[3]:	Starter	Grower	Finisher	Withdraw
Treatments:				
CT	22.33 (22.0)	20.15 (20.0)	17.81 (17.5)	16.70 (16.5)
CT-0.5%	21.72 (21.5)	19.39 (19.5)	17.29 (17.0)	16.07 (16.0)
CT-1.0%	21.10 (21.0)	19.34 (19.0)	16.18 (16.5)	15.67 (15.5)
CT-1.5%	20.70 (20.5)	18.12 (18.5)	16.39 (16.0)	15.30 (15.0)

[1] To originate CT-0.5% and CT-1.0%, CT and CT-1.5% diets were mixed and then blended together in different proportions. For CT-0.5%, 2/3 of the mix corresponded to diet CT and the remaining 1/3 to diet CT-1.5% whereas for CT-1.0%, 1/3 of the mix corresponded to CT and 2/3 to CT-1.5% for all feeding phases.
[2] Analyzed values (calculated values). Diets were analyzed by Degussa Corp. (Kennesaw, GA).
[3] Starter diet was fed from 0 to 14 days of age, Grower from 14 to 28 days, and Finisher: 28 to 42 days, and Withdraw from 42 to 49 days.

Table 4.3: Diet composition of the control (CT) and the diet with the lowest level of crude protein (CT-1.5%)[1]

	TREATMENTS[2]			
	Starter		Grower	
Ingredients, %	CT	CT-1.5%	CT	CT-1.5%
Corn	57.69	62.25	63.00	67.93
Soybean meal	33.67	29.67	28.75	24.43
Poultry by-product	3.50	3.50	3.50	3.50
Animal & vegetal fat	2.15	1.35	2.04	1.18
Dicalcium phosphate	1.21	1.25	0.99	1.03
Limestone	0.86	0.85	0.86	0.85
DL Methionine	0.22	0.25	0.18	0.22
Lysine.HCl	0.00	0.11	0.00	0.13
L-Threonine	0.00	0.06	0.00	0.06
Others[3]	0.72	0.72	0.69	0.69
Diet cost, US$/MT[4]	205.15	204.05	198.98	197.73
Chemical composition (amino acids on a total basis[5]) as analyzed:				
ME, Kcal/kg[6]	3,067	3,067	3,122	3,122
Crude Protein[7], %	22.33 (22.0)	20.70 (20.5)	20.15 (20.0)	18.12 (18.5)
Lysine, %	1.29	1.27	1.18	1.13
Arginine, %	1.58	1.44	1.47	1.28
Methionine, %	0.57	0.59	0.51	0.52
TSAA, %	0.93	0.93	0.85	0.83
Threonine, %	0.90	0.90	0.85	0.79
Isoleucine, %	0.97	0.86	0.89	0.82
Leucine, %	1.92	1.79	1.83	1.69
Valine, %	1.10	0.98	1.01	0.95
Glycine, %	1.14	1.07	1.09	0.97
Serine, %	1.12	1.06	1.06	0.90

Table 4.3 *(cont)*:

	TREATMENTS[2]			
	Finisher		Withdrawal	
Ingredients, %	CT	CT-1.5%	CT	CT-1.5%
Corn	68.95	73.89	71.73	75.85
Soybean meal	22.65	18.31	20.12	16.54
Poultry by-product	3.50	3.50	3.50	3.50
Animal & vegetal fat	2.19	1.33	2.32	1.56
Dicalcium phosphate	1.06	1.10	0.71	0.74
Limestone	0.87	0.86	0.84	0.83
DL Methionine	0.13	0.17	0.12	0.15
Lysine.HCl	0.02	0.15	0.03	0.15
L-Threonine	0.00	0.06	0.00	0.05
Others[3]	0.64	0.64	0.63	0.63
Diet cost, US$/MT[4]	192.55	191.42	189.92	188.90
Chemical composition (amino acids on a total basis[5]) as analyzed:				
ME, Kcal/kg[6]	3,190	3,190	3,230	3,230
Crude Protein[7], %	17.81 (17.5)	16.39 (16.0)	16.70 (16.5)	15.30 (15.0)
Lysine, %	1.01	0.88	0.93	0.91
Arginine, %	1.25	0.95	1.13	1.03
Methionine, %	0.43	0.43	0.38	0.37
TSAA, %	0.72	0.68	0.64	0.63
Threonine, %	0.72	0.64	0.67	0.64
Isoleucine, %	0.78	0.60	0.70	0.62
Leucine, %	1.61	1.31	1.50	1.42
Valine, %	0.90	0.72	0.81	0.73
Glycine, %	0.95	0.80	0.88	0.82
Serine, %	0.89	0.69	0.97	0.78

[1] Diets were formulated to contain the following levels of CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.5%, CT-1.0%: 21.0%, and CT-1.5%: 20.5%]; [(Grower: 2 to 4wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%]; [(Withdraw: 6 to 7wks): CT: 16.5%, CT-0.5%: 16.0%, CT-1.0%, 15.5%, and CT-1.5%, 15.0%].
[2] To originate the intermediate treatments CT-0.5% and CT-1.0%, CT and CT-1.5% diets were mixed and then blended together in different proportions. For CT-0.5%, 2/3 of the mix corresponded to diet CT and the remaining 1/3 to diet CT-1.5% whereas for CT-1.0%, 1/3 of the mix corresponded to CT and 2/3 to CT-1.5% for all feeding phases.
[3] Others = NaCl: Starter, 0.42%; Grower, 0.39%, and Finisher, 0.34%); Selenium premix, 0.025% supplying 0.15 mg Se/kg diet; copper sulfate pentahydrate, 0.012% or 30.25 mg Cu/kg diet; Mineral mix (0.10%) mg supplied per kg of diet: Ca, 25; Fe, 60; Mg, 26.8, Mn, 110; Zn, 110; I, 2; Vitamin mix (0.075%) supplied per kilogram of diet: vitamin D_3, 2,625 ICU; vitamin A, 6,000 IU; vitamin E, 9.4 IU; niacin, 37.5mg; D-pantothenic acid, 11.25mg; riboflavin, 4.5mg; pyridoxine, 1.5mg; menadione, 1.13mg; folic acid, 0.94mg; thiamine, 0.75 mg; biotin, 0.15 mg; vitamin B12, 7.5 µg; Coccidiostatic, 0.075% (60% sodium monensin premix, Elanco Animal Health, Greenfield, IN).
[4] MT (metric ton) = 1,000 kg.
[5] Feed samples sent to Degussa Corp., Kennesaw, GA, USA for CP and AA analyses.
[6] Calculated values.
[7] Analyzed values (calculated values).

Table 4.4: Effect of decreasing crude protein levels on performance of Ross 308 broilers FED from hatch to six weeks of age[1,2]

	0 to 14 days			0 to 28 days			0 to 42 days			0 to 49 days		
Treatments[2]	FI	BWG	FDGN	FI	BWG	FDGN	FI	BWG	FDGN	FI	BWG	FDGN
	(g)	(g)	(g:g)	(kg)	(kg)	(kg:kg)	(kg)	(kg)	(kg:kg)	(kg)	(kg)	(kg:kg)
CT	413^{a}	291	1.42	1.68^{a}	1.12	1.51^{a}	3.90	2.23	1.75	5.31	2.87	1.85
CT-0.5%	439^{ab}	292	1.50	1.73^{b}	1.13	1.52^{ab}	4.00	2.28	1.76	5.45	2.93	1.86
CT-1.0%	451^{b}	297	1.52	1.73^{b}	1.13	1.53^{ab}	3.99	2.23	1.76	5.46	2.94	1.87
CT-1.5%	419^{b}	286	1.46	1.68^{a}	1.10	1.54^{b}	3.98	2.23	1.78	5.51	2.87	1.90
SEM	*0.007*	*0.003*	*0.020*	*0.012*	*0.010*	*0.009*	*0.036*	*0.034*	*0.009*	*0.077*	*0.040*	*0.017*
							Probabilities					
ANOVA	0.022	0.174	0.057	0.023	0.074	0.104	0.168	0.608	0.314	0.250	0.388	0.257
Linear	0.472	0.478	0.184	0.968	0.114	0.023	0.129	0.816	0.056	0.054	0.987	0.086
Quadratic	0.001	0.081	0.004	0.001	0.018	0.607	0.102	0.389	0.769	0.499	0.077	0.317

[1] Data are averaged means of 12 replicates of 30 birds each.
[2] FI = feed intake; BWG = body weight gain; FDGN = feed to gain.
[3] Diets were formulated to contain the following levels of CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.5%, CT-1.0%: 21.0%, and CT-1.5%: 20.5%]; [(Grower: 2 to 4wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%]; [(Withdraw: 6 to 7wks): CT: 16.5%, CT-0.5%: 16.0%, CT-1.0%, 15.5%, and CT-1.5%, 15.0%].
[a, b] Values within column with different superscripts differ significantly ($P < 0.05$).

Table 4.5: Effect of decreasing crude protein levels on processing responses, expressed as percentage over live body weight, of Ross 308 broilers[1]

	CARCASS[2]	FAT PAD	LEG	THIGH	WING	MAJOR	MINOR	BREAST[3]
Treatments[4]				(%)				
CT	79.50	2.53^{b}	12.38	15.31^{b}	11.19	24.52	5.29	29.86
CT-0.5%	78.20	2.56^{b}	12.58	15.53^{a}	11.07	23.72	5.34	29.14
CT-1.0%	78.25	2.89^{a}	12.71	15.39^{ab}	11.03	24.40	5.32	29.64
CT-1.5%	77.73	2.98^{a}	12.48	16.25^{b}	11.12	24.12	5.07	29.04
SEM	*0.924*	*0.192*	*0.244*	*0.478*	*0.291*	*0.510*	*0.188*	*0.550*
				Probabilities				
ANOVA	0.200	0.065	0.372	0.085	0.940	0.257	0.304	0.203
Linear	0.203	0.052	0.375	0.050	0.808	0.280	0.133	0.200
Quadratic	0.665	0.680	0.087	0.407	0.402	0.375	0.253	0.674

[1] Processing measurements are averaged means of 12 replicates of four birds each (two males and two females) with body weights close to pen average (2.94 kg) at 7 weeks of age.
[2] Carcass = Chilled carcass (without blood, feathers, head, hocks, offal, and abdominal fat pad).
[3] Breast = Major + Minor.
[4] Diets were formulated to contain the following levels of CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.5%, CT-1.0%: 21.0%, and CT-1.5%: 20.5%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6 wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%]; [(Withdraw: 6 to 7 wks): CT: 16.5%, CT-0.5%: 16.0%, CT-1.0%, 15.5%, and CT-1.5%, 15.0%].

Table 4.6: Effect of decreasing crude protein levels[1] on processing responses, expressed as percentage over live body weight, of male and female Ross 308 broilers[2,3]

	CARCASS[4]	FAT PAD	LEG	THIGH	WING	MAJOR	MINOR	BREAST[5]
Gender				(%)				
Female	79.50[a]	3.04[a]	12.21[b]	15.62	11.23	24.38	5.43[a]	29.82
Males	77.35[b]	2.44[b]	12.87[a]	15.61	10.98	23.95	5.09[b]	29.02
SEM	*0.924*	*0.192*	*0.244*	*0.478*	*0.291*	*0.510*	*0.188*	*0.550*
				Probabilities				
TRT	0.065	0.200	0.372	0.085	0.940	0.257	0.304	0.203
Gender	0.001	0.001	<.0001	0.980	0.185	0.143	0.004	0.150
Gender X TRT	0.570	0.938	0.364	0.303	0.767	0.832	0.611	0.691

[1] Diets were formulated to contain the following levels of CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.5%, CT-1.0%: 21.0%, and CT-1.5%: 20.5%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6 wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%]; [(Withdraw: 6 to 7 wks): CT: 16.5%, CT-0.5%: 16.0%, CT-1.0%, 15.5%, and CT-1.5%, 15.0%].

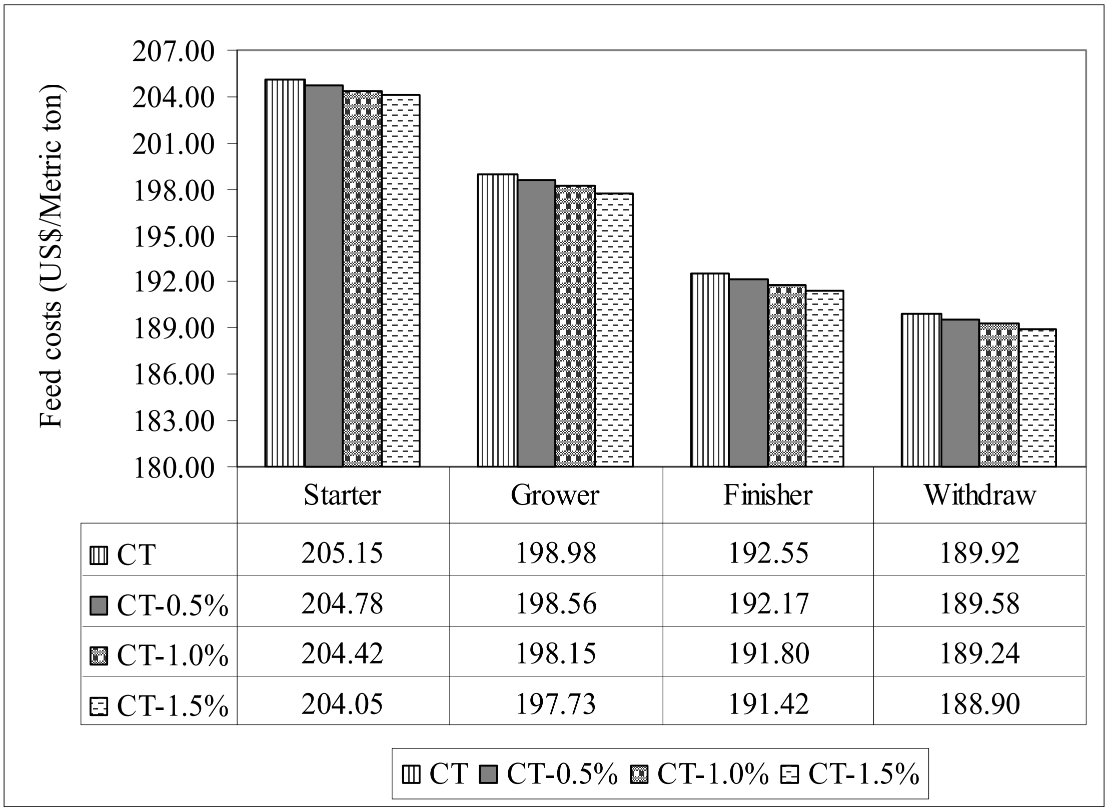
[2] Processing measurements are averaged means of 12 replicates of 4 birds each (2 males and 2 females) with body weights close to pen average (2.94 kg) at 7 weeks of age.

[3] Because no relevant interactions were detected ($P > 0.05$), only the main effect means for gender are shown. For treatment effects, see table 5.

[4] Carcass = Chilled carcass (without blood, feathers, head, hocks, offal, and abdominal fat pad).

[5] Breast = Major + Minor.

[a, b] Values within column with different superscripts differ significantly ($P < 0.05$).



	Starter	Grower	Finisher	Withdraw
CT	205.15	198.98	192.55	189.92
CT-0.5%	204.78	198.56	192.17	189.58
CT-1.0%	204.42	198.15	191.80	189.24
CT-1.5%	204.05	197.73	191.42	188.90

Figure 4.1: Effect of up to 1.5% decrease in crude protein levels on feed costs of Ross 308 broilers[1,2]

[1] Feedstuff prices (US$/1,000 kg): Corn, 144.00; Soybean meal, 245.00; Poultry by-product meal, 335.00; DL-Methionine, 2,200.00; Lysine.HCl, 1,980.00; L-Threonine, 2,494.80.
[2] Dietary Treatments CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.5%, CT-1.0%: 21.0%, and CT-1.5%: 20.5%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6 wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%]; [(Withdraw: 6 to 7 wks): CT: 16.5%, CT-0.5%: 16.0%, CT-1.0%, 15.5%, and CT-1.5%, 15.0%].

Table 4.7: Effect of decreasing crude protein levels on economics of Ross 308 broilers[1]

Economic values, US$/MT[2,3]	CT	CT-0.5%	CT-1.0%	CT-1.5%
Feed costs/MT live BW	359.11	358.42	357.73	357.03
Feed cost savings/MT live BW[4]	----	0.69	1.39	2.08
Feed costs/MT carcass	457.94	457.05	456.17	455.28
Feed cost savings/MT carcass[4]	----	0.88	1.77	2.65
Feed costs/MT breast meat	1,556.58	1,553.54	1,550.53	1,547.53
Feed cost savings/MT breast meat[4]	----	3.01	6.01	9.02

[1] Average BW = 2.94 kg at 7 weeks of age; average carcass yield = 78.42%; average breast meat yield = 29.42%.

[1] MT (metric ton) = 1,000 kg.

[2] Economic value for carcass, US$ 1.76/kg; and breast meat, US$3.08/kg (USDA, June 2007). Prices for feedstuffs (Feedstuffs, 2007): corn (US$ 144.00/MT), soybean meal (US$ 245.00/MT), and poultry by-product meal (US$335.00/MT).

[3] Feed cost savings relative to CT.

CHAPTER V

EFFECTS OF REDUCED PROTEIN DIETS ON PERFORMANCE AND ECONOMICS OF ROSS 708 BROILERS FED FROM HATCH TO EIGHT WEEKS OF AGE

ABSTRACT

A study was conducted to determine the effects of reduced dietary crude protein on performance of Ross 708 broilers at 56 days of age. 1440 straight-run broiler chicks were assigned to four treatments (12 replicate pens of 30 birds per treatment). Diets were formulated to have the minimum digestible level for lysine, and same ratios to lysine for TSAA, threonine, valine, isoleucine, and tryptophan across the four phases (starter, grower, finisher, and withdrawal). An industry standard diet was the control (CT). The remainder of the treatments (CT-0.5%, CT-1.0%, and CT-1.5%) had CP reduced in 0.5% increments. Feed and birds were weighed at 14, 28, 45, and 56 days of age for feed to gain calculation. At 56 d, four birds per pen (48/trt) were sacrificed and meat yield was determined. Feed cost savings (FCS) per metric ton (MT) of live BW, carcass, and breast meat were determined. Treatments had no effect ($P > 0.05$) on performance throughout

the 8-week period. Treatments had no effect on carcass and breast meat yield at 8 weeks. However, there was a linear increase ($P > 0.05$) in abdominal fat pad yield as the level of crude protein was reduced (CT, 1.87%, CT-0.5%, 2.09%, CT-1.0%, 2.19%, and CT-1.5%, 2.12%). For MT of live BW, relative to CT, FCS were US$ 2.64 when CT-1.5% was fed; for MT of carcass, US$ 3.69; and for MT of breast meat, US$ 15.47. To conclude, a decrease of CP by 1.5% did not affect performance, carcass, and meat yield, and resulted in higher revenues.

INTRODUCTION

Formulating broilers diets on a digestible amino acid basis and utilizing the economically feasible commercial amino acid supplements (i.e. methionine, lysine, and threonine) results in diets marginally reduced in crude protein (CP) that support equal growth to diets containing higher crude protein (Corzo *et al.*, 2005; Kidd *et al.*, 2002). A further reduction in crude protein will render isoleucine or valine as the next limiting amino acid in broiler diets supplemented with methionine, lysine, and threonine. As a result, there are conflicting reports on the effects of feeding low crude protein amino acid-supplemented diets to broiler chickens (Aletor *et al.*, 2000). While some studies have reported impaired weight gain and feed efficiency when broilers were fed low protein diets (Edmonds *et al.*, 1985; Fancher and Jensen, 1989a; Holsheimer and Janssen, 1991; Jensen, 1991; Moran *et al.*, 1992; and Bregendahl *et al.*, 2002), others have reported identical performance with low protein-amino acid supplemented diets (Lipstein *et al.*, 1975; Schutte, 1987; Parr and Summers, 1991; Deschepper and De Groote, 1995; Yamazaki *et al.*, 1996, 1998; Aletor *et al.,* 2000). The most consistent observation in these studies has been the increased deposition of abdominal fat in low protein fed chickens (Aletor *et al.*, 2000).

Aletor *et al.* (2000) reported that in all these investigations, there were three objectives with conflicting interests. The first, from a production standpoint, is the need to maintain optimal and economic poultry productivity. The second, from the consumer standpoint, is to maintain desirable carcass characteristics and composition. Finally, the compelling need to protect the environment via decreased nitrogen excretion (Aletor *et al.*, 2000).

It is generally accepted that the CP in the diet should represent a balance of essential and nonessential amino acids supporting the needs for maintenance and tissue accretion. In a corn and soybean meal diet, methionine, lysine, and threonine are considered to be the first, second, and third limiting amino acids and synthetic forms of these amino acids are commercially available (Emmert *et al.*, 2000). If the level of CP is reduced beyond threonine supplementation (the third limiting amino acid), the low CP diet may become deficient in other amino acids, such as valine and isoleucine because commercial sources of these amino acids are not yet available. Therefore, lowering dietary CP without regard to the balance of amino acids may reduce growth performance (Emmert *et al.*, 2000).

In previous studies performed at University of Missouri, Cobb 500 and Ross 308 broilers were fed diets with a 1.5% reduction in CP and no negative effects on performance and parts yield were observed (Guaiume, unpublished data). The difference between these studies and the studies reported in the literature where performance, meat yield or both was worsened by the decrease in CP is that the CP decrease was minimal (not more than 1.5%) and emphasis was given to the digestible amino acid levels in the diet rather than solely on CP. Therefore, although CP was reduced, amino acid ratios were maintained the same as the control diet by adding supplemental amino acid. In addition, valine and isoleucine served as the constraints to how much CP could be reduced without provoking any known amino acid deficiency.

The objective of this study was to determine if a 1.5% decrease in CP with adequate amino acid supplementation would affect biological and economical performance of Ross 708 broilers fed from hatch to week 8.

MATERIAL AND METHODS

Experimental facility:

The experiment was conducted in a facility containing 48 floor pens on concrete with side wall curtains. Each floor pen measured 1.80 x 1.20 m (0.072 m^2/bird) and contained one tube feeder, a nipple drinker line (five nipples per pen), and used litter. From day 1 to 7, supplemental pan feeders were used in each pen to ensure good feed consumption at placement. The facility was heated with electric heat lamps in each pen and propane heaters were placed in the center of the aisle.

Experimental Design and Animal Husbandry:

Fourteen hundred and forty industry standard one-day-old straight-run Ross 708 broiler chicks were purchased from a commercial hatchery (Townsend Inc., Baytesville, AR), weighed, and randomly assigned to four treatments with 12 replicate pens containing 30 birds each from day 1.

The 48 floor-pen facility was divided into six blocks, based on house location, and treatments were randomly allotted within blocks with two replicates per block. Chicks were maintained on a 23-h constant light schedule and allowed food and water *ad libitum.* Birds were monitored daily for signs of morbidity and mortality. The animal care and use protocol was reviewed and approved by the University of Missouri-Columbia Animal Care and Use Committee.

Dietary treatments:

Diets were least-cost formulated to be isocaloric and to have the same minimum digestible level for lysine (Lys), and the same minimum ideal amino acid ratios to lysine for TSAA, threonine (Thr), valine (Val), isoleucine (Ile), arginine (Arg), and tryptophan (Trp) across the four feeding phases [starter (0 to 2 wks), grower (2 to 4 wks), finisher (4 to 6 wks), and withdrawal (6 to 7 wks)] (Table 5.1). The ratios to lysine were based on Baker's recommendation (Baker, 1994) (Table 5.2). L-Threonine was then allowed to the least cost into the diets until the most limiting amino acids (isoleucine, valine, and tryptophan) restricted further reduction of intact protein. The control diets followed the current United States' industry (Agristats, 2005) diets in composition, energy, digestible amino acid levels, and feeding program Dietary treatments included four different dietary levels of CP. Crude protein levels of the test diets were CT: control; CT-0.5%, the control diet with 0.5% reduction in CP; CT-1.0%, CT with 1.0% reduction; and CT-1.5%, CT with 1.5% reduction in CP (Table 5.2). To originate the intermediate dietary treatments, two diets were mixed (CT and CT-1.5%) and then blended together in different proportions to originate the intermediate treatments (CT-0.5% and CT-1.0) (Table 5.3). For CT-0.5%, 2/3 of the mix corresponded to diet CT and the remaining 1/3 to diet CT-1.5% whereas for CT-1.0%, 1/3 of the mix corresponded to CT and 2/3 to CT-1.5%. This treatment regimen continued throughout the 8-week period.

Feed samples were sent to Degussa Corporation (Kennesaw, GA, USA) for CP and amino acid analyses and the coefficient of digestibility of amino acids was obtained from Ajinomoto Heartland, LLC (Chicago, IL, USA).

Performance data:

Body weight and feed intake was recorded at days 14, 28, 42, and 45, and 56 days of age and used for feed to gain calculation. Mortality was also recorded on a pen basis and feed consumption data were adjusted. Mortality remained low and occurred randomly throughout the treatments. Therefore, mortality data were not analyzed statistically.

Carcass Measurements:

At the end of week 8, four birds per pen (two males and two females), totaling 48 birds per treatment were randomly selected, weighed, wing-banded, and transported to the processing plant, where they remained without feed, but with access to water for 12 hours prior to processing. Birds were hung on shackles, stunned with electric shock, and bled for 5 minutes after severance of the jugular vein. Birds remained on shackles and were dipped in a hot water scalder for 45 seconds with the thermostat set at 60ºC. They were then transferred to an automated drum picker and defeathered for 60 seconds. After hocks and heads were removed, birds were eviscerated and washed manually. Therefore, carcass consisted of the whole bird without blood, feathers, hocks, heads, offal, and abdominal fat. Abdominal fat and carcasses were weighed to determine abdominal fat pad yield. Carcasses were then rewashed and chilled in an ice bath for a minimum of 2 hours. After 2 hours, breast muscles (*pectoralis major* and *pectoralis minor)*, thighs, legs, and wings were severed from the chilled carcasses on a manual deboning line, weighed, and recorded for determination of parts yield. All carcass measurements were expressed as percentage over live body weight at processing.

Economical Analysis:

A program was designed to determine feed costs per metric ton (MT) of live BW, carcass, and total breast meat. Feed cost savings (FCS)/MT of live BW, carcass, and breast meat were determined for each of the dietary treatments that had a decrease in crude protein by comparing their costs to the control diet cost of the correspondent feeding phase (Table 5.7). Because there were no statistical differences among the treatments, all the numbers obtained from the different treatments were averaged to determine FCS (average BW of 2.93 kg/bird; average carcass yield of 71.49%; and average total breast meat yield of 23.85%). Feed ingredient prices were obtained from Feedstuffs (June, 2007) and they were Kansas City prices. The prices for synthetic amino acids were obtained from the University of Missouri's Feed mill. The prices were, in

US$/metric ton: corn (144.00); soybean meal (245.00); poultry by product (335.00); DL-Methionine (2,200.00); Lysine.HCl (1,980.00); L-Threonine (2,494.80). Prices for broiler chicken items were obtained from USDA Market News (June, 2007). Carcass and total breast meat (boneless) values were US$ 1.76/kg and US$ 3.08/kg, respectively.

Statistical Analysis:

Pen was the experimental unit for all analyses. Performance data were analyzed as a completely randomized block design (CRBD) using the Mixed procedure (Proc Mixed) of SAS (SAS Institute, 2003) by the following model:

$$Y_{ijk} = \mu + B_i + T_j + B(T)_{i(j)} + \epsilon_{k(ij)}$$

Where μ is the common mean; B_i is the effect if the *i*th block; T_j is the effect of *j*th treatment; $B(T)_{i(j)}$ is the effect of the *j*th treatment within the *i*th block, and $\epsilon_{k(ij)}$ is the random error.

For the processing data, the effect of gender and the gender x treatment interactions were fitted in the statistical model. Processing data were also analyzed as a CRBD using Proc Mixed by the following model:

$$Y_{ijkl} = \mu + B_i + T_j + G_k + TG_{ik} + B(TxG)_{i(jk)} + \epsilon_{l(ijk)}$$

Where μ is the common mean; B_i is the effect if the *i*th block; T_j is the effect of *j*th treatment; G_k is the effect of the *k*th gender; TG_{ik} is the interaction between the effect of *j*th treatment and the effect of the *k*th gender; $B(TxG)_{i(jk)}$ is the interaction between the effect of *j*th treatment and the effect of the *k*th gender within the *i*th block, and $\epsilon_{k(ij)}$ is the random error.

Means showing significance in ANOVA were compared using Fisher's protected least significant difference procedure (Snedecor and Cochran, 1989). All statements of difference were based on a significance of $P < 0.05$. Linear and quadratic polynomial contrasts were performed using Proc Mixed of SAS (SAS Institute, 2003).

RESULTS

Performance:

Results for feed intake (FI), body weight gains (BWG), and feed to gain (FDGN) are demonstrated in Table 5.4. There was no treatment effects ($P > 0.05$) on any of variables analyzed throughout the 8-week period.

Processing measurements:

Processing attributes are listed on Table 5.5. At week 7, treatments had no effect ($P > 0.05$) on carcass, leg, drum, wing, and breast meat yields. In addition, there was a linear increase ($P = 0.025$) in abdominal fat pad yield as the level of crude protein decreased (CT: 1.87%; CT-0.5%: 2.09%; CT-1.0%: 2.19%; and CT-1.5%, 2.12%). Furthermore, Table5. 6 lists the effect of gender on the processing attributes. Females had higher ($P > 0.05$) percentage of abdominal fat pad, minor, and whole breast yields when compared to males (fat pad: females, 2.38%; males, 1.76%; minor: females, 4.21%; males, 3.82%; and whole breast: females, 24.19%; males, 23.51%). In contrast, males had higher percentage ($P > 0.05$) of carcass, leg, and thigh yields when compared to females (carcass: males, 71.97%; females, 71.02%; leg: males, 9.44%; females, 8.68%; thigh: males, 11.97%; females, 11.41%). Gender had no effect on wing and major yields. No relevant gender by treatment interactions was observed, except for abdominal fat pad. Basically, females were more sensitive to the decrease in CP than males. For males, as the level of CP decreased, the percentage of abdominal fat pad yield remained constant.

Economical Analysis:

Feed costs decreased as CP levels were decreased in the diets and this effect was consistent for each of the feeding phases. Therefore, as the levels of CP decreased, there was a decrease in feed costs (Figure 5.1). Moreover, as diet costs decreased, there was a reduction in feed costs/MT of BW, carcass, and total breast meat (Table 5.7) of up to US$ 2.64/MT of live BW, US$ 3.69/MT of carcass, and US$ 15.47/MT of breast meat when CT-1.5% was compared to CT.

DISCUSSION

In this present study, diets had CP levels decreased up to 1.5% and receiving adequate amino acid supplementation. Valine and isoleucine served as the constraints to how much CP could be reduced because commercial forms of these amino acids are not yet available. Therefore, although the diets had different levels of CP, amino acids other than lysine, methionine, and threonine remained above the requirements and obeying the ratios to lysine based Baker's recommendation (Baker, 1994).

Furthermore, Corzo *et al.* (2005) points out that formulating broiler diets on a digestible amino acid basis and utilizing supplemental lysine, methionine, and threonine results in diets marginally reduced in CP that support equal broiler growth to diets containing higher CP and excess amino acids (Kidd *et al.*, 2002).

Emmert and authors (2000) reported that if the level of CP is reduced beyond threonine supplementation (the third limiting amino acid), the low CP diet may become deficient in other amino acids, such as valine and isoleucine because commercial sources of these amino acids are not yet available. Therefore, lowering dietary CP without regard to the balance of amino acids may reduce growth performance (Emmert *et al.*, 2000). As CP levels are decreased, soybean meal is replaced by corn which can alter the balance of non-essential amino acids (i.e. glycine), about which little is known about requirements for broiler. Leucine also becomes marginal in the low CP (compared to NRC, 1994); however, as with glycine not to much information is available in the literature to determine the importance of this amino acid in low CP diets for broilers.

One recent study performed by Corzo *et al.* (2005), the authors fed Ross 508 broiler chicks a control diet containing 22% CP and a low CP diet with 18% CP and supplemented with either Leu or Gly. The authors reported similar BW and feed conversion of chicks fed the control diet.

The increase in abdominal fat yield observed in this study is consistent with the literature. Aletor *et al.* (2000) stated that the most consistent observation in studies with decreasing levels of CP has been the increased deposition of abdominal fat in low protein fed chickens. However, it is important to mention that in this present study, the increase in abdominal fat pad yield was observed for females, but not for males (Figure 5.2).

CONCLUSION

Overall, these results indicate that a decrease of CP by 1.5% with adequate amino acid supplementation, as compared with industry standards, did not affect performance and meat yield of Ross 708 broilers at 8 weeks of age, and resulted in significantly higher revenues.

Table 5.1: Minimum digestible lysine level and the ratios of essential amino acids to lysine utilized for the four dietary treatments for each feeding phase

	FEEDING PHASES[1]				
	Starter	Grower	Finisher	Withdraw	Ratios[2]
Lysine[3], %	1.09	0.97	0.84	0.79	100
Amino Acids, %					
Threonine	0.720	0.650	0.560	0.525	66
Methionine	0.495	0.440	0.380	0.360	45
TSAA	0.810	0.730	0.630	0.600	74
Tryptophan	0.170	0.150	0.130	0.125	15
Isoleucine	0.730	0.645	0.550	0.530	65
Valine	0.850	0.750	0.647	0.620	77
Arginine	1.123	1.000	0.870	0.810	102

[1] Starter diet was fed from 0 to 14 days of age; Grower from 14 to 28 days; Finisher: 28 to 45 days; and Withdraw from 45 to 56 days of age.
[2] Ratios based on Baker's recommendation (Baker, 1994).
[3] Lysine and all amino acids are expressed in a digestible basis.

Table 5.2: Crude protein levels of the different dietary treatments per feeding phase.

	CRUDE PROTEIN LEVELS (%)[1,2]			
Feeding phases[3]:	Starter	Grower	Finisher	Withdraw
Treatments:				
CT	22.33 (22.0)	20.15 (20.0)	17.81 (17.5)	16.70 (16.5)
CT-0.5%	21.72 (21.5)	19.39 (19.5)	17.29 (17.0)	16.07 (16.0)
CT-1.0%	21.10 (21.0)	19.34 (19.0)	16.18 (16.5)	15.67 (15.5)
CT-1.5%	20.70 (20.5)	18.12 (18.5)	16.39 (16.0)	15.30 (15.0)

[1] To originate CT-0.5% and CT-1.0%, CT and CT-1.5% diets were mixed and then blended together in different proportions. For CT-0.5%, 2/3 of the mix corresponded to diet CT and the remaining 1/3 to diet CT-1.5% whereas for CT-1.0%, 1/3 of the mix corresponded to CT and 2/3 to CT-1.5% for all feeding phases.
[2] Analyzed values (calculated values). Diets were analyzed by Degussa Corp. (Kennesaw, GA).
[3] Starter diet was fed from 0 to 14 days of age, Grower from 14 to 28 days, Finisher: 28 to 45 days, and Withdraw from 45 to 56 days.

Table 5.3: Diet composition of the control (CT) and the diet with the lowest level of crude protein (CT-1.5%)[1]

	TREATMENTS[2]			
	Starter		Grower	
Ingredients, %	CT	CT-1.5%	CT	CT-1.5%
Corn	57.69	62.25	63.00	67.93
Soybean meal	33.67	29.67	28.75	24.43
Poultry by-product	3.50	3.50	3.50	3.50
Animal & vegetal fat	2.15	1.35	2.04	1.18
Dicalcium phosphate	1.21	1.25	0.99	1.03
Limestone	0.86	0.85	0.86	0.85
DL Methionine	0.22	0.25	0.18	0.22
Lysine.HCl	0.00	0.11	0.00	0.13
L-Threonine	0.00	0.06	0.00	0.06
Others[3]	0.72	0.72	0.69	0.69
Diet cost, US$/MT[4]	205.15	204.05	198.98	197.73
Chemical composition (amino acids on a total basis[5]) as analyzed:				
ME, Kcal/kg[6]	3,067	3,067	3,122	3,122
Crude Protein[7], %	22.21 (22.0)	20.62 (20.5)	20.15 (20.0)	18.79 (18.5)
Lysine, %	1.29	1.31	1.12	1.11
Arginine, %	1.60	1.52	1.42	1.31
Methionine, %	0.56	0.56	0.51	0.50
TSAA, %	0.93	0.92	0.85	0.83
Threonine, %	0.86	0.90	0.79	0.80
Isoleucine, %	0.96	0.92	0.87	0.81
Leucine, %	1.90	1.87	1.72	1.68
Valine, %	1.08	1.04	0.99	0.94
Glycine, %	1.07	1.05	0.96	0.92
Serine, %	1.11	1.08	1.03	0.97

Table 5.3 *(cont)*:

	TREATMENTS[2]			
	Finisher		Withdraw	
Ingredients, %	CT	CT-1.5%	CT	CT-1.5%
Corn	68.95	73.89	71.73	75.85
Soybean meal	22.65	18.31	20.12	16.54
Poultry by-product	3.50	3.50	3.50	3.50
Animal & vegetal fat	2.19	1.33	2.32	1.56
Dicalcium phosphate	1.06	1.10	0.71	0.74
Limestone	0.87	0.86	0.84	0.83
DL Methionine	0.13	0.17	0.12	0.15
Lysine.HCl	0.02	0.15	0.03	0.15
L-Threonine	0.00	0.06	0.00	0.05
Others[3]	0.64	0.64	0.63	0.63
Diet cost, US$/MT[4]	192.55	191.42	189.92	188.90
Chemical composition (amino acids on a total basis[5]) as analyzed:				
ME, Kcal/kg[6]	3,190	3,190	3,230	3,230
Crude Protein[7], %	17.96 (17.5)	16.34 (16.0)	16.75 (16.5)	15.11 (15.0)
Lysine, %	0.99	0.98	0.96	0.95
Arginine, %	1.25	1.11	1.20	1.09
Methionine, %	0.43	0.43	0.42	0.45
TSAA, %	0.75	0.74	0.74	0.75
Threonine, %	0.71	0.70	0.69	0.69
Isoleucine, %	0.76	0.68	0.74	0.68
Leucine, %	1.58	1.52	1.62	1.53
Valine, %	0.89	0.82	0.87	0.82
Glycine, %	0.87	0.81	0.86	0.81
Serine, %	0.92	0.86	0.91	0.83

[1] Diets were formulated to contain the following levels of CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.5%, CT-1.0%: 21.0%, and CT-1.5%: 20.5%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6½ wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%]; [(Withdraw: 6½ to 7 wks): CT: 16.5%, CT-0.5%: 16.0%, CT-1.0%, 15.5%, and CT-1.5%, 15.0%].

[2] To originate the intermediate treatments CT-0.5% and CT-1.0%, CT and CT-1.5% diets were mixed and then blended together in different proportions. For CT-0.5%, 2/3 of the mix corresponded to diet CT and the remaining 1/3 to diet CT-1.5% whereas for CT-1.0%, 1/3 of the mix corresponded to CT and 2/3 to CT-1.5% for all feeding phases.

[3] Others = NaCl: Starter, 0.42%; Grower, 0.39%, and Finisher, 0.34%); Selenium premix, 0.025% supplying 0.15 mg Se/kg diet; copper sulfate pentahydrate, 0.012% or 30.25 mg Cu/kg diet; Mineral mix (0.10%) mg supplied per kg of diet: Ca, 25; Fe, 60; Mg, 26.8, Mn, 110; Zn, 110; I, 2; Vitamin mix (0.075%) supplied per kilogram of diet: vitamin D_3, 2,625 ICU; vitamin A, 6,000 IU; vitamin E, 9.4 IU; niacin, 37.5mg; D-pantothenic acid, 11.25 mg; riboflavin, 4.5 mg; pyridoxine, 1.5 mg; menadione, 1.13 mg; folic acid, 0.94 mg; thiamine, 0.75 mg; biotin, 0.15 mg; vitamin B12, 7.5µg; Coccidiostatic, 0.075% (60% sodium monensin premix, Elanco Animal Health, Greenfield, IN).

[4] MT (metric ton) = 1,000 kg.

[5] Feed samples sent to Degussa Corp., Kennesaw, GA, USA for CP and AA analyses.

[6] Calculated values.

[7] Analyzed values (calculated values).

Table 5.4: Effects of decreasing crude protein levels on performance of Ross 708 broilers fed from hatch to eight weeks of age[1,2]

	0-15 d			0-29 d			0-45 d			0-56 d		
TRT[2]	FI	BWG	FDGN	FI	BWG	FDGN	FI	BWG	FDGN	FI	BWG	FDGN
	-------(g)-------		(g:g)	----(kg)------		(g:g)	-----(kg)------		(g:g)	-----(kg)------		(g:g)
CT	536	352	1.52	2.04	1.33	1.53	4.76	2.76	1.73	6.94	3.61	1.92
CT-0.5%	521	351	1.49	2.01	1.32	1.52	4.76	2.75	1.73	6.87	3.62	1.90
CT-1.0%	520	347	1.50	2.01	1.32	1.53	4.73	2.75	1.72	6.90	3.62	1.91
CT-1.5%	541	350	1.55	2.03	1.32	1.54	4.87	2.76	1.76	6.90	3.59	1.92
SEM	*0.010*	*0.004*	*0.027*	*0.018*	*0.010*	*0.011*	*0.051*	*0.027*	*0.014*	*0.090*	*0.033*	*0.019*
	-----------Probability-----------											
Anova	0.325	0.928	0.338	0.628	0.525	0.577	0.312	0.998	0.103	0.955	0.923	0.760
Linear	0.747	0.636	0.446	0.905	0.188	0.232	0.249	0.930	0.095	0.875	0.808	0.959
Quadratic	0.068	0.659	0.128	0.186	0.448	0.545	0.204	0.873	0.080	0.689	0.565	0.298

[1] Data are averaged means of 12 replicates of 30 birds each.
[2] FI = feed intake; BWG = body weight gain; FDGN = feed to gain.
[3] Diets were formulated to contain the following levels of CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.5%, CT-1.0%: 21.0%, and CT-1.5%: 20.5%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6½ wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%]; [(Withdraw: 6½ to 8 wks): CT: 16.5%, CT-0.5%: 16.0%, CT-1.0%, 15.5%, and CT-1.5%, 15.0%].
[a, b] Values within column with different superscripts differ significantly ($P < 0.05$).

Table 5.5: Effect of decreasing crude protein levels on processing responses, expressed as percentage over live body weight, of Ross 708 broilers[1]

	FAT PAD	CARCASS[2]	LEG	THIGH	WING	MAJOR	MINOR	BREAST[3]
Treatments[4]				(%)				
CT	1.87[b]	71.53	9.07	11.52	7.22	20.06	4.14	24.20
CT-0.5%	2.09[ab]	71.74	9.06	11.86	7.16	19.94	3.98	23.91
CT-1.0%	2.19[a]	71.26	8.98	11.69	7.19	19.68	3.97	23.65
CT-1.5%	2.12[a]	71.45	9.14	11.70	7.23	19.66	3.98	23.64
SEM	*0.143*	*0.575*	*0.187*	*0.344*	*0.176*	*0.542*	*0.130*	*0.559*
				Probabilities				
ANOVA	0.055	0.813	0.754	0.574	0.945	0.710	0.250	0.532
Linear	0.025	0.694	0.848	0.651	0.941	0.261	0.173	0.161
Quadratic	0.131	0.906	0.526	0.314	0.614	0.851	0.255	0.648

[1] Processing measurements are averaged means of 12 replicates of 4 birds each (2 males and 2 females) with body weights close to pen average (2.94 kg/bird) at 8 weeks of age.
[2] Carcass = Chilled carcass (without blood, feathers, head, hocks, offal, and abdominal fat pad).
[3] Breast = Major + Minor.
[4] Diets were formulated to contain the following levels of CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.5%, CT-1.0%: 21.0%, and CT-1.5%: 20.5%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6½ wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%]; [(Withdraw: 6½ to 8 wks): CT: 16.5%, CT-0.5%: 16.0%, CT-1.0%, 15.5%, and CT-1.5%, 15.0%].

Table 5.6: Effect of decreasing crude protein levels[1] on processing responses, expressed as percentage over live body weight, of male and female Ross 708 broilers[2,3]

	FAT PAD	CARCASS[4]	LEG	THIGH	WING	MAJOR	MINOR	BREAST[5]
Gender	(%)							
Females	2.38[a]	71.02[b]	8.68[b]	11.41[b]	7.14	19.97	4.21[a]	24.19[a]
Males	1.76[b]	71.97[a]	9.44[a]	11.97[a]	7.27	19.69	3.82[b]	23.51[b]
SEM	*0.575*	*0.143*	*0.244*	*0.344*	*0.176*	*0.542*	*0.130*	*0.559*
	Probabilities							
TRT	0.055	0.813	0.754	0.574	0.945	0.710	0.250	0.532
Gender	<.0001	0.011	<.0001	0.002	0.149	0.351	<.0001	0.035
Gender X TRT	0.025	0.889	0.788	0.788	0.261	0.981	0.391	0.999

[1] Diets were formulated to contain the following levels of CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.5%, CT-1.0%: 21.0%, and CT-1.5%: 20.5%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6½ wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%]; [(Withdraw: 6½ to 8 wks): CT: 16.5%, CT-0.5%: 16.0%, CT-1.0%, 15.5%, and CT-1.5%, 15.0%].
[2] Processing measurements are averaged means of 12 replicates of 4 birds each (2 males and 2 females) with body weights close to pen average (2.94 kg/bird) at 8 weeks of age.
[3] Because no relevant interactions were detected ($P > 0.05$), only the main effect means for gender are shown. For treatment effects, see table 5.
[4] Carcass = Chilled carcass (without blood, feathers, head, hocks, offal, and abdominal fat pad).
[5] Breast = Major + Minor.
[a, b] Values within column with different superscripts differ significantly ($P < 0.05$).

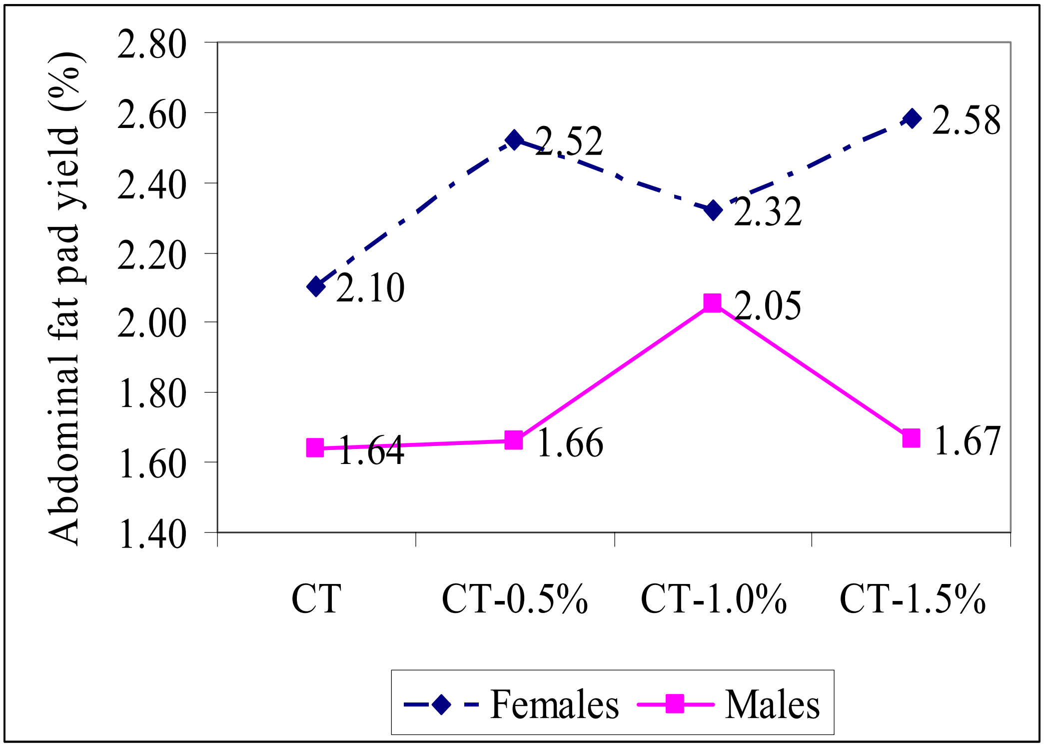
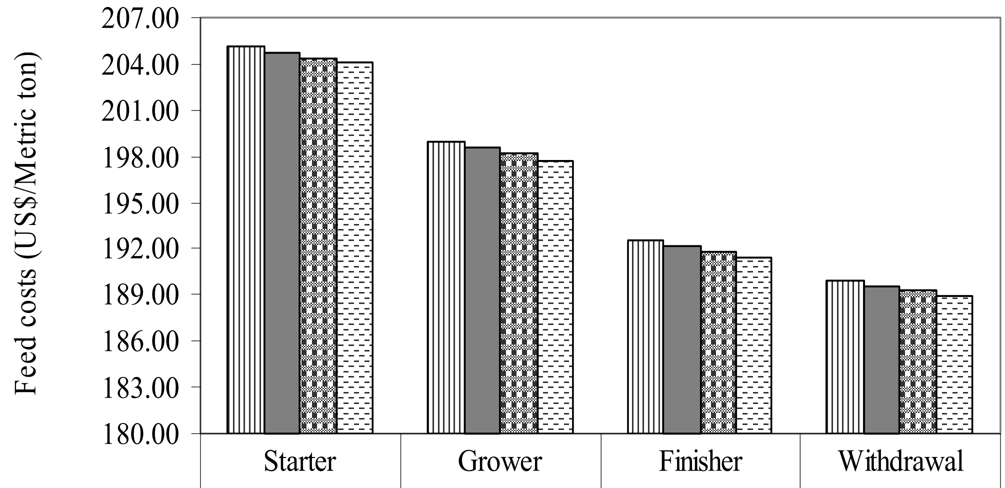


Figure 5.1: Gender by treatment interaction observed for abdominal fat pad yield of Ross 708 broilers[1].

[1] Dietary treatments: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.5%, CT-1.0%: 21.0%, and CT-1.5%: 20.5%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6½ wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%]; [(Withdraw: 6½ to 8 wks): CT: 16.5%, CT-0.5%: 16.0%, CT-1.0%, 15.5%, and CT-1.5%, 15.0%].



	Starter	Grower	Finisher	Withdrawal
CT	205.15	198.98	192.55	189.92
CT-0.5%	204.78	198.56	192.17	189.58
CT-1.0%	204.42	198.15	191.80	189.24
CT-1.5%	204.05	197.73	191.42	188.90

CT CT-0.5% CT-1.0% CT-1.5%

Figure 5.2: Effect of up to 1.5% decrease in crude protein levels on feed costs of Ross 708 broilers[1,2]

[1] Feedstuff prices (US$/1,000 kg): Corn, 144.00; Soybean meal, 245.00; Poultry by-product meal, 335.00; DL-Methionine, 2,200.00; Lysine.HCl, 1,980.00; L-Threonine, 2,494.80.
[2] Dietary Treatments CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.5%: 21.5%, CT-1.0%: 21.0%, and CT-1.5%: 20.5%]; [(Grower: 2 to 4wks): CT: 20.0%, CT-0.5%: 19.5%, CT-1.0%: 19.0%, and CT-1.5%: 18.5%]; [(Finisher: 4 to 6½wks): CT: 17.5%, CT-0.5%: 17.0%, CT-1.5%: 16.5%; and CT-1.5%: 16.0%]; [(Withdrawal: 6½ to 7wks): CT: 16.5%, CT-0.5%: 16.0%, CT-1.0%, 15.5%, and CT-1.5%, 15.0%].

Table 5.7: Effect of decreasing crude protein levels on economics of Ross 708 broilers.[1]

Economic values, US$/MT[2,3]	CT	CT-0.5%	CT-1.0%	CT-1.5%
Feed costs/MT live BW	457.26	456.38	455.50	454.62
Feed cost savings/MT live BW[4]	----	0.88	1.76	2.64
Feed costs/MT carcass	639.57	638.34	637.11	635.88
Feed cost savings/MT carcass[4]	----	1.23	2.46	3.69
Feed costs/MT breast meat	2,681.62	2,676.46	2,671.31	2,666.15
Feed cost savings/MT breast meat[4]	----	5.16	10.31	15.47

[1] Average BW = 2.94 kg at 8 weeks of age; average carcass yield = 71.49%; average breast meat yield = 23.85%.
[1] MT (metric ton) = 1,000 kg.
[2] Economic values for carcass, US$ 1.76/kg; and breast meat, US$3.08/kg (USDA, June 2007). Prices for feedstuffs (Feedstuffs, 2007): corn (US$ 144.00/MT), soybean meal (US$ 245.00/MT), and poultry by-product meal (US$335.00/MT).
[3] Feed cost savings relative to CT.

CHAPTER VI

EFFECTS OF REDUCED PROTEIN DIETS SUPPLEMENTED WITH CRYSTALLINE ARGININE, VALINE, ISOLEUCINE, AND LEUCINE ON PERFORMANCE OF BROILERS FED FROM HATCH TO FIFTY ONE DAYS AGE

ABSTRACT

Two studies (EXP 1 and EXP 2) were conducted: (1) to determine if a 2.1% reduction of crude protein (CP) would affect performance of Ross 708 broilers fed from hatch to 56 d; (2) to determine if supplementation of the low CP from EXP 1 diet with crystalline arginine (Arg), valine (Val), isoleucine (Ile), leucine (Leu), or a mixture with these amino acids (All) would restore performance of Ross 708 broilers fed from hatch to 51-d (EXP 2) of age. Fourteen hundred and forty (EXP 1) or 1,410 (EXP 2) straight-run broiler chicks were randomly assigned to four treatments with 12 replicate pens (EXP 1) or seven treatments with seven replicate pens (EXP 2) containing 30 birds per replicate pen. Diets were formulated to be isocaloric and to have the same lysine digestible level and TSAA, threonine, and tryptophan ratios to lysine. For EXP 1 and EXP 2, an industry standard diet served as the control (CT). For EXP 1, the remainder of the treatments (CT-0.7%, CT-1.4%, and CT-2.1%) had CP reduced in 0.7% increments. CT-2.1% contained the lowest level of CP. For EXP2, CT-2.1% was supplemented with Arg, Val, Ile, Leu, or All to increase the levels of these amino acids to CT level. Feed and birds were weighed at 14, 28, 45, and 56-d (EXP 1) or 15, 29, 44, and 51-d (EXP 2) for feed to gain calculation. At the end of the studies, four birds per pen were sacrificed and had fat pad and carcass weighed, and carcass and meat yield determined. Results for EXP 1 showed that treatments had no effect on performance from 0 to 56-d ($P > 0.05$). In addition, there was a linear increase ($P < .0001$) in abdominal fat pad yield as CP decreased and breast meat yield decreased ($P = 0.032$) when CT-2.1% was fed. Interestingly, in EXP 2, treatments had no effect on breast meat yield, but CT-2.1% decreased carcass yield ($P = 0.017$). Supplementation of CT-2.1% with Ile and All restored carcass yield to CT level. Abdominal fat pad yield increased as CP decreased and supplementation of CT-2.1% with Val and Arg decreased fat pad yield to CT level.

INTRODUCTION

A series of three studies has been performed at the University of Missouri where Cobb 500, Ross 308, and Ross 708 broilers were fed diets with crude protein (CP) levels reduced in 0.5% increments with a maximal reduction of 1.5% when compared to Agristats (Agristats, 2005; Guaiume, unpublished data). No negative effects were observed on performance and meat yield of Cobb 500 fed from hatch to d 42, Ross 308 from hatch to d 49, and Ross 708 from hatch to d 56. An increase in abdominal fat pad yield was observed for Ross 308; however, for Ross 708 the increase in fat pad was observed only on females, but not on males (Guaiume, unpublished data). In these studies, CP was reduced at the expense of crystalline amino acids to supplement lysine, methionine, and threonine. In addition, valine and isoleucine served as the constraint to CP.

Supplementation of poultry diets with crystalline amino acids (i.e. lysine, methionine [Waldroup *et al.*, 2005], and threonine [Corzo *et al.*, 2005]) may improve the overall amino acid balance and enable a reduction in the CP level (Waldroup *et al.*, 2005) that support equal broiler growth to diets containing higher CP and excess amino acids (Kidd *et al.*, 2002). However, the question remained is to which extent CP can be reduced at the expense of crystalline amino acid supplementation without affecting performance and meat yield, especially breast meat yield, in broilers.

Aftab *et al.* (2006) reported that after a review of the literature regarding low CP for broilers, a 10% reduction of CP, compared to NRC (1994), for each phase did not negatively affected performance when compared to the standard CP diets. Therefore, the calculated CP levels could be as low as 20.7, 18.0, and 16.2%, respectively for 0 to 21, 21 to 42, and 42 to 56 days of age; levels that are in agreement with Guaiume (unpublished data). The authors also note that the magnitude of protein reduction, without affecting the growth performance of the broilers, could have been increased depending upon the essential amino acid concentration of the CP diet relative to the standard CP diet as well as the response criteria used (gain vs. composition of gain) (Aftab *et al.*, 2006) and that further reduction in dietary CP can result in depressed live or carcass yield in almost all cases.

In a corn-soybean meat diet, as CP decreases beyond threonine supplementation, amino acids such as arginine and the branched-chain amino acids valine, isoleucine, and leucine follow this same trend. While valine and isoleucine are considered to be the fourth and fifth limiting amino acids in a broiler diet, little information is available in the literature regarding arginine and leucine supplementation in a threonine-supplemented low CP diet.

In this study, two experiments were designed: (1) to determine if a 2.1% reduction in CP with supplemental lysine, methionine, and threonine would have a negative effect on performance and meat yield of Ross 708 broilers fed from hatch to d 56; (2) to determine if supplementation of this low CP diet with crystalline arginine, valine, isoleucine, and leucine would restore any negative effect that a 2.1%-reduced CP diet may have on performance and breast meat yield of Ross 708 broilers fed from hatch to d 51.

MATERIAL AND METHODS

Experimental facility:

The experiments were conducted in a facility containing 48 floor pens on concrete with side wall curtains. Each floor pen measured 1.80 x 1.20 m (0.072 m^2/bird) and contained one tube feeder, a nipple drinker line (five nipples per pen), and used litter.

From day 1 to 7, supplemental pan feeders were used in each pen to ensure good feed consumption at placement. The facility was heated with electric heat lamps in each pen and propane heaters were placed in the center of the aisle.

Experimental Designs:

Fourteen hundred and forty one-day-old straight-run Ross 708 broilers (EXP 1) or 1,410 one-day-old straight-run Ross 708 broiler chicks (EXP 2) were purchased from a commercial hatchery (Townsend Inc., Baytesville, AR), weighed and randomly assigned to four treatments with 12 replicate pens containing 30 birds each from hatch to d 56 (EXP 1) or seven treatments with either six (CT and CT-2.1%) or seven (remaining five treatments) replicate pens containing 30 birds each from hatch to d 51. The 48 floor-pen facility was divided into six blocks, based on house location, and treatments were randomly allotted within blocks. Each block consisted of 8 pens.

Dietary Treatments:

Experiment 1:

The dietary treatments consisted of a control diet (CT) based on the current United States' industry (Agristats, 2005) diets in composition, energy, digestible amino acid levels, and feeding program. The treatment with the lowest level of CP (CT-2.1%) consisted of CT with a reduction of 2.1% in CP at the expense of supplemental lysine, methionine, and threonine (Table 6.1). To originate the two treatments with intermediate levels of CP, CT with a reduction of 0.7% of CP (CT-0.7%) and CT with a 1.4% reduction in CP (CT-1.4%), CT and CT-2.1% were mixed separately and then blended together in different proportions. For CT-0.7%, 2/3 of the mix corresponded to CT and the remaining 1/3 to CT-2.1% whereas for CT-1.4%, 1/3 of the mix corresponded to CT and 2/3 to CT-2.1%. This treatment regimen continued throughout the 56 d period. Dietary treatments with the respective CP levels are listed on Table 6.2.

Diets were least-cost formulated to be isocaloric and to have the same minimum digestible level for lysine, and the same minimum ideal amino acid ratios to lysine for TSAA, threonine, and tryptophan across the four feeding phases [starter (0 to 15 d), grower (15 to 28 d), finisher (28 to 45 d), and withdrawal (45 to 56 d)]. The ratios to lysine were based on Baker (1994). Valine, isoleucine, arginine, and leucine were allowed to fluctuate as CP decreased (Table 6.3).

Experiment 2:

For EXP2, CT and CT-2.1% were formulated according to EXP1. Then, to CT-2.1%, L-arginine, L-valine, L-isoleucine, L-leucine, or a mixture of these four amino acids was added in order to bring the levels of these amino acids to CT level (Table 6.4). The crystalline amino acids were forced into the formulation program at appropriate levels so that CT and CT-2.1% had the exact amounts of these amino acids. CT and CT-2.1% were isonitrogenous. The dietary treatments were: control (CT), CT with a decrease of 2.1% in CP (CT-2.1%); CT-2.1% supplemented with L-Arginine (CT-2.1+Arg); CT-2.1% supplemented with L-Valine (CT-2.1+Val); CT-2.1% with L-Isoleucine (CT-2.1+Ile); CT-2.1% with L-Leucine (CT-2.1+Leu).

Feed samples from EXP 1 and EXP 2 were sent to Degussa Corporation (Kennesaw, GA, USA) for CP and amino acid analyses according to Llames and Fontaine (1994).

Feedstuffs' coefficient of digestibility of amino acids was obtained from Ajinomoto Heartland, LLC (Chicago, IL, USA).

Animal Husbandry (EXP 1 and EXP 2):

Chicks were maintained on a 23-h constant light schedule and allowed food and water *ad libitum.* Birds were monitored daily for signs of morbidity and mortality. The animal care and use protocol was reviewed and approved by the University of Missouri-Columbia Animal Care and Use Committee.

Performance data (EXP 1 and EXP 2):

Body weight and feed intake was recorded at days 15, 28, 45, and 56 days and 14, 28, 44, and 51 days of age, respectively for EXP 1 and EXP 2 and used for feed to gain calculation. Mortality was also recorded on a pen basis and feed consumption data were adjusted. Mortality remained low and occurred randomly throughout the treatments. Therefore, mortality data were not analyzed statistically.

Carcass Measurements (EXP 1 and EXP 2):

At days 56 (EXP 1) and 51 (EXP 2), four birds per pen (two males and two females), totaling 48 birds per treatment (EXP 1) and 24 birds per treatment (EXP 2; treatments CT and CT-2.1%) or 28 birds/treatments (EXP 2; remaining treatments) were randomly selected, weighed, wing-banded, and transported to the processing plant, where they remained without feed, but with access to water for 12 hours prior to processing. Birds were hung on shackles, stunned with electric shock, and bled for 5 minutes after severance of the jugular vein. Birds remained on shackles and were dipped in a hot water scalder for 45 seconds with the thermostat set at 60ºC. They were then transferred to an automated drum picker and defeathered for 60 seconds. After hocks and heads were removed, birds were eviscerated and washed manually. Therefore, carcass consisted of the whole bird without blood, feathers, hocks, heads, offal, and abdominal fat. Abdominal fat and carcasses were weighed to determine abdominal fat pad yield. Carcasses were then rewashed and chilled in an ice bath for a minimum of 2 hours. After 2 hours, breast muscles (*pectoralis major* and *pectoralis minor)*, thighs, legs, and wings were severed from the chilled carcasses on a manual deboning line, weighed, and recorded for determination of parts yield. All carcass measurements were expressed as percentage over live body weight at processing.

Economic Analysis (EXP 1):

Because the diets for EXP 2 were not least-cost formulated due to the fact that arginine, valine, isoleucine, and leucine are highly priced, economic analysis was only performed for EXP 1. An Excel spreadsheet program (Microsoft, 2003) was designed to determine feed costs per metric ton (MT) of live BW, carcass, and total breast meat. Feed cost savings (FCS)/MT of live BW, carcass, and breast meat were determined for each of the dietary treatments that had a decrease in crude protein by comparing their costs to the control diet cost of the correspondent feeding phase (Figures 6.2 to 6.4). Feed ingredient prices were obtained from Feedstuffs (June, 2007) and they were Kansas City prices. The prices for crystalline amino acids were obtained from the University of Missouri's Feed mill. The prices were, in US$/metric ton: corn (144.00); soybean meal

(245.00); poultry by product (335.00); DL-Methionine (2,200.00); Lysine.HCl (1,980.00); L-Threonine (2,494.80). Prices for broiler chicken items were obtained from USDA Market News (June, 2007). Carcass and total breast meat (boneless) values were US$ 1.76/kg and US$ 3.08/kg, respectively.

Statistical Analysis (EXP 1 and EXP 2):

Pen was the experimental unit for all analyses. Performance data were analyzed as a completely randomized block design (CRBD) using the Mixed procedure (Proc Mixed) of SAS (SAS Institute, 2003) by the following model:

$$Y_{ijk} = \mu + B_i + T_j + B(T)_{i(j)} + \epsilon_{k(ij)}$$

Where μ is the common mean; B_i is the effect if the ith block; T_j is the effect of jth treatment; $B(T)_{i(j)}$ is the effect of the jth treatment within the ith block, and $\epsilon_{k(ij)}$ is the random error.

For the processing data, the effect of gender and the gender x treatment interactions were fitted in the statistical model. Processing data were also analyzed as a CRBD using Proc Mixed by the following model:

$$Y_{ijkl} = \mu + B_i + T_j + G_k + TG_{ik} + B(TxG)_{i(jk)} + \epsilon_{l(ijk)}$$

Where μ is the common mean; B_i is the effect if the ith block; T_j is the effect of jth treatment; G_k is the effect of the kth gender; TG_{ik} is the interaction between the effect of jth treatment and the effect of the kth gender; $B(TxG)_{i(jk)}$ is the interaction between the effect of jth treatment and the effect of the kth gender within the ith block, and $\epsilon_{k(ij)}$ is the random error.

Means showing significance in ANOVA were compared using Fisher's protected least significant difference procedure (Snedecor and Cochran, 1989). All statements of difference were based on a significance of $P < 0.05$. Linear contrasts (EXP1 and EXP2) and quadratic polynomials (EXP2) were performed using Proc Mixed of SAS (SAS Institute, 2003).

RESULTS

Experiment 1:

Performance:

Results for feed intake (FI), body weight gains (BWG), and feed to gain (FDGN) are demonstrated in Table 6.4. From 0 to 15-day period, there was a linear increase ($P = 0.02$) in BWG as CP decreased. Furthermore, reducing CP resulted in a linear improvement ($P = 0.02$) in FDGN for the same period (BWG (g): CT, 257; CT-0.7%, 270; CT-1.4%, 267; and CT-2.1%, 270; FDGN (g:g): CT, 2.04; CT-0.7%, 2.04; CT-1.4%, 1.98; and CT-2.1%, 1.96. However, from the 0 to 29-day period and 0 to 45-day period, there was a linear worsening (0 to 29-d: $P = 0.003$; 0 to 45-d: $P = 0.006$) in FDGN as CP was decreased (0 to 29-d (kg:kg): CT, 1.65; CT-0.7%, 1.67; CT-1.4%, 1.68; and CT-2.1%, 1.70; 0 to 45-d (kg:kg): CT, 1.87; CT-0.7%, 1.85; CT-1.4%, 1.89; and CT-2.1%, 1.93). There was no treatment effects ($P > 0.05$) on any of variables analyzed from 0 to 56 days of age ($P > 0.05$).

Processing measurements:

Processing responses are listed on Table 6.5. There was a linear increase ($P < .0001$) in abdominal fat pad yield as CP decreased (CT: 2.19%; CT-0.7%, 2.50; CT-1.4%, 2.67%; CT-2.1%, 2.69%). Treatments had no effect on carcass yield ($P > 0.05$); however, there was a linear decrease ($P = 0.0318$) in breast meat yield as CP decreased (CT: 23.92%; CT-0.7%, 24.02; CT-1.4%, 23.45%; CT-2.1%, 23.01%). Furthermore, Table 6.6 lists the effect of gender on the processing attributes. Females had higher ($P > 0.05$) percentage of abdominal fat pad, major, minor, and whole breast yields when compared to males (fat pad (%): females, 2.80; males, 2.24; major (%): females, 19.73; males, 19.12; minor: females, 4.33%; males, 4.02%; and whole breast: females, 24.06%; males, 23.14%). In contrast, males had higher percentage ($P > 0.05$) of leg when compared to females (leg: males, 9.52%; females, 8.92%). Gender had no effect on carcass, thigh, and wing yields. In addition, no relevant gender by treatment interactions was observed.

Economic Analysis:

Feed costs decreased as CP decreased and this effect was consistent across the 4 feeding phases. Therefore, as the levels of CP decreased, there was a decrease in feed costs (Figure 6.1). For live BW (Figure 6.2), relative to CT, FCS was US$ 4.13/MT and for carcass (Figure 6.3), US$ 5.59/MT when CT-2.1% was fed. For breast meat (Figure 6.4), FCS was US$ 5.78 and US$ 11.57, respectively for CT-0.7% and CT-1.4%. However, when CT-2.1% was fed, there was an increase in feed costs of US$ 23.14/MT of breast meat when compared to CT as a result of the decrease in breast meat yield when CT-2.1% was fed.

Experiment 2:

Performance:

Results for feed intake (FI), body weight gains (BWG), and feed to gain (FDGN) are demonstrated in Table 6.7. From 0 to 15-day period, treatments had no effect ($P > 0.05$) on performance. For the 0 to 28-day period, treatments had no effect on FI ($P = 0.64$). However, BWG decreased as CP decreased and supplementation with crystalline amino acids did not ameliorate this effect. For FDGN, supplementation of CT-2.1% with Val, Ile, or Leu worsened FDGN ($P < 0.05$) when compared to CT, CT-2.1%, CT-2.1+Arg, and CT-2.1+All. For the 0 to 44-day period, FI was not affected ($P = 0.30$). Although CT and CT-2.1% did not differ ($P > 0.05$), when CT-2.1% was supplemented with Arg, Val, Ile, or Leu, BWG decreased ($P < 0.05$). However, when CT-2.1% was supplemented with the mixture, BWG was restored to CT level. Furthermore, addition of isoleucine and valine negatively affected FDGN from 0 to 44 days of age. The remaining treatments did not differ among them ($P > 0.05$). Finally, for the 0 to 51-day period, FI was not affected ($P = 0.27$) and BWG was lower for the diets supplemented with Ile or Leu. Diets supplemented with Arg, Valine, and All did not differ from CT and CT-2.1%. However, when CT-2.1% was supplemented with isoleucine or leucine, FDGN was worsened.

Processing measurements:

Processing attributes are listed on Table 6.8. Abdominal fat pad yield increased ($P = 0.030$) as CP decreased (CT, 2.06%; CT-2.1%, 2.63%). Valine and Arg supplementation restored fat pad yield to levels that were not statistically ($P > 0.05$) different than CT

(CT-2.1+Val, 2.08%; CT-2.1+Arg, 2.34%). All other treatments did not differ from CT-2.1%. In contrast to EXP1, carcass yield decreased ($P < 0.05$) as CP decreased (CT, 74.90%; CT-2.1%, 72.98%) and supplementation with Ile and All brought up carcass yield to levels that were not statistically different than CT (CT-2.1+Ile, 74.11%; CT-2.1+All, 74.27%). Furthermore, breast meat yield was not affected ($P = 0.499$). Furthermore, Table 6.10 demonstrates the effect of gender on processing variables. Females had higher ($P > 0.05$) percentage of abdominal fat pad, minor, and whole breast meat yields when compared to males (fat pad (%): females, 2.57; males, 2.13; minor (%): females, 4.17; males, 3.93; breast (%): females, 23.11; males, 22.31). In contrast, males had higher percentage ($P > 0.05$) of carcass, leg, and thigh yields when compared to females (carcass(%): males, 73.77; females, 74.06; leg (%): males, 9.70; females, 9.12; thigh (%): males, 11.68; females, 11.18). Gender had no effect on wing and major yields. In addition, no relevant gender by treatment interactions was observed.

DISCUSSION

The difference between CT and CT-2.1% is the considerable decrease in isoleucine (Ile), valine (Val), arginine (Arg), and leucine (Leu) levels in CT-2.1%. There is an agreement in the literature that Val and Ile are the fourth and fifth limiting amino acid (AA) in a broiler diet and the order of limitation may very based on the feeding phases or the ingredients being utilized (Kidd *et al.*, 2004; Corzo *et al.*, 2004; Han *et al.*, 1992;

Fernandez *et al*., 1994). Valine limitation is aggravated at older ages when dietary protein decreases and grain extends its contribution (Corzo *et al.*, 2004). Kidd *et al.* (2000) fed Ross x Acre male broilers diet varying in Ile from d 22 to 42. Dietary isoleucine did not affect growth performance, but breast meat yield was significantly increased by dietary Ile.

According to this study, the decrease in CP by 2.1% did not affect performance from hatch to 56 (EXP 1). At d 51 (EXP 2), BWG and FDGN was negatively affected when CT-2.1% was supplemented with Ile or Leu. In addition, a decrease in breast meat yield was observed in EXP 1, but not in EXP 2. This may have been the result of fewer replicate pens utilized in the EXP 2. It is important to mention that the diets from the two experiments utilized the same batch of corn, soybean meal, and poultry by-product meal.

When CT-2.1% was supplemented with Ile and Leu, 51 d BWG and FDGN was significantly affected; however, when the low CP diet did not receive any supplementation or was supplemented with Val, Arg, or All, treatments did not differ from CT. The branched chain-amino acids (BCAA) Val, Ile, and Leu share the same enzymatic pathway (Featherston and Horn, 1973; Nonami *et al.*, 1995; Denoya *et al.*, 1995). It has been documented that excess of Leu affects Ile and Val utilization (D'Mello and Lewis, 1970; Allen and Baker, 1972; Tuttle and Balloun, 1976), especially when these two amino acids are marginal or limiting. Moreover, BCAA antagonism has been investigated in rats (Hagihira *et al.*, 1960; Harper *et al.*, 1970; Harper, 1974) and in chicks (Smith and Austic, 1978). These authors observed that when Leu was fed to broilers at 50 g/kg of a diet with adequate levels of Val and Ile or with Leu at 37.5 g/kg of a diet deficient in Ile and Val, performance was negatively affected. In addition, the authors reported that excesses of Val or Ile caused smaller depressions of concentrations of the two other amino acids (Smith and Austic, 1978).

In a practical low CP corn-soybean meal formulation, the level of Leu is about three times less than the levels tested by Smith and Austic (1978). In addition, Leu level in this present study decreased as much as Val and Ile when CP was decreased (Table 6.4) ruling out a Leu/Ile antagonism. Furthermore, in this study Val supplementation did not affect performance, which supports the argument that the negative effects of Ile and Leu supplementation is not due to BCAA antagonism. Furthermore, Waldroup *et al.* (2002) tested imbalanced ratios of BCAA in broilers up to 21 d of age and reported that the antagonism among Leu, Ile, and Val is not likely to result in depressed performance of broilers fed practical type diets when these amino acids are above their minimum requirement.

In terms of abdominal fat pad yield, there was an increase in fat pad yield when CP decreased and this effect was observed in EXP 1 and EXP 2. Aletor *et al.* (2000) reported that the most consistent observation in studies with low CP diets has been the increased deposition of abdominal fat in the low protein fed chickens. However, when CT-2.1% was supplemented with Val, fat pad yield returned to CT level. It is interesting that Val supplementation resulted in decreased abdominal fat pad because it has been reported in the literature that Val has no effect on body fatness (Corzo *et al.*, 2004; Leclerq, 1998). In contrast, Thornton *et al.* (2006) reported that 3 to 6 wk broiler fed 0.64% digestible Val (Val:Lys = 67%) had more abdominal fat pad than birds given 0.74% (Val:Lys = 78%). The ideal Val:Lys ratio found in the literature varies from

77.5% (Baker, 1997; Baker *et al.*, 2002), to 81% (Mack *et al.,* 1999), to 86% (Corzo *et al.*, 2004). For this study, CT-2.1% had Val:Lys ratio at 73%.

Arginine is involved in immunity and wound healing (Collier and Vallance, 1989; Efron and Barbul, 1998), is essential to maintenance and growth of broilers (Dean and Scott, 1965; Allen and Baker, 1972; Burton and Waldroup, 1979; Cuca and Jensen, 1990) and carcass quality (Hurwitz *et al.*, 1998; Corzo *et al.*, 2003). The latter two authors reported decreases in extractable carcass fat and depot fat from the abdominal cavity when low CP diets were supplemented with arginine. These results are consistent with this study as when CT-2.1% was supplemented with L-arginine, a decrease in abdominal fat was observed.

Overall, as CP is decreased beyond threonine supplementation, other amino acids may become limiting and unknown interactions may take place. In this study, the effect of a decrease in CP by 2.1% had contradictory responses which can be related to the fewer replicate pens used in EXP2. In EXP1, it negatively affected breast meat yield whereas in EXP2 it had no effect on breast meat yield. The diets were formulated with the same ingredients and EXP2 took place a month after EXP1 was finished during winter 2007. Both flocks seem to be healthy, mortality rate, the incidence of ascites, and leg abnormalities was low. It is possible that 2.1% may be borderline and after and may be at this level, meat yield may be compromised.

CONCLUSION

The results of these experiments demonstrated that a decrease of CP by 2.1%, as compared with industry standards, did not affect performance and carcass yield, but decreased breast meat yield in EXP 1. However, when a second experiment was performed using the same diet formulation with the same ingredients, it had no effect on breast meat yield. This effect may have been due to the fewer replications used in EXP 2.

Table 6.1: Diet composition of the control (CT) and the diet with the lowest level of crude protein (CT-2.1%)[1,2]

	Starter		Grower	
Ingredients, %	CT	CT-2.1%	CT	CT-2.1%
Corn	61.49	65.92	67.29	71.62
Soybean meal	29.72	24.05	24.68	19.13
Poultry by-product	3.50	3.50	3.50	3.50
Animal & vegetal fat	1.00	1.00	1.00	1.00
Dicalcium phosphate	1.60	1.65	1.36	1.41
Limestone	1.50	1.75	0.98	0.99
DL Methionine	0.20	0.25	0.16	0.22
Lysine.HCl	0.05	0.23	0.06	0.24
L-Threonine	0.00	0.05	0.00	0.05
Sodium bicarbonate	0.20	0.45	0.20	0.87
Salt	0.40	0.65	0.47	0.65
Choline chloride	0.06	0.21	0.00	0.03
Others[3]	0.29	0.29	0.29	0.29
Chemical composition (amino acids on a total basis[5]) as analyzed:				
ME, Kcal/kg[6]	3,067	3,067	3,122	3,122
Crude Protein[7], %	22.60 (22.0)	20.09 (19.9)	20.29 (20.0)	18.40 (17.9)
Lysine, %	1.29	1.31	1.12	1.11
Arginine, %	1.60	1.52	1.42	1.31
Methionine, %	0.56	0.56	0.51	0.50
TSAA, %	0.93	0.92	0.85	0.83
Threonine, %	0.86	0.90	0.79	0.80
Isoleucine, %	0.96	0.92	0.87	0.81
Leucine, %	1.90	1.87	1.72	1.68
Valine, %	1.08	1.04	0.99	0.94
Glycine, %	1.07	1.05	0.96	0.92
Serine, %	1.11	1.08	1.03	0.97

Table 6.1 *(cont)*:

	Finisher		Withdrawal	
Ingredients, %	CT	CT-2.1%	CT	CT-2.1%
Corn	72.56	78.69	75.24	75.85
Soybean meal	18.67	12.82	16.14	16.54
Poultry by-product	3.50	3.50	3.50	3.50
Animal & vegetal fat	1.71	1.06	2.00	1.56
Dicalcium phosphate	1.41	1.46	1.05	0.74
Limestone	1.00	1.01	0.94	0.83
DL Methionine	0.13	0.17	0.12	0.15
Lysine.HCl	0.09	0.28	0.11	0.15
L-Threonine	0.00	0.05	0.00	0.05
Sodium bicarbonate	0.20	0.20	0.20	0.20
Salt	0.40	0.40	0.40	0.40
Choline chloride	0.05	0.07	0.00	0.02
Others[3]	0.29	02.9	0.29	0.29
Chemical composition (amino acids on a total basis[5]) as analyzed:				
ME, Kcal/kg[6]	3190	3190	3234	3234
Crude Protein[7], %	17.61 (17.5)	15.38 (15.4)	16.70 (16.5)	14.30 (14.4)
Lysine, %	1.19	1.22	0.98	0.87
Arginine, %	1.47	1.35	1.16	0.86
Methionine, %	0.53	0.58	0.42	0.41
TSAA, %	0.88	0.90	0.75	0.69
Threonine, %	0.82	0.81	0.68	0.59
Isoleucine, %	0.89	0.83	0.75	0.58
Leucine, %	1.82	1.80	1.67	1.38
Valine, %	1.02	0.95	0.91	0.71
Glycine, %	1.01	0.96	0.94	0.67
Serine, %	1.04	0.99	0.78	0.58

[1] Diets were formulated to contain the following levels of CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.7%: 21.3%, CT-1.4%: 20.6%, and CT-2.1%: 19.9%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.7%: 19.3%, CT-1.4%: 18.6%, and CT-2.1%: 17.9%]; [(Finisher: 4 to 6½ wks): CT: 17.5%, CT-0.7%: 16.8%, CT-1.4%: 16.1%; and CT-2.1%: 15.4%]; [(Withdrawal: 6½ to 8 wks): CT: 16.5%, CT-0.7%: 15.8%, CT-1.4%, 15.1%, and CT-2.1%, 14.4%].
[2] To originate the intermediate treatments CT-0.7% and CT-1.4%, CT and CT-2.1% diets were mixed and then blended together in different proportions. For CT-0.5%, 2/3 of the mix corresponded to diet CT and the remaining 1/3 to diet CT-2.1% whereas for CT-1.4%, 1/3 of the mix corresponded to CT and 2/3 to CT-2.1% for all feeding phases.
[3] Others = Selenium premix, 0.025% supplying 0.15mg Se/kg diet; copper sulfate pentahydrate, 0.012% or 30.25mg Cu/kg diet; Mineral mix (0.10%) mg supplied per kg of diet: Ca, 25; Fe, 60; Mg, 26.8, Mn, 110; Zn, 110; I, 2; Vitamin mix (0.075%) supplied per kilogram of diet: vitamin D_3, 2,625 ICU; vitamin A, 6,000 IU; vitamin E, 9.4 IU; niacin, 37.5 mg; D-pantothenic acid, 11.25 mg; riboflavin, 4.5 mg; pyridoxine, 1.5 mg; menadione, 1.13 mg; folic acid, 0.94 mg; thiamine, 0.75 mg; biotin, 0.15 mg; vitamin B12, 7.5 µg; Coccidiostatic, 0.075% (60% sodium monensin premix, Elanco Animal Health, Greenfield, IN).
[4] MT (metric ton) = 1,000 kg.
[5] Feed samples sent to Degussa Corp., Kennesaw, GA, USA for CP and AA analyses.
[6] Calculated values.
[7] Analyzed values (calculated values).

Table 6.2: Crude protein of the different dietary treatments per feeding phase.

	CRUDE PROTEIN LEVELS (%)[1,2]			
Feeding phases[3]:	Starter	Grower	Finisher	Withdrawal
Treatments:				
CT	22.60 (22.0)	20.29 (20.0)	17.61 (17.5)	16.70 (16.5)
CT-0.7%	21.52 (21.3)	19.83 (19.3)	16.09 (16.8)	16.07 (15.8)
CT-1.4%	20.61 (20.6)	19.13 (18.6)	15.65 (16.1)	15.17 (15.1)
CT-2.1%	20.09 (19.9)	18.40 (17.9)	15.38 (15.4)	14.30 (14.4)

[1] To originate CT-0.7% and CT-14%, CT and CT-2.1% diets were mixed and then blended together in different proportions. For CT-0.7%, 2/3 of the mix corresponded to diet CT and the remaining 1/3 to diet CT-2.1% whereas for CT-1.4%, 1/3 of the mix corresponded to CT and 2/3 to CT-2.1% for all feeding phases.
[2] Analyzed values (calculated values). Diets were analyzed by Degussa Corp. (Kennesaw, GA) according to Llames and Fontaine (1994).
[3] EXP1: Starter diet fed from 0 to 14 d, Grower: 14 to 28 d, Finisher: 28 to 45 d, Withdrawal: 45 to 56 d; EXP2: Starter: 0 to 15d, Grower: 15 to 28 d, Finisher: 28 to 44 d, Withdrawal: 44 to 51 d.

Table 6.3: Digestible amino acid levels for CT and CT-2.1% for each feeding phase.

	FEEDING PHASES[1]							
	Starter		Grower		Finisher		Withdrawal	
Amino Acids, %	CT	CT-2.1%	CT	CT-2.1%	CT	CT-2.1%	CT	CT-2.1%
Lysine[2] %	1.09	1.09	0.97	0.97	0.84	0.84	0.79	0.79
Threonine	0.72	0.69	0.65	0.62	0.56	0.53	0.53	0.50
Methionine	0.50	0.50	0.44	0.44	0.38	0.38	0.36	0.36
TSAA	0.81	0.81	0.73	0.73	0.63	0.63	0.60	0.60
Tryptophan	0.17	0.17	0.17	0.17	0.13	0.13	0.12	0.12
Isoleucine	0.82	0.71	0.73	0.66	0.63	0.53	0.58	0.48
Valine	0.90	0.80	0.82	0.77	0.72	0.62	0.68	0.58
Arginine	1.34	1.17	1.19	0.78	1.01	0.83	0.93	0.76
Leucine	1.76	1.60	1.64	1.45	1.48	1.34	1.42	1.27

[1] Starter diet fed from 0 to 14 d; Grower: 14 to 28 d; Finisher: 28 to 45 d; and Withdrawal: 45 to 56 d.
[2] Lysine and all amino acids are expressed in a digestible basis.

Table 6.4: Effects of decreasing crude protein levels on performance of Ross 708 broilers from hatch to eight weeks of age[1,2]

	0-15 d			0-29 d			0-45 d			0-56 d		
TRT[3]	FI	BWG	FDGN	FI	BWG	FDGN	FI	BWG	FDGN	FI	BWG	FDGN
	------(g)-------		(g:g)	----(kg)------		(g:g)	-------(kg)------		(g:g)	-------(kg)------		(g:g)
CT	523	257[b]	2.04[a]	1.85	1.12	1.65[c]	4.48	2.40	1.87[b]	6.78	3.28	2.10
CT - 0.7%	549	270[a]	2.04[a]	1.88	1.12	1.67[b]	4.49	2.43	1.85[b]	6.91	3.37	2.05
CT - 1.4%	528	267[a]	1.98[ab]	1.87	1.11	1.68[ab]	4.58	2.42	1.89[ab]	7.22	3.33	2.17
CT - 2.1%	529	270[a]	1.96[b]	1.88	1.11	1.70[a]	4.54	2.36	1.93[a]	6.99	3.30	2.12
SEM	*8.42*	*3.81*	*0.03*	*0.02*	*0.01*	*0.01*	*0.05*	*0.03*	*0.02*	*0.14*	*0.07*	*0.05*
	Probability											
ANOVA	0.20	0.04	0.18	0.52	0.72	0.007	0.45	0.23	0.02	0.21	0.80	0.41
LINEAR	0.95	0.02	0.03	0.24	0.30	0.003	0.22	0.26	0.006	0.14	0.97	0.40

[1] Data are averaged means of 12 replicates of 30 birds each.

[2] FI = feed intake; BWG = body weight gain; FDGN = feed to gain.

[3] Diets were formulated to contain the following levels of CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.7%: 21.3%, CT-1.4%: 20.6%, and CT-2.1%: 19.9%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.7%: 19.3%, CT-1.4%: 18.6%, and CT-2.1%: 17.9%]; [(Finisher: 4 to 6½ wks): CT: 17.5%, CT-0.7%: 16.8%, CT-1.4%: 16.1%; and CT-2.1%: 15.4%]; [(Withdraw: 6½ to 8 wks): CT: 16.5%, CT-0.7%: 15.8%, CT-1.4%, 15.1%, and CT-2.1%, 14.4%].

[a, b] Values within column with different superscripts differ significantly ($P < 0.05$).

Table 6.5: Effect of decreasing crude protein levels on processing responses, expressed as percentage over live body weight, of Ross 708 broilers[1]

TRT[4]	FAT PAD	CARCASS[2]	LEG	THIGH	WING	MAJOR	MINOR	BREAST[3]
	(%)							
CT	2.19[b]	74.59	9.21	12.18	7.88	19.60[a]	4.32[a]	23.92[a]
CT - 0.7%	2.50[a]	73.24	9.17	11.94	7.52	19.87[a]	4.15[ab]	24.02[a]
CT - 1.4%	2.67[a]	74.03	9.22	11.89	7.71	19.26[ab]	4.19[ab]	23.45[ab]
CT – 2.1%	2.69[a]	73.59	9.28	11.95	7.64	18.97[b]	4.05[b]	23.01[b]
SEM	*0.08*	*0.53*	*0.11*	*0.18*	*0.11*	*0.40*	*0.08*	*0.45*
	Probability							
ANOVA	0.0005	0.327	0.889	0.639	0.120	0.129	0.143	0.116
LINEAR	<.0001	0.349	0.624	0.335	0.186	0.059	0.018	0.032

[1] Processing measurements are averaged means of 12 replicates of 4 birds each (2 males and 2 females) with body weights close to pen average (2.94 kg/bird) at 8 weeks of age.
[2] Carcass = Chilled carcass (without blood, feathers, head, hocks, offal, and abdominal fat pad).
[3] Breast = Major + Minor.
[4] [3] Diets were formulated to contain the following levels of CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.7%: 21.3%, CT-1.4%: 20.6%, and CT-2.1%: 19.9%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.7%: 19.3%, CT-1.4%: 18.6%, and CT-2.1%: 17.9%]; [(Finisher: 4 to 6½ wks): CT: 17.5%, CT-0.7%: 16.8%, CT-1.4%: 16.1%; and CT-2.1%: 15.4%]; [(Withdraw: 6½ to 8 wks): CT: 16.5%, CT-0.7%: 15.8%, CT-1.4%, 15.1%, and CT-2.1%, 14.4%].
[a, b] Values within column with different superscripts differ significantly ($P < 0.05$).

Table 6.6: Effect of decreasing crude protein levels[1] on processing responses, expressed as percentage over live body weight, of male and female Ross 708 broilers[2,3]

GENDER	FAT PAD	CARCASS	LEG	THIGH	WING	MAJOR	MINOR	BREAST[3]
	(%)							
FEMALE	2.80^{a}	74.00	8.92^{b}	11.94	7.74	19.73^{a}	4.33^{a}	24.06^{a}
MALE	2.24^{b}	73.72	9.52^{a}	12.04	7.64	19.12^{b}	4.02^{b}	23.14^{b}
SEM	*0.06*	*0.38*	*0.08*	*0.13*	*0.08*	*0.34*	*0.06*	*0.39*
	Probability							
GENDER	<.0001	0.5938	<.0001	0.5891	0.3721	0.0358	0.0005	0.0069
TRT	0.0005	0.3273	0.8890	0.6393	0.1200	0.1289	0.1434	0.1159
GENDER x TRT	0.6836	0.5687	0.1281	0.2449	0.6643	0.2894	0.2232	0.2289

[1] CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.7%: 21.3%, CT-1.4%: 20.6%, and CT-2.1%: 19.9%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.7%: 19.3%, CT-1.4%: 18.6%, and CT-2.1%: 17.9%]; [(Finisher: 4 to 6½ wks): CT: 17.5%, CT-0.7%: 16.8%, CT-1.4%: 16.1%; and CT-2.1%: 15.4%]; [(Withdraw: 6½ to 8 wks): CT: 16.5%, CT-0.7%: 15.8%, CT-1.4%, 15.1%, and CT-2.1%, 14.4%].

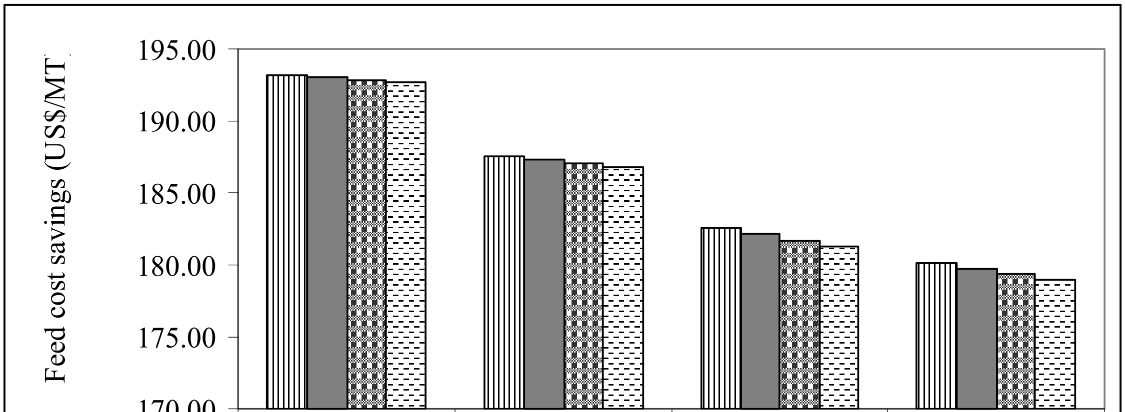
[2] Processing measurements are averaged means of 12 replicates of four birds each (two males and two females) with body weights close to pen average (2.94 kg/bird) at 8 weeks of age.

[3] Because no relevant interactions were detected (P > 0.05), only the main effect means for gender are shown. For treatment effects, see Table 6.5.

[4] Carcass = Chilled carcass (without blood, feathers, head, hocks, offal, and abdominal fat pad).

[5] Breast = Major + Minor.

[a, b] Values within column with different superscripts differ significantly (P < 0.05).



	Starter	Grower	Finisher	Withdrawal
CT	193.16	187.56	182.59	180.10
CT-0.7%	193.02	187.30	182.14	179.72
CT-1.4%	192.88	187.03	181.70	179.33
CT-2.1%	192.74	186.77	181.25	178.95

Figure 6.1: Effect of up to 2.1% decrease in crude protein levels on feed costs[1,2]

[1] Feedstuff prices (US$/1,000 kg): Corn, 144.00; Soybean meal, 245.00; Poultry by-product meal, 335.00; DL-Methionine, 2,200.00; Lysine.HCl, 1,980.00; L-Threonine, 2,494.80.
[2] Dietary Treatments CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.7%: 21.3%, CT-1.4%: 20.6%, and CT-2.1%: 19.9%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.7%: 19.3%, CT-1.4%: 18.6%, and CT-2.1%: 17.9%]; [(Finisher: 4 to 6½ wks): CT: 17.5%, CT-0.7%: 16.8%, CT-1.4%: 16.1%; and CT-2.1%: 15.4%]; [(Withdrawal: 6½ to 8 wks): CT: 16.5%, CT-0.7%: 15.8%, CT-1.4%, 15.1%, and CT-2.1%, 14.4%].

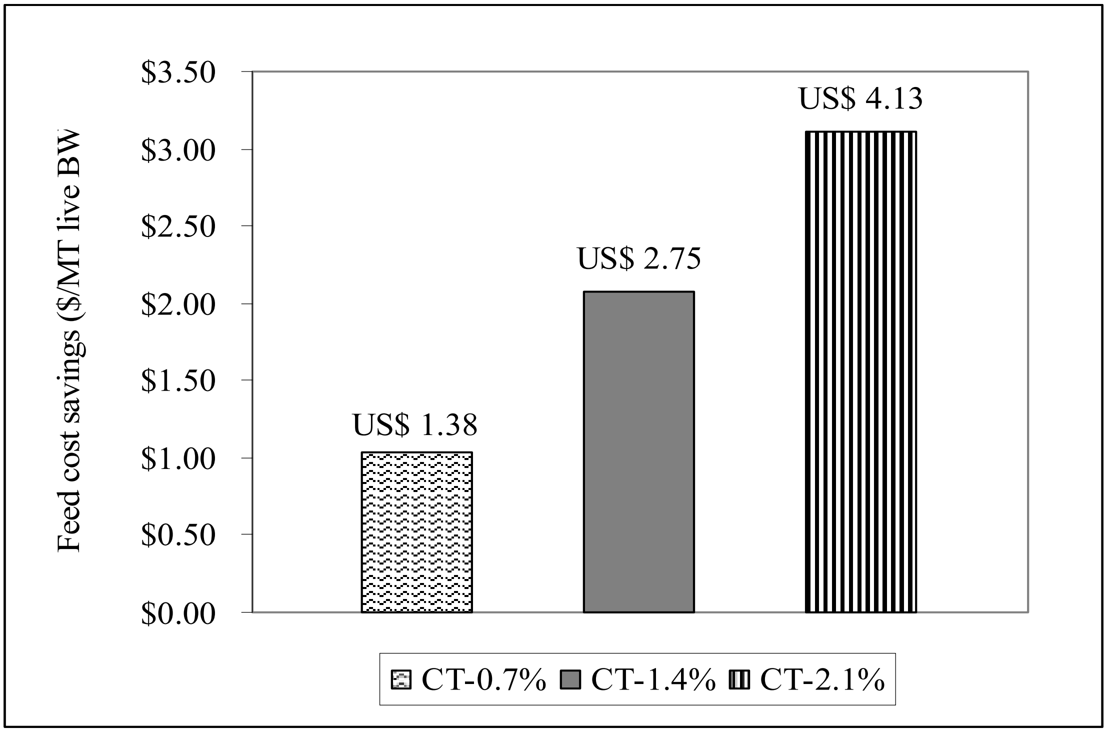


Figure 6.2: Feed cost savings per metric ton of live BW of Ross 708 broilers fed diets with up to 2.1% decrease in crude protein levels[1,2]

[1] Feedstuff prices (US$/1,000 kg): Corn, 144.00; Soybean meal, 245.00; Poultry by-product meal, 335.00; DL-Methionine, 2,200.00; Lysine.HCl, 1,980.00; L-Threonine, 2,494.80.
[2] Dietary Treatments CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.7%: 21.3%, CT-1.4%: 20.6%, and CT-2.1%: 19.9%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.7%: 19.3%, CT-1.4%: 18.6%, and CT-2.1%: 17.9%]; [(Finisher: 4 to 6½ wks): CT: 17.5%, CT-0.7%: 16.8%, CT-1.4%: 16.1%; and CT-2.1%: 15.4%]; [(Withdrawal: 6½ to 8 wks): CT: 16.5%, CT-0.7%: 15.8%, CT-1.4%, 15.1%, and CT-2.1%, 14.4%].

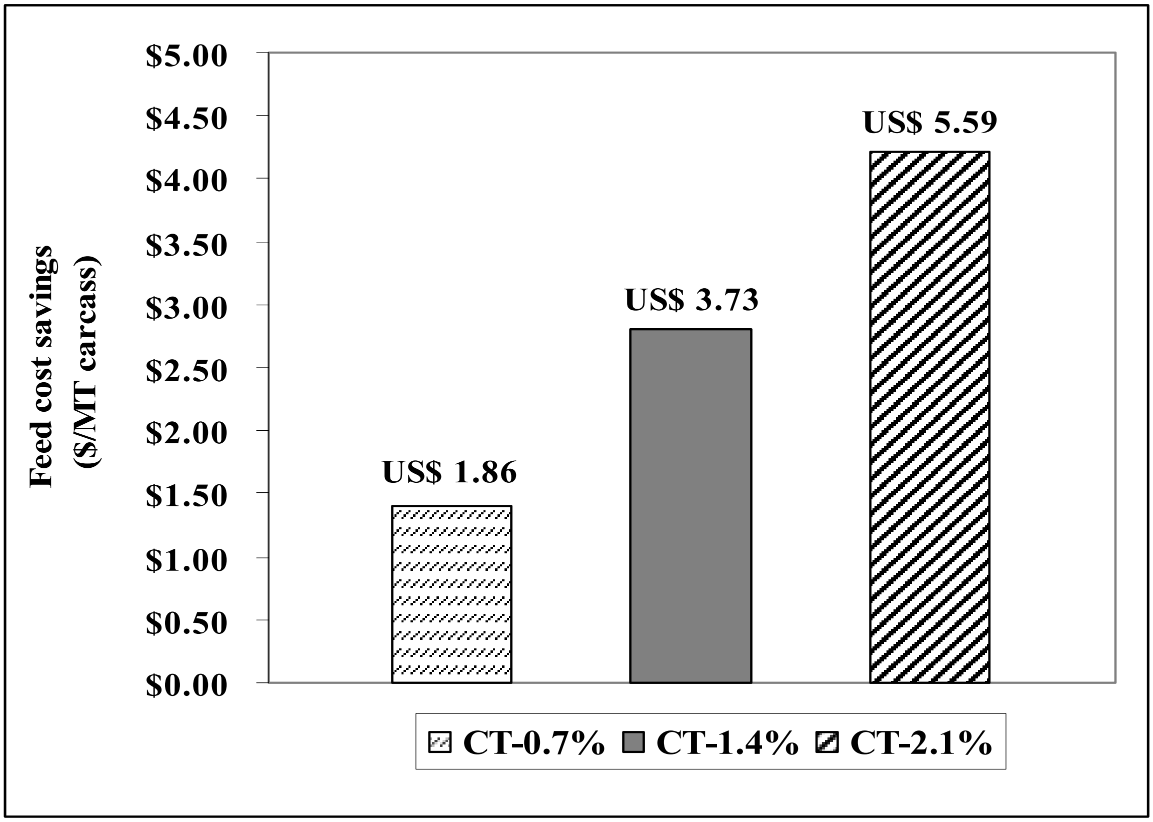


Figure 6.3: Feed cost savings per metric ton of carcass of Ross 708 broilers fed diets with up to 2.1% decrease in crude protein levels [1,2]

[1] Feedstuff prices (US$/1,000 kg): Corn, 144.00; Soybean meal, 245.00; Poultry by-product meal, 335.00; DL-Methionine, 2,200.00; Lysine.HCl, 1,980.00; L-Threonine, 2,494.80.

[2] Dietary Treatments CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.7%: 21.3%, CT-1.4%: 20.6%, and CT-2.1%: 19.9%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.7%: 19.3%, CT-1.4%: 18.6%, and CT-2.1%: 17.9%]; [(Finisher: 4 to 6½ wks): CT: 17.5%, CT-0.7%: 16.8%, CT-1.4%: 16.1%; and CT-2.1%: 15.4%]; [(Withdrawal: 6½ to 8 wks): CT: 16.5%, CT-0.7%: 15.8%, CT-1.4%, 15.1%, and CT-2.1%, 14.4%].

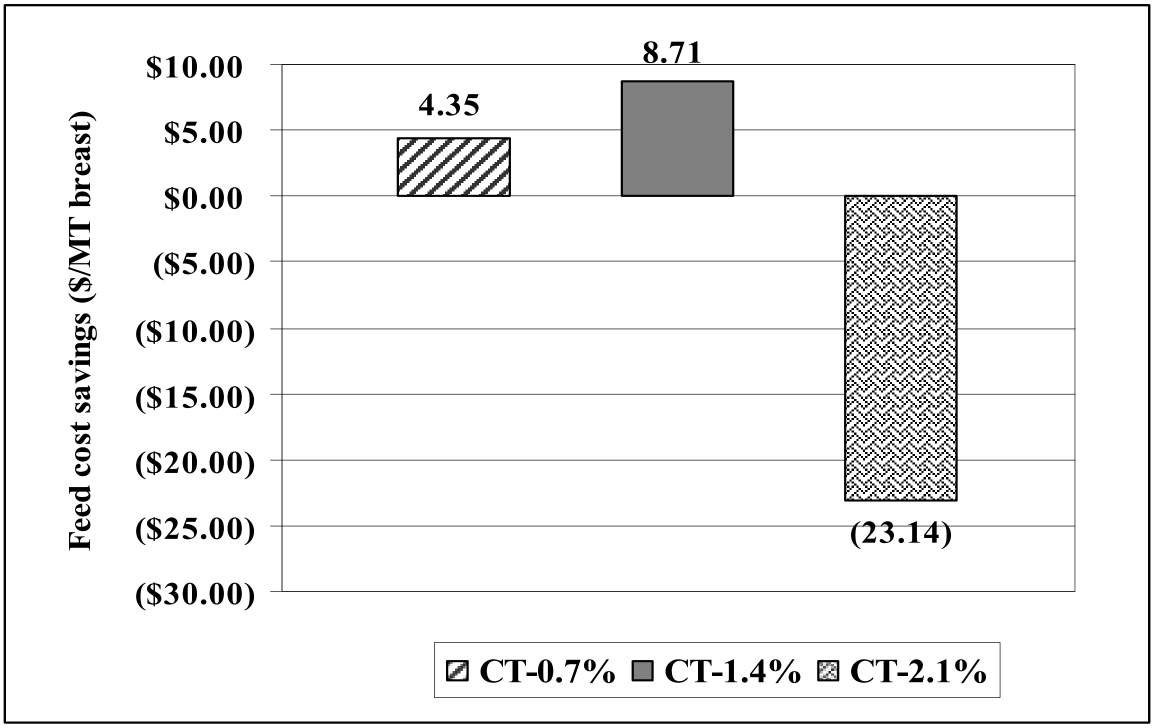


Figure 6.4: Feed cost savings per metric ton of breast meat of Ross 708 broilers fed diets with up to 2.1% decrease in crude protein levels[1,2]

[1] Feedstuff prices (US$/1,000 kg): Corn, 144.00; Soybean meal, 245.00; Poultry by-product meal, 335.00; DL-Methionine, 2,200.00; Lysine.HCl, 1,980.00; L-Threonine, 2,494.80.

[2] Dietary Treatments CP: [(Starter: 0 to 2 wks): CT: 22.0%, CT-0.7%: 21.3%, CT-1.4%: 20.6%, and CT-2.1%: 19.9%]; [(Grower: 2 to 4 wks): CT: 20.0%, CT-0.7%: 19.3%, CT-1.4%: 18.6%, and CT-2.1%: 17.9%]; [(Finisher: 4 to 6½ wks): CT: 17.5%, CT-0.7%: 16.8%, CT-1.4%: 16.1%; and CT-2.1%: 15.4%]; [(Withdrawal: 6½ to 8 wks): CT: 16.5%, CT-0.7%: 15.8%, CT-1.4%, 15.1%, and CT-2.1%, 14.4%].

Table 6.7: Reduced CP level diets supplemented with arginine, valine, isoleucine, leucine, or a mixture containing these four amino acids on performance of Ross 708 broilers.

	0-15 d			0-28 d			0-44 d			0-51 d		
	FI	BWG	FDGN	FI	BWG	FDGN	FI	BWG	FDGN	FI	BWG	FDGN
TRT[1,2]	------(g)-------		(g:g)	----(kg)------		(kg:kg)	-----(kg)------		(kg:kg)	-----(kg)------		(kg:kg)
CT	544	365	1.49	1.99	1.35^{a}	1.48	4.78	2.75^{a}	1.74^{b}	5.90	3.19^{a}	1.85^{b}
CT-2.1%	512	346	1.48	1.99	1.26^{b}	1.58	4.79	2.68^{ab}	1.79^{ab}	5.97	3.18^{a}	1.87^{ab}
CT-2.1+Arg	522	358	1.46	1.97	1.25^{b}	1.57	4.70	2.63^{b}	1.79^{ab}	5.78	3.08^{ab}	1.88^{ab}
CT-2.1+Val	546	350	1.56	2.00	1.25^{b}	1.60	4.75	2.66^{b}	1.79^{ab}	5.91	3.15^{ab}	1.88^{ab}
CT-2.1+Ile	521	347	1.50	1.98	1.23^{b}	1.61	4.71	2.58^{b}	1.83^{a}	5.82	3.06^{b}	1.90^{a}
CT-2.1+Leu	544	348	1.57	1.98	1.23^{b}	1.61	4.63	2.55^{b}	1.82^{a}	5.75	2.99^{b}	1.92^{a}
CT-2.1+All	511	361	1.42	1.88	1.26^{b}	1.49	4.60	2.68^{ab}	1.72^{b}	5.72	3.14^{ab}	1.82^{b}
SEM	*0.023*	*0.005*	*0.042*	*0.052*	*0.014*	*0.042*	*0.062*	*0.033*	*0.025*	*0.077*	*0.039*	*0.020*
	---------------------------Probability---------------------------											
ANOVA	0.418	0.056	0.206	0.636	0.0004	0.183	0.295	0.010	0.056	0.266	0.029	0.046
LINEAR	0.817	0.241	0.252	0.888	0.0003	<.0001	0.361	0.034	0.021	0.544	0.212	0.107
QUADRATIC	0.042	0.379	0.101	0.476	0.476	0.023	0.616	0.088	0.032	0.587	0.363	0.316

[1] Treatments: CT, CP at Agristats level (Agristats, 2005); CT-2.1%, CT with 2.1% reduction in CP; CT-2.1+Arg, CT-2.1% supplemented with arginine; CT-2.1+ Val, with valine supplementation; CT-2.1+Ile, with isoleucine; CT-2.1+Leu, with leucine; and CT-2.1+All, CT-2.1% supplemented with a mixture containing crystalline forms of Arg, Val, Ile, and Leu.

[2] CT and CT-2.1%, data are means of 6 replicates of 30 birds each; remaining treatments, data are means of seven replicates of 30 birds.

[a,b] Means with different superscripts within a column are significantly different ($P < 0.05$).

Table 6.8: Reduced CP diet supplemented with arginine, valine, isoleucine, leucine, or a mixture containing these four amino acids on processing responses, expressed as percentage of live BW, of Ross 708 broilers.

TRT[1,2]	FAT PAD	CARCASS	LEG	THIGH	WING	MAJOR	MINOR	BREAST[3]
	(%)							
CT	2.06[b]	74.90[a]	9.67	11.72	7.81	18.73	4.19	22.92
CT-2.1%	2.63[a]	72.98[c]	9.28	11.09	7.66	18.46	4.06	22.52
CT-2.1+Arg	2.34[ab]	73.72[bc]	9.26	11.22	7.64	18.53	4.05	22.59
CT-2.1+Val	2.08[b]	73.89[b]	9.57	11.79	7.99	18.42	3.98	22.40
CT-2.1+Ile	2.45[a]	74.11[ab]	9.46	11.51	7.83	19.38	4.12	23.50
CT-2.1+Leu	2.40[a]	73.54[bc]	9.48	11.10	7.70	18.43	3.99	22.42
CT-2.1+All	2.49[a]	74.27[ab]	9.14	11.59	7.67	18.62	3.97	22.59
SEM	*0.13*	*0.34*	*0.13*	*0.18*	*0.12*	*0.42*	*0.08*	*0.45*
	Probability							
ANOVA	0.030	0.017	0.056	0.028	0.287	0.615	0.457	0.499
LINEAR	0.586	0.168	0.622	0.597	0.343	0.650	0.077	0.443
QUADRATIC	0.0005	0.004	0.005	0.001	0.053	0.820	0.716	0.782

[1] Treatments: CT, CP at Agristats level (Agristats, 2005); CT-2.1%, CT with 2.1% reduction in CP; CT-2.1+Arg, CT-2.1% supplemented with arginine; CT-2.1+ Val, with valine supplementation; CT-2.1+Ile, with isoleucine; CT-2.1+Leu, with leucine; and CT-2.1+All, CT-2.1% supplemented with a mixture containing crystalline forms of Arg, Val, Ile, and Leu.
[2] CT and CT-2.1%, data are means of 6 replicates of 30 birds each; remaining treatments, data are means of seven replicates of 30 birds.
[a,b] Means with different superscripts within a column are significantly different ($P < 0.05$).
[3] Breast yield = Major + Minor yields.

Table 6.9: Reduced CP diet supplemented with arginine, valine, isoleucine, leucine, or a mixture containing these four amino acids on processing responses, expressed as percentage over live body weight, of male and female Ross 708 broilers[1,2]

GENDER	FAT PAD	CARCASS	LEG	THIGH	WING	MAJOR	MINOR	BREAST[3]
	(%)							
FEMALE	2.57[a]	73.77	9.12[b]	11.18[b]	7.78	18.93	4.17[a]	23.11[a]
MALE	2.13[b]	74.06	9.70[a]	11.68[a]	7.74	18.37	3.93[b]	22.31[b]
SEM	*0.06*	*0.38*	*0.08*	*0.13*	*0.08*	*0.34*	*0.06*	*0.39*
	Probability							
GENDER	0.030	0.017	0.056	0.028	0.287	0.615	0.457	0.499
TRT	<.0001	0.250	<.0001	0.0007	0.618	0.076	0.0005	0.016
GENDER x TRT	0.465	0.393	0.922	0.941	0.298	0.606	0.684	0.641

[1] Treatments: CT, CP at Agristats level (Agristats, 2005); CT-2.1%, CT with 2.1% reduction in CP; CT-2.1+Arg, CT-2.1% supplemented with arginine; CT-2.1+ Val, with valine supplementation; CT-2.1+Ile, with isoleucine; CT-2.1+Leu, with leucine; and CT-2.1+All, CT-2.1% supplemented with a mixture containing crystalline forms of Arg, Val, Ile, and Leu.

[2] CT and CT-2.1%, data are means of 6 replicates of four birds (two males and two females); remaining treatments, data are means of 7 replicates of 4 birds.

[a,b] Means with different superscripts within a column are significantly different ($P < 0.05$).

[3] Breast yield = Major + Minor yields.

CHAPTER VII

CONCLUSION

Feed costs accounts for 75% of the cost associated with meat production. Therefore, many attempts have been done to decreased the cost of feed and therefore increase the profit of a company. A decrease in dietary crude protein with no significant effect on performance can be achieved by slightly decreases in dietary crude protein (CP) at the expense of amino acids.

A series of experiments has been performance to determine the effects of reduced crude protein for different strains of commercial boilers fed up to market age. In experiment 1, the effects of 1.5% reduction in CP on performance and economics of Cobb 500 broilers fed from hatch to d 42 were tested. The decrease in CP did not affect performance, carcass yield, percentage of abdominal fat pad, breast meat yield, thigh, and wing. A decrease in the cost of the diets was also observed. The same result was obtained when Ross 508 broilers were fed from hatch to d 49 and Ross 708 broilers fed from hatch to d 56.

In attempt to determine how low CP could be without affecting performance and meat yield, 2 other experiments were designed to determine if a 2.1% reduction in dietary CP would negatively affect performance and breast meat yield of Ross 708 broilers fed from hatch to d 51. For the first experiment, diets had CP decreased in 0.7% increments up to 2.1% less CP than the control. A decrease in meat yield was observed when the 2.1% reduced CP diet was fed. When the diet with the lowest level of CP was compared with the control, the levels of the less limiting amino acids isoleucine, valine, arginine, and valine became limiting or very close to the required levels. Therefore, a follow up experiment was performed where the low CP diet was supplemented with these amino acids individually or with a mixture containing all of them. However, in this second experiment, breast meat yield was not affected which may have been caused by the few replicate pens used when the second experiment was realized. However, carcass yield was decreased in experiment 2 and supplementation of low CP diet with isoleucine and all amino acids restored carcass yield to control level. Abdominal fat pad yield increased as CP decreased and supplementation of valine and arginine decreased fat pad yield to control level.

Overall, these experiments suggest that a decrease of 1.5% in dietary crude protein does not affect performance and meat yield. However, a 2.1% decrease in CP may be too drastic even when the diet is balanced with synthetic amino acids.

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