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PROGRAMA DE PÓS-GRADUAÇÃO EM ZOOTECNIA

DESEMPENHO E RETORNO ECONÔMICO DE PROGRAMAS DE ALIMENTAÇÃO VARIANDO ENERGIA E LISINA DIGESTÍVEL PARA FRANGOS DE CORTE

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“O conhecimento serve para encantar as pessoas, não para humilhá-las.”

– Mario Sergio Cortella

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DESEMPENHO E RETORNO ECONÔMICO DE PROGRAMAS DE ALIMENTAÇÃO VARIANDO ENERGIA E LISINA DIGESTÍVEL PARA FRANGOS DE CORTE

Autor: Pablo Lima Ibairro dos Santos

Orientador: Sergio Luiz Vieira

Resumo - Foi realizado um estudo para avaliar o desempenho e os impactos econômicos de frangos de corte Cobb 500 alimentados com dieta milho-soja contendo três níveis de energia metabolizável aparente (EMA) (alto, moderado e baixo) e três densidades de Lisina digestível (dig. Lys) (alta, moderada e baixa). Os níveis moderados de EMA consistiram em 3.000, 3.080, 3.140, 3.160 e 3.180 kcal/kg para as fases pré-inicial, inicial, crescimento 1, crescimento 2 e retirada, respectivamente. Nível baixo e alto de EMA foi de 50 kcal/kg acima ou abaixo dos níveis moderados para a respectiva fase. As densidades moderadas de Lisina foram: 1,33, 1,24, 1,13, 1,04 e 0,96 % para as fases pré-inicial, inicial, crescimento 1, crescimento 2 e retirada, respectivamente. As densidades de dig. Lys. baixa e moderada foram 5% maiores ou menores que os valores moderados de acordo com cada fase. Um total de 1.800 pintos machos foram distribuídos aleatoriamente em 9 tratamentos e 8 repetições com 25 aves cada. O desempenho zootécnico foi ajustado por meio de regressões para 2.950 g de peso corporal, estimado a partir da pesagem de frangos de corte de 35 a 38 dias. Níveis mais elevados de EMA e dig. Lys apresentaram maior ganho de peso corporal (GP), maior consumo de ração (CR) e menor taxa de conversão alimentar (CA). CA e CR foram menores para frangos alimentados com maiores níveis de EMA e maiores densidades de dig. Lys ($P<0,05$), quando o desempenho de crescimento foi ajustado para 2.950 g, com menos dias de alojamento para frangos de corte. Frangos alimentados com alta dig. Lys apresentaram maior valor para peito ($P<0,05$) quando comparados àqueles alimentados com menor densidade de dig. Lys, porém não houve diferença para os níveis de EMA ($P>0,05$). O nível de EMA e dig. Lys não influenciou ($P>0,05$) rendimento de carcaça, gordura abdominal, coxas, sobrecoxas, asas e dorso ($P>0,05$). Frangos de corte alimentados com alto nível de EMA e alta densidade de dig. Lys apresentaram menores valores de CA por kg de peito produzido e CA por kg de carcaça ($P<0,05$). Custo de alimentação, custo por kg de peso corporal, custo por kg de carcaça e custo por kg de peito foram maiores quando os frangos de corte foram alimentados com altos níveis de EMA e altas densidades de dig. Lys. Os dados do presente estudo sugerem que o desempenho apresenta melhores resultados quando os frangos de corte são alimentados com altos níveis de densidades de EMA e dig. Lys, porém esses custos são mais elevados. Ajustando o peso corporal para 2.950 g, o custo de alimentação foi menor para o baixo nível de EMA e alta densidade de dig. Lys. É necessário avaliar diferentes cenários de preços de milho e soja visando utilizar estratégias para encontrar o melhor equilíbrio entre densidade de nutrientes e custo.

Palavras-chave: aminoácido, custos, energia metabolizável, frangos de corte.

PERFORMANCE AND ECONOMIC RETURN OF FEEDING PROGRAMS VARYING ENERGY AND DIGESTIBLE LYSINE FOR BROILERS

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Abstract - A study was conducted study was to evaluate performance and economic impacts of broilers Cobb 500 fed corn-soy diet containing three AME levels (high, moderate, and low) and three digestible Lysine (dig. Lys) densities (high, moderate, and low). Moderate levels of AME consisted in 3,000, 3,080, 3,140, 3,160 and 3,180 kcal/kg for pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. Low and high levels of AME was 50 kcal/kg above or below moderate levels for the respective phase. Moderate density of dig. Lys were: 1.33, 1.24, 1.13, 1.04 and 0.96 % digestible lysine for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. Low and moderate IP densities were 5% higher or lower than moderate values according to each phase. A total of 1,800 male chicks were randomly distributed in 9 treatments and 8 replications with 25 birds each one. Growth performance was adjusted through regressions to 2,950 g of body weight, estimated from weighing broilers from 35 to 38 days. Higher levels of AME and dig. Lys presented higher body weight gain (BWG), higher feed intake (FI), and lower feed conversion rate (FCR). FCR and FI were lower for broilers fed higher AME levels and higher dig. Lys densities ($P < 0.05$) when growth performance was adjusted to 2,950 g, with fewer days of housing for broilers. Broilers fed high dig. Lys presented higher value for breast ($P < 0.05$) when compared to those fed lower dig. Lys density, however, there was no difference for AME levels ($P > 0.05$). The level of AME and dig. Lys did not influence ($P > 0.05$) carcass yield, abdominal fat, things, drumsticks, wings, back ($P > 0.05$). Broilers fed high AME level and high density of dig. Lys presented lowest values for FCR per kg of breast produced and FCR per kg of carcass ($P < 0.05$). Feeding cost, cost per kg body weight, cost per kg of carcass and cost per kg of breast were higher when broilers were fed high AME levels and high dig. Lys densities. Data from the present study suggest that performance present better results when broilers are fed high levels of AME and dig. Lys densities, however, these costs are more expansive. Adjusting body weight to 2,950 g, the feeding cost were lower for low level AME and high dig. Lys density. It is necessary to evaluate different price scenarios of corn and soybeans to use strategies to find the best balance of nutrient densities and cost.

Keywords: amino acid, broiler, costs, metabolizable energy.

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LISTA DE ABREVIATURAS

AA	Aminoácido(s)
CA	Conversão Alimentar
CR	Consumo de Ração
d	dias
dig. Lys.	Lisina digestível
EMA	Energia Metabolizável Aparente
g	grama(s)
GP	Ganho de Peso

CAPÍTULO I

INTRODUÇÃO

A seleção genética em frangos de corte nas últimas décadas foi muito intensa e determinante para chegarmos no produto que se têm atualmente, com foco na taxa de crescimento e na eficiência alimentar, apresentando velocidades de crescimento e rendimento de carcaça diferentes (BENYI et al., 2009; VIEIRA et al., 2007). Os planos nutricionais influenciam diretamente sobre esses parâmetros supracitados, o nível de energia e o perfil proteico devem ser estrategicamente utilizados, para potencializar o ganho de peso e a conversão alimentar afim de que os frangos expressem seu máximo potencial genético (LITZ et al., 2014; VIEIRA et al., 2007).

Determinar o nível de proteína e energia é a principal e mais importante tomada de decisão do nutricionista no momento de formular uma dieta para frangos de corte (LEANDRO et al., 2003). Há alguns anos, as dietas para frangos de corte eram formuladas para atender o requerimento de proteína bruta, porém, com o advento da indústria de aminoácidos sintéticos, tornou-se possível a formulação com base nas exigências cada vez mais específicas de aminoácidos essenciais, reduzindo custos sem afetar o desempenho (BERRES et al., 2010; MAIORKA et al., 2004). Esse notável progresso na nutrição de aves visa garantir que haja um equilíbrio de aminoácidos na dieta, visto que a utilização deliberada e posterior absorção em excesso de um aminoácido em relação ao primeiro limitante, faria com que esse excesso seja excretado na forma de nitrogênio (LEMME, 2003).

Historicamente, pensava-se que quanto mais energia se utilizava na formulação das dietas para frangos de corte, maior seria a sua taxa de crescimento, contudo, alguns problemas metabólicos se tornaram mais frequentes, como a ascite. Assim, tentou-se buscar estratégias para que se formulasse as dietas com menor teor de energia e a taxa de crescimento sofresse pouca alteração, de forma que, em tese, as aves seriam capazes de controlar o consumo de ração para atender sua demanda energética. A capacidade da ave de se ajustar a dieta, além de interferir sobre o desempenho animal também poderia trazer efeitos negativos sobre a qualidade da carcaça (ATAEI et al., 2022; LEESON et al., 1996). O objetivo do estudo foi avaliar o desempenho e os impactos econômicos de frangos de corte Cobb 500 alimentados com dieta milho-soja contendo três níveis de energia metabolizável aparente (EMA) (alto, moderado e baixo) e três densidades de Lisina digestível (dig. Lys) (alta, moderada e baixa).

REVISÃO BIBLIOGRÁFICA

Há algum tempo o peso dos frangos de corte vem melhorando de acordo com a idade, em decorrência dessa melhora, o produto a base de carne de frango que é ofertado ao consumidor também vem sofrendo alterações. A indústria necessita de uma carcaça que atinja o seu máximo rendimento de carne comestível e a partir disso busca-se a otimização da alimentação, visando a melhor eficiência alimentar na produção e um produto de melhor qualidade (SUMMERS et al., 1992).

Energia em rações para frangos de corte

A energia dos ingredientes, serve como base para calcular e obter o valor energético das rações nas diferentes fases de criação (MEZA et al., 2015). Carboidratos, gorduras e proteínas são importantes componentes presentes numa ração, visando a manutenção das atividades vitais, manutenção da temperatura corporal, bem como o crescimento dos tecidos corporais e necessidade de energia requerida pelos frangos varia de acordo com a idade, taxa de crescimento e até fatores ambientais (TEIXEIRA, 2017; NELSON and COX, 2008).

Vários estudos vêm demonstrando efeitos positivos sobre o aumento da energia da dieta sobre o desempenho, principalmente se tratando do ganho de peso e a taxa de conversão alimentar (NUNES et al., 2015; DOZIER et al., 2011). Discute-se a regulação do consumo de ração de frangos de corte de acordo com o nível de energia usado e alguns autores concluem que os frangos não têm capacidade de regulação do consumo em decorrência da porção energética da dieta (ATAEI et al., 2022; PLUMSTEAD et al., 2007).

Uma das estratégias mais utilizadas, é a adição de gordura nas dietas para frangos de corte, com o propósito de aumentar a quantidade de energia. Com o acirramento da procura por fontes energéticas de origem vegetal para produção de biodiesel, causando competição entre os setores, o custo para se utilizar a energia na dieta de frangos de corte aumentou e ainda se conhece pouco sobre alternativas viáveis como fonte energética na ração (AHIWE et al., 2018; VIEIRA et al., 2015). Normalmente as aves ingerem ração com o objetivo de satisfazer sua exigência energética independente da exigência dos outros nutrientes necessários, podendo causar queda no desempenho e aumento da deposição de gordura abdominal ou na carcaça (AHIWE et al., 2018; SUMMERS et al., 1992).

Restrição alimentar

Buscando uma melhor eficiência econômica na produção de frangos de corte, a restrição alimentar surge como uma alternativa de manejo capaz de reduzir o consumo de ração e consequentemente o custo com a alimentação, que foi impulsionado nos últimos anos, de forma que não haja queda na taxa de ganho de peso. (SAHRAEI, 2012).

O crescente desenvolvimento dos parâmetros de desempenho zootécnico dos frangos de corte são características importantes e esperadas, entretanto, salienta-se o aparecimento de alguns problemas em decorrência desse desenvolvimento acelerado, como aumento na deposição de gordura abdominal, dificuldades locomotoras e distúrbios metabólicos, de forma que ocasione perdas econômicas, em contrapartida, a eficiência alimentar torna a produção mais rentável, devido a compensação no ganho, sem que haja grandes reduções no peso de abate (RAMOS et al., 2011; FIGUEIREDO et al., 1998).

Na fase inicial de produção, a utilização da restrição alimentar se torna benéfica com a melhora na eficiência alimentar e redução dos custos com alimentação, mesmo que o desempenho inicial das aves seja reduzido. O crescimento acentuado pode ser notado a partir da adoção da restrição alimentar, simultaneamente são notados alguns problemas esqueléticos nos frangos de corte, nos ossos longos como tíbia e fêmur. A restrição alimentar pode ser feita de duas formas, a restrição pode ocorrer pela diminuição da quantidade de ração ofertada ou então através da diluição da dieta, com níveis nutricionais mais baixos que os usuais (MELO et al., 2021 e ZHAN et al., 2007).

A adoção de um programa de restrição alimentar deve prever o baixo desempenho inicial das aves para que se tenha sucesso. Entretanto, a partir da realimentação contínua, para que as aves apresentem bom desempenho produtivo e econômico, é necessário que as mesmas demonstrem compensação no ganho de peso (FIGUEIREDO et al, 1998 e BUTZEN et al, 2013). Após o período de restrição, as aves devem ter tempo suficiente de realimentação, para que as aves atinjam o peso semelhante àquelas que estavam recebendo ração a vontade (YU e ROBINSON, 1992).

Restrição qualitativa

Existem dois métodos atualmente aceitos para que se adote a técnica de restrição alimentar e cada um deles apresenta um resultado diferente no desempenho dos animais. Na restrição qualitativa os animais são submetidos a uma limitação no consumo de nutrientes da dieta, ou seja, a dieta é formulada com níveis mais baixos que o usual. Já na restrição quantitativa, limita-se o consumo físico da ração, mas em ambos os métodos, após um período de restrição, os animais tendem a apresentar um rápido crescimento, chamado de ganho compensatório (VAN DER KLEIN et al., 2017).

Conceitualmente, a restrição alimentar é realizada a partir da diluição de nutrientes da dieta, ou seja, há redução na relação de energia e proteína. A restrição na quantidade de proteína e energia que as aves ingerem enquanto jovens é capaz de induzir o ganho compensatório, mas com maior acúmulo de gordura corporal (SUMMERS et al., 1990). A resposta à restrição alimentar varia de acordo com o tempo de duração, entretanto, quando for aplicada por um período mais prolongado, o ganho compensatório pode acabar sendo prejudicado (OMOSEBI et al., 2014).

A restrição alimentar, seja qualitativa ou quantitativa, tem por objetivo a redução da taxa de crescimento dos frangos, principalmente quando são criados por períodos mais longos. Outro propósito da utilização da restrição alimentar é para modificar a composição da carcaça, visto que a diluição da dieta a partir de fibras inertes, apresentam maior maciez na carne, menor teor de gordura e maior deposição de proteína na carcaça (NIELSEN et al., 2003).

Proteína ideal

O conceito de proteína ideal refere-se ao melhor balanço de aminoácidos (AA) presentes no alimento e que atende da melhor forma possível a exigência das aves para mantença e produção, todos os AA essenciais são expressos na forma de porcentagem com relação a um aminoácido referência (ARAÚJO et al., 2001). Antigamente, as rações para frangos de corte eram formuladas apenas para atender a demanda de proteína bruta, com os avanços nutricionais, as dietas passaram a ser formuladas através dos níveis totais de AA para que se atendesse as exigências proteicas das aves (NETO e OLIVEIRA, 2009).

Dari et al (2005) relataram que dietas formuladas aplicando o conceito de proteína ideal e uso de aminoácidos digestíveis promove maior ganho de peso em comparação com dietas formuladas com base nos aminoácidos totais. O aminoácido usado como referência na formulação das rações para frangos de corte é a Lisina, segundo aminoácido limitante, é usada para acrescentar e para manter a proteína corporal, sua análise em rações é simples e sua exigência amplamente estudada (OLIVEIRA et al., 2016; EMMERT and BAKER, 1997).

Toledo et al. (2004) avaliaram o desempenho e viabilidade econômica da formulação de rações a partir da proteína bruta e da proteína ideal de duas linhagens de frangos de corte (Hybro G e Hybro PG) na estação de inverno. Foi observado maior consumo de ração quando as aves foram alimentadas com o conceito de proteína bruta, o que segundo os autores, deve-se a influência do teor de proteína da dieta sobre o consumo. Existe a tendência de que as aves consumam mais alimento na busca por uma ingestão suficiente de AA em caso de deficiência na dieta. Entretanto, quando as aves foram alimentadas com base no conceito de proteína ideal, houve maior ganho de peso e melhor conversão alimentar.

Efeito de diferentes densidades proteicas para frangos de corte

Kidd et al., 2004 relataram em estudo que a partir da avaliação de diferentes densidades de AA em diferentes fases de alimentação. Foram utilizadas 4 fases: 1 a 14, 15 a 28, 29 a 35 e 36 a 49 dias e para cada fase foi utilizado 3 densidades de AA, alto (H), médio (M) e baixo (L). Para o nível alto de Lisina, foi considerado 1,38, 1,22 para o médio e 1,13% para o baixo nível de inclusão de Lisina de 1 a 14 dias, 1,19; 1,10 e 1,03 para alto, médio e baixo, respectivamente de 15 a 28 dias, 1,11; 0,98; e 0,85 de 28 a 35 dias e para a fase final de 36 a 49 dias, 1,06; 0,90 e 0,79. Os autores concluíram que com o uso da densidade moderada de AA, foi possível melhorar a CA, entretanto, o mesmo efeito não foi observado no peso final e no rendimento de peito e as dietas com alta densidade de AA nas fases iniciais possibilitou melhora no peso e no rendimento de peito.

Trindade Neto et al., 2009, trabalharam com diferentes níveis de Lisina digestível para frangos de corte de 37 a 49 dias de idade e observaram que o nível de Lisina apontou diferença significativa apenas para CA, utilizando 1,00% de Lisina digestível na dieta, os autores observaram que houve uma diminuição na deposição de gordura abdominal e quando foi usado uma maior inclusão, a deposição de gordura abdominal foi maior.

Fatufe et al., 2004, ofertando diferentes concentrações de Lisina na dieta (3,8 a 16,8 g/kg) para frangos de corte de 8 a 21 dias, com o objetivo de mensurar o ganho de peso, proteína e o perfil individual de aminoácidos e fizeram a comparação com machos de 2 genótipos diferentes, um híbrido de frango e um híbrido de postura, os autores concluíram que a eficiência de utilização de aminoácidos pode depender do genótipo utilizado.

Já Vieira et al., 2007, realizaram um estudo e avaliaram a resposta de frangos de corte fêmeas de duas linhagens diferentes (Cobb 500 e Ross 308), alimentados com diferentes níveis proteicos e 4 fases de alimentação: 1 a 7, 8 a 21, 22 a 31 e 32 a 37 dias de idade. Até os 21 dias, as aves receberam dietas com níveis alto (A), médio (M) e baixo (B) de proteína. A partir dos 22 dias até os 37, os tratamentos foram redistribuídos, metade das aves que estavam recebendo a dieta A, passaram a receber B e metade das aves que estavam recebendo a dieta B, passaram a receber A, as que receberam a dieta M, não houve mudança e concluíram que a linhagem Cobb apresentou melhor CA independentemente do nível proteico utilizado e o nível médio foi o suficiente para atingir o ótimo desempenho, tanto para peso quanto para CA.

HIPÓTESES E OBJETIVOS

Hipóteses

Frangos de corte alimentados com alta Energia e alta Lisina digestível apresentam melhor desempenho zootécnico;

Frangos de corte alimentados com alta Energia e alta Lisina digestível apresentam maior rendimento de carcaça e cortes comerciais;

Frangos de corte alimentados com alta Energia e alta Lisina digestível apresentam melhor custo-benefício.

Objetivo Geral

Avaliar o desempenho, rendimento de carcaça e custo de produção de frangos de corte machos alimentados com níveis crescentes de Energia e Lisina digestível.

Objetivo específico

Determinar a relação de energia e proteína que traga o melhor custo-benefício.

CAPÍTULO II

Performance and economic return of feeding programs varying energy and digestible lysine for broilers

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ABSTRACT: A study was conducted study was to evaluate performance and economic impacts of broilers Cobb 500 fed corn-soy diet containing three AME levels (high, moderate, and low) and three digestible Lysine (dig. Lys) densities (high, moderate, and low). Moderate levels of AME consisted in 3,000, 3,080, 3,140, 3,160 and 3,180 kcal/kg for pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. Low and high levels of AME was 50 kcal/kg above or below moderate levels for the respective phase. Moderate density of dig. Lys were: 1.33, 1.24, 1.13, 1.04 and 0.96 % digestible lysine for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. Low and moderate IP densities were 5% higher or lower than moderate values according to each phase. A total of 1,800 male chicks were randomly distributed in 9 treatments and 8 replications with 25 birds each one. Growth performance was adjusted through regressions to 2,950 g of body weight, estimated from weighing broilers from 35 to 38 days. Higher levels of AME and dig. Lys presented higher body weight gain (BWG), higher feed intake (FI), and lower feed conversion rate (FCR). FCR and FI were lower for broilers fed higher AME levels and higher dig. Lys densities ($P < 0.05$) when growth performance was adjusted to 2,950 g, with fewer days of housing for broilers. Broilers fed high dig. Lys presented higher value for breast ($P < 0.05$) when compared to those fed lower dig. Lys density, however, there was no difference for AME levels ($P > 0.05$). The level of AME and dig. Lys did not influence ($P > 0.05$) carcass yield, abdominal fat, things, drumsticks, wings, back ($P > 0.05$). Broilers fed high AME level and high density of dig. Lys presented lowest values for FCR per kg of breast produced and FCR per kg of carcass ($P < 0.05$). Feeding cost, cost per kg body weight, cost per kg of carcass and cost per kg of breast were higher when broilers were fed high AME levels and high dig. Lys densities. Data from the present study suggest that performance present better results when broilers are fed high levels of AME and dig. Lys densities, however, these costs are more expansive. Adjusting body weight to 2,950 g, the feeding cost were lower for low level AME and high dig. Lys density. It

is necessary to evaluate different price scenarios of corn and soybeans to use strategies to find the best balance of nutrient densities and cost.

Keywords: amino acid, broiler, metabolizable energy, performance.

Summary

From the genetic and nutritional advances and the price competitiveness of the ingredients commonly used in the formulation of diets, the poultry industry has sought different nutritional programs, aiming to supply the exact amount of nutrients that the poultry need, through the offer of balanced feeds, since that energy and protein in the diet directly influence the cost of feed. In the pre-starter and starter phases, amino acid requirements are greater and their efficiency is related to the increase in muscle mass, therefore, any adjustment that is made to the diet enables important gains, both productive and economic, since poultry companies have aiming to produce an increasingly competitive and quality product for the consumer market. In poultry nutrition, Lysine is used as a reference amino acid, it is an amino acid that is easy to analyze, has no metabolic interactions with other amino acids and is almost exclusively used in protein synthesis.

Description of Problem

In the current context, in which the performance of modern broilers has improved considerably over time (Havenstein et al., 2003; Zubair and Leeson, 1996); feeding programs, diet formulation, and production goals are continually changing. A trend of poultry marketing for heavier weights has been increasing over the last years. Since costs of major feed ingredients, such as soybean meal (SBM), corn, and vegetable fats have dramatically increased in the last few years (Teixeira, 2017; Infante-Rodríguez et al., 2016; Rosegrant et al., 2013), the value of this production has been questioned. As more than 70% of poultry productions regards to the feed, being energy and amino acids (AA) representing most of the diet cost, the actual aim form modern poultry industry is to reduce feed cost for optimal economic returns (Faraj, 2016; Toledo et al., 2007).

When formulating a broilers diet, the relationship between protein and energy concentrations is challenging, as both are the largest and most expensive components in broilers diet (Sharma et al., 2018). It is being shown in the literature that nutritionally balanced diets with an ideal energy and ideal protein ratio have a great influence on broiler performance, carcass yield, breast yield, as well as in economic viability, increasing feed efficiency (Dozier III et al., 2006; Basurco et al., 2015). Thus, to obtain the best cost benefit, the balance between energy and protein needs to be taken in consideration.

In the composition of the total cost of a broiler diet, energy is the most relevant item, significantly increasing the cost of poultry production (O'neill et al., 2012; Vasconcellos et al., 2012), as the feed costs become higher with increasing levels of metabolizable energy. Broiler are fed diets with high energy content, as it is recognized to maximize growth rate (Basurco et al., 2015; Hussein et al., 2020).

Meeting AA requirements represents large part of the cost of a broiler diet, allowing also better broiler performance (Vieira and Angel, 2012). The affordable prices of synthetic essential AA supplementation in commercial fed made it easier to adjust its actual requirement in the diet achieving requirement levels of AA closer to broilers needs (Costa et al., 2001; Baker et al., 2002). AA requirements change due to factors as growth phase, dietary composition and genetics. However, the ideal ratios among essential AA remain similar, thus only an accurate requirement for Lys, the major limiting AA for poultry fed corn and SBM diet, needs to be established (NRC, 1994). Lysine is considered the standard AA, with the remaining AA being added as a percentage of its content, under the concept of ideal protein (Baker et al., 2002; Schutte and de Jong, 1999; Emmert and Baker, 1997). Thus, the requirements of this AA must be measured with high precision to obtain the best animal performance (Oliveira et al., 2016; Si et al., 2001).

In this context, providing broilers diets containing excess or at suboptimum concentrations of AME and AA may decrease profits by increased feed cost or reduced meat yield. Several scientific studies have evaluated the economic impact of the density of the nutritional content of diets (Dozier III et al., 2006; a; Corzo et al., 2010; Lilly et al., 2011; Basurco et al., 2015). However, experimental results recorded in the literature are varied and sometimes contradictory with no consensus for economic analysis evaluating performance and carcass composition of chickens fed diets containing different levels of apparent metabolizable energy (AME) and digestible Lysine (dig. Lys). Therefore, further investigation with modern genotypes is needed. The present study was conducted to evaluate performance, carcass yield and cost of production of Cobb x Cobb 500 male broilers fed increasing levels of AME and IP from 1 to 38 days of age.

Material and methods

The Ethics and Research Committee of the Federal University of Rio Grande do Sul, Porto Alegre, Brazil, approved all procedures used in the present study.

Bird Husbandry and Dietary Treatments

The experiment took place at Aviário de Ensino e Pesquisa of Federal University of Rio Grande do Sul. A total of 1,800 d old male Cobb x Cobb 500 broilers were placed in 72 boxes (1.65 x 1.65 m) in a completely randomized design. The experiment consisted of 9 treatments in a factorial of 3 apparent metabolized energy (AME) diets (high, moderate, and low) and 3 digestible Lysine levels (dig. Lys) diets (high, moderate, and low), 8 replicates, with 25 birds in each one (Table 1).

Analyses of AA in ingredients and diets were conducted using an HPLC auto analyzer and employed performic acid oxidation of the feed sample prior to acid hydrolysis (AOAC 914.12; AOAC International, 2006). Diet samples were analyzed for gross energy using a calorimeter calibrated with benzoic acid as a standard (IKA Werke, Parr Instruments, Staufen, Germany). Study diets were formulated using average nutrient and AME allowances data obtained from a representative number of Brazilian nutritionists responding to a survey on dietary programs used in their commercial operations. Data originated from this survey was reported as digestible (dig) ratios of essential AA to Lys as well as AME used in feeding programs in these operations.

The diets were exclusively vegetable based on corn and soy-bean meal (SBM) formulated by the Vibra nutrition team. A 5-phase feeding program was used: pre-starter (1 to 7 d), starter (8 to 12 d), grower 1 (13 to 21 d), grower 2 (21 to 31 d), and withdrawal (31 to 38 d) (tables 2. 3. 4. 5 and 6). Feed and water were provided *ad libitum*. Birds were vaccinated for Marek's disease at hatchery. Environmental temperature was controlled to maintain bird comfort. Temperature and lighting schedule follow breeder's recommendation. All pens were checked for sick and dead birds on daily basis.

Performance and carcass yields

Data obtained for body weight gain (BWG), feed intake (FI), and feed conversion ratio (FCR) corrected for the weight of dead birds was determined at d 7, 14, 21, 28, 35 and 38. Mortality was recorded daily. From this information, weight gain, feed intake, feed conversion ratio corrected for mortality and feed cost were determined by the ratio between feed cost and consumption from each phase. At 38 d, 5 birds were randomly obtained from each pen, fasted for 8 h, and individually weighed for in-line processing. Birds were electrically stunned with 45 V for 3 s and then bled for 3 min after a jugular vein cut, being then scalded at 55 °C for 45 s with feathers being mechanically plucked afterwards. Evisceration was manual (lungs remained in the carcass), and carcasses were immediately immersed in slush ice for approximately 3 h. Eviscerated carcasses were hung for 3 min to remove excess water prior to their individual weighing. For the sake of data recording and statistical analyses, carcass yield was expressed relatively to live weight.

Economic Analysis

Evaluation was conducted to obtain the feeding cost of live bird production related to each feeding treatment as well as to carcass yield. In order to provide an unbiased evaluation, body weights were corrected to 2,950 g. This was, obtained through the use of linear regressions (days to achieve 2,950 g) between 35 and 38 days. Feeds utilized in the present study were least cost formulated using considering feed ingredient market prices in April of 2023. Production cost of each feed was used as the basis for all other economic calculations. Feeding cost per kg body weight was calculated as the ratio of feed cost per body weight at 38 d. Feeding cost per kg of carcass was calculated as the ratio of feed cost per kg of carcass produced, feeding cost per kg of breast was calculated as the ratio of feed cost per kg of breast produced. Values that were used for the calculations of the economic analysis were determined so that the costs of processing and transporting the feed were already considered. Costs of feeds provided in the different treatments (U$ per kg) were as follow: 0.41 for the standard pre-starter phase, 0.39 for the reduced pre-starter phase, 0.41 for the standard starter phase, 0.38 for the reduced starter phase, 0.40 for the standard grower phase 1, 0.37 for the reduced grower phase 1, 0.39 for the grower phase 2 and 0.38 for the finisher phase.

Statistical analysis

Data were tested for homoscedasticity and normality of the variance prior to statistical analyses (Shapiro and Wilk, 1965). Data that were not normally distributed were arcsine transformed for analyses, whereas real means are presented in tables of results. Data were submitted to analysis of variance using the MIXED procedure of SAS (2012) with significance accepted as $P \leq 0.05$. Mean separation was done using Tukey multiple-range test when the model effect was significant (Tukey, 1991).

Results

There was no difference in BWG for broilers feed different levels of AME from 1 to 7 d (P > 0.05), 1 to 14 (P > 0.05), 1 to 21 d (P > 0.05) (Table 7). However, from 1 to 28 d, increase BWG was observed when broilers were fed H AME, when compared to those fed M and L AME (P < 0.05), from 1 to 35 d and 1 to 42 d, increase BWG was observed when broilers were fed H and M AME, compared to those fed L AME (P < 0.05). From 1 to 14 d, broilers that given feed with H dig. Lys presented higher BWG when compared to those fed L dig. Lys (P < 0.05). From 1 to 21, 1 to 28, 1 to 38 d, broilers fed H dig. Lys presented higher BWG when compared to birds fed M dig. Lys diet, and broilers fed treatment with M dig. Lys presented higher BWG (P < 0.05) when compared to L dig. Lys (P < 0.05). From 1 to 35 d, it could be observed interaction (Table 10), broilers fed M and L AME presented higher BWG when given diets H and M dig. Lys compared to those fed L dig. Lys (P < 0.05). In the other hand, broilers fed L dig. Lysine presented higher BWG when given diets H AME compared to those fed M and L AME (P < 0.05).

From 1 to 14 and 1 to 21 d, broilers that given H AME presented lower FCR when compared those fed M dig. Lys (P < 0.05), and broiler that given M dig. Lys presented lower FCR when compared those fed H AME (P < 0.05) (Table 8). From 1 to 28 and 1 to 38 d, broilers fed L AME presented lower FCR (P < 0.05) when compared to M and L AME.

From 1 to 35 d, it could be observed interaction (Table 11), broilers fed H and M AME presented lower FCR when fed H dig. Lys (P < 0.05). Broilers fed L AME presented lower FCR when given H and M dig. Lys (P < 0.05). Broilers fed H dig. Lys presented lower FCR when given H AME when compared L AME (P < 0.05). Broilers fed with L dig. Lys presented lower FCR when given H AME and to those fed M AME presented lower FCR when compared L AME (P < 0.05).

From 1 to 14 d, H and M AME presented lower FI when compared to L AME (P < 0.05). From 1 to 21 d, H AME resulted in lower FI when compared to L AME (P < 0.05) (Table

9). Cumulative FI until 28, 35 and 38 d did not present difference among treatments for different AME inclusions (P > 0.05). From 1 to 14 d, animals submitted to H dig. Lys resulted in lower FI when compared to those feed M and L dig. Lys (P < 0.05). From 1 to 21 d, broilers fed H dig. Lys diet presented lower FI when compared to those that received L dig. Lys (P < 0.05). Cumulative FI until 28, 35 and 38 d did not present difference among treatments for different level of dig. Lys inclusion (P > 0.05).

There was no difference for carcass yield (Table 12) among treatments (P > 0.05). Also, it was not observed difference among different AME for abdominal fat, breast fillets, breast tenders, drumsticks, wings and back (P > 0.05). There was no difference for breast tenders, thighs, wings and back (P > 0.05) to any dig. Lys level. In the other hand, significantly difference was observed in abdominal fat when broilers given L dig. Lys compared H and M dig. Lys (P < 0.05). Broilers fed H dig. Lys presented higher breast fillets when compared to those fed L dig. Lys (P < 0.05).

When analyzing the FCB (Table 13), there was no difference for AME levels (P > 0.05). In the other hand, broilers fed H AME presented lower FCC when compared to those fed M and L AME (P < 0.05). However, broilers fed H dig. Lys presented lower FCB and FCC when compared to those fed M and L dig. Lys (P < 0.05).

The feeding cost varied up to 38 d (Table 14). The feeding cost per broiler, per kg body weight, per kg of carcass and per breast were lower to L AME. In the other hand, broilers fed L dig. Lys presented lower feeding cost per broiler. Broilers that given H and L dig. Lys presented lower feeding cost. However, to feeding cost per kg of breast, broilers that given H dig. Lys presented lower feeding cost.

When correcting for 2,950 g of BW (Table 15), it could be observed that FCR was lower in broilers fed H AME when compared to those fed M and L AME (P < 0.05). It could be observed higher FI for broilers fed L AME (P < 0.05). It was observed lower FCR (P < 0.05) when broilers were submitted to H dig. Lys treatment, when compared those that given M dig. Lys, in turn, presented lower FCR when compared to L dig. Lys ($P < 0.05$). It could be observed higher FI ($P < 0.05$) for broilers fed L dig. Lys when compared to those fed M dig. Lys, in turn, presented higher FI ($P < 0.05$) when compared to those that given H dig. Lys. To broilers achieve 2,950 g, from H to L AME it took: 37.5, 37.6 and 37.9 days, respectively; and from H to L dig. Lys it took: 37.2, 37.6 and 38.1 days, respectively. However, feeding cost to H and M AME showed to be more expensive when compared L AME. In the other hand, H and L dig. Lys presented lower feeding cost.

Discussion

The basal diets used in this experiment were formulated with corn and soybean meal based on commercial diet formulation in Brazil, except for containing 3 different levels of AME (L, M and H) and dig. Lys (L, M and H). These diets were supplemented with increasing levels of AME (pre-starter 2,950, 3,000, and 3,050; starter: 3,030, 3,080, and 3,130; grower 1: 3,090, 3,140, and 3,190; grower 2: 3,110, 3,160, and 3,210; withdraw: 3,130, 3,180, and 3,230) and dig. Lys (pre-starter: 1.26, 1.33, and 1.40; starter: 1.17, 1.24, and 1.31; grower 1: 1.05, 1.13, and 1.21; grower 2: 0.96, 1.04, and 1.12; withdraw: 0.90, 0.96, and 1.02). Analyzed AA and AME of the study diets was in an acceptable range as expected from feed formulation (Table 2 to 6).

Performance

According to Leeson et al. (1996), broilers with free access to feed have reduced or increased feed consumption in diets with higher or lower level of metabolizable energy, respectively, concluding that energy consumption does not vary. This shows an efficient control of the broiler chickens regarding the calorie intake. However, in the present study, broilers presented higher FI in L dig. Lys and AME diet until 21 d and did not presented difference among treatments in cumulative FI until the end of the experiment period.

Based on data presented in Table 7 to 12, it can be stated that Cobb × Cobb 500 male broiler benefited significantly from H protein and energy density. In the present study, feeding H dig. Lys and AME improved performance when compared to L energy and protein, in corroboration with other researchers (Leeson, 1996; Hidalgo et al., 2004; Dozier III et al., 2006). Infante-Rodríguez et al. (2016) testing 3,040 kcal/kg in the diet, obtained lower FI and FCR from 1 to 21 d. Basurco et al. (2015) tested diets varying in AME and AA densities to Cobb 500 female broiler grillers and found improvements in live performance in parallel with increases in AME and AA. Some reports observed improves in the growth performance when broilers fed high density AA (Dozier III et al., 2006; Vieira et al., 2006; Corzo et al., 2010; Hirai et al., 2022).

Carcass and Cuts

According to the present results, there were not differences among treatments in carcass yeald and comercial cuts. Previous studies have reported the same results (Corzo et al., 2010; Infante-Rodrugues et al., 2016). Abdominal fat is known to be a good indicator of overall body fat (Sonaiya, 1985). In agreement, (Corzo et al., 2010) suggested that when broilers were fed L AA density diets during the last feeding phase, it led to higher values for abdominal fat percentage. In contrast, as birds received increasing concentrations of amino acid density, this resulted in lower abdominal fat absolute and relative weights, different from what was reported by Quentin et al. (2003) who did not find significant differences for abdominal fat, with diets containing different levels of energy and digestible Lysine.

In the present study observed that broilers fed high dig. Lys in the feed presented higher breast fillets. Previous studies have reported increased breast along with increased dig. Lys in feeds (Kerr et al., 1999; Sterling et al., 2006; Berri et al., 2008; Cruz et al., 2017).

The effect of diets with high nutritional density in broiler chickens goes far beyond what is visible in live performance, the result of the present study demonstrated significant differences on FCB and FCC.

Costs

For the 9 treatments, the number of days to broilers achieve 2,950 kg was between 37 and 38 d. Formulating higher nutrient densities diets results in more expensive diets (Basurco et al., 2015).

When comparing increasing levels of AME, to produce broilers with 2,950 g, the H AME was more expansive when compared to M and L levels (0.03 and 0.05, respectively). Also, M levels of dig. Lys was more expensive than H and L level diets to produce 2,950 g broiler (0.01 for both). High densities diets have been shown to cause improve growth performance and breast yields of broilers, as it could be observed in the present study. Once there is a worry about feeding costs, the economic analysis evaluating the cost of production per kg emerge as an alternative. Therefore, H dig. Lys and L AME levels in diet can be used to reach maximum cost benefit.

Conclusions and Applications

High densities diets have been shown to cause improve growth performance and breast yields of broilers, as it could be observed in the present study. Only considering feed formulation costs or performance can lead to incorrect conclusions of poultry production cost benefit. Economic analysis emerges as an opportunity of making better decisions and reducing costs by using low AME and high digestible Lysine in broilers diet with corrected live weight for 2,950 g.

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Table 1. Distribution of treatments

Treatments		Pre-starter		Starter		Grower 1		Grower 2		Withdraw	
		AME (kcal)	Dig Lys	AME (kcal)	Dig Lys	AME (kcal)	Dig Lys	AME (kcal)	Dig Lys	AME (kcal)	Dig Lys
1	High AME/High dig. Lys		1.40		1.31		1.21		1.12		1.02
2	High AME /Moderate dig. Lys	3,050	1.33	3,130	1.24	3,190	1.13	3,210	1.04	3,230	0.96
3	High AME /Low dig. Lys		1.26		1.17		1.05		0.96		0.90
4	Moderate AME /High dig. Lys		1.40		1.31		1.21		1.12		1.02
5	Moderate AME [1]/Moderate[2] dig. Lys	3,000	1.33	3,080	1.24	3.140	1.13	3,160	1.04	3,180	0.96
6	Moderate AME /Low dig. Lys		1.26		1.17		1.05		0.96		0.90
7	Low AME /High dig. Lys		1.40		1.31		1.21		1.12		1.02
8	Low AME /Moderate dig. Lys	2,950	1.33	3,030	1.24	3.090	1.13	3,110	1.04	3,130	0.96
9	Low AME /Moderate dig. Lys		1.26		1.17		1.05		0.96		0.90

[1]AME Moderate: 3,000, 3,080, 3,140, 3,160 and 3,180 kcal/kg for the pre-starter, starter, grower 1, grower 2 and withdrawal phases. respectively. Levels with high or low AME were 50 kcal/kg more or less than the moderate level.

[2]Lys Moderate: 1.33, 1.24, 1.13, 1.04 and 0.96% digestible lysine for the pre-starter, starter, grower 1, grower 2 and withdrawal phases. respectively. The levels with high and low digestible lysine increased or decreased in the pre-starter and starter phases by 0.07% from the moderate level. 0.08% for the grower 1 and grower 2 phases. 0.06% for the withdrawal. with minimum ratios: TSSA 0.75; Thr 0.65; Val 0.76; Trp 0.19%.

Table 2. Ingredient and nutrient composition of diets having varying levels of AME and digestible Lys fed to broilers from 1 to 7 d.

Ingredients, %	High AME			Moderate AME			Low AME		
	High Lys	Moderate Lys	Low Lys	High Lys	Moderate Lys	Low Lys	High Lys	Moderate Lys	Low Lys
Corn	52.74	56.10	59.26	53.85	57.11	60.37	54.95	58.11	60.67
Soybean meal	40.30	37.50	34.80	40.10	37.40	34.70	40.00	37.30	34.80
Soybean oil	2.30	1.80	1.40	1.40	0.90	0.40	0.40	-	-
Limestone	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.20
Dicalcium phosphate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90
Sodium sulfate, 32%	0.28	0.29	0.30	0.28	0.29	0.30	0.28	0.29	0.30
Sodium chloride	0.32	0.32	0.31	0.32	0.32	0.31	0.32	0.31	0.31
Vit. And min. mix[a]	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Choline chloride, 75%	0.05	0.06	0.07	0.05	0.06	0.07	0.05	0.06	0.07
Biolys, 77%[b]	0.37	0.36	0.35	0.37	0.36	0.35	0.37	0.36	0.35
DL-Methionine, 99%	0.42	0.39	0.35	0.42	0.39	0.35	0.42	0.38	0.35
L-Threonine, 98.5%	0.16	0.15	0.13	0.16	0.14	0.13	0.16	0.14	0.13
L-Valine, 96.5%	0.08	0.06	0.05	0.08	0.06	0.05	0.07	0.06	0.05
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Diet cost, R$/kg[c]	2.47	2.40	2.33	2.40	2.33	2.26	2.33	2.26	2.22
Energy and nutrient composition. %									
AME, kcal/kg	3,050	3,050	3,050	3,000	3,000	3,000	2,950	2,950	2,950
Crude Protein	24.65 (24.30)	23.54 (23.93)	22.46 (22.40)	24.64 (24.13)	23.57 (23.10)	22.49 (22.11)	24.68 (24.22)	23.59 (23.62)	22.51 (22.37)
Calcium	0.99 (0.79)	0.99 (0.80)	0.98 (0.80)	0.99 (0.79)	0.99 (0.79)	0.98 (0.80)	0.99 (0.79)	0.99 (0.79)	0.98 (0.80)
Total Phosphorus	0.73 (0.55)	0.73 (0.54)	0.73 (0.54)	0.73 (0.55)	0.73 (0.55)	0.73 (0.56)	0.73 (0.55)	0.73 (0.55)	0.73 (0.54)
Available phosphorus	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Sodium	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Choline, mg/kg	1,731	1,729	1,728	1,731	1,731	1,731	1,727	1,727	1,731
Dig Lysine[d]	1.40	1.33	1.26	1.40	1.33	1.26	1.40	1.33	1.26
Dig TSAA[e]	1.05	1.00	0.95	1.05	1.00	0.95	1.05	1.00	0.95
Dig Threonine	0.92	0.88	0.83	0.92	0.88	0.83	0.92	0.88	0.83
Dig Valine	1.07	1.01	0.96	1.06	1.01	0.96	1.06	1.01	0.96
Total Lysine	1.51 (1.47)	1.43 (1.42)	1.36 (1.34)	1.51 (1.49)	1.43 (1.41)	1.36 (1.35)	1.51 (1.50)	1.43 (1.44)	1.36 (1.35)
Total TSAA	1.13 (1.10)	1.07 (1.05)	1.01 (1.01)	1.13 (1.13)	1.07 (1.04)	1.01 (0.98)	1.13 (1.14)	1.07 (1.07)	1.02 (1.00)
Total Threonine	1.04 (1.04)	0.99 (1.01)	0.93 (0.92)	1.04 (1.04)	0.99 (0.97)	0.93 (0.94)	1.04 (1.04)	0.99 (0.98)	0.94 (0.92)
Total Valine	1.17 (1.14)	1.11 (1.09)	1.05 (1.01)	1.17 (1.15)	1.11 (1.12)	1.05 (1.06)	1.17 (1.18)	1.11 (1.10)	1.05 (1.03)

[a] Mineral and vitamin premix supplied the following per kg of feed: Cu, 10 mg; Zn, 80 mg; Mn, 80 mg; Fe, 50 mg; Se, 0.60 mg; Iodine, 0.7 mg; vitamin A, 9,000 IU; vitamin D3, 2,500 IU; vitamin E, 30 IU; vitamin C, 50 mg; vitamin K3, 2 mg; vitamin B12, 12 µg; thiamine, 2 mg; riboflavin, 6 mg; vitamin B6, 2,5 mg; niacin, 35 mg; pantothenic acid, 15 mg; folic acid, 1 mg; biotin, 0.08 mg; carbohydrate enzyme complex, 1.250 xylanase UV and 860 β-glucanase UV; Phytase, 1000 FYT;

[b]Evonik Industries AG, Hanau, Germany, contains 60% L-Lys as L-Lys sulfate; 0.24% Thr; 0.02% Trp; 0.12% TSAA; 0.2% Cys; 0.5% Leu; 0.61% Arg; 0.24% Ile; 0.33% Val.

[c]Prices (Brazilian Real (R$) per kilogram) used during formulation were: corn: 1.585; SBM: 2.625; soybean oil: 8.575; limestone: 0.334; dicalcium phosphate: 5.660; sodium sulfate 32%: 1.906; sodium chloride: 0.669; vit. and min. mix: 21.47; choline chloride 75%: 8.300; biolys 77%: 11.510; DL-Methionine 99%: 18.390; L-Threonine 98.5%: 13.850; L-valine: 22.23; By the time this paper was written, exchange rate was 4.94 R$ per 1 U$.
[d]Digestible amino acids; minimum ratios to Lys in formulated diets were: TSAA 0.75; Thr 0.66; Val 0.77; Trp 0.19.
[e]Dig. TSAA, digestible total sulphur amino acids.
[f]Analyzed values in parentheses.

Tabela 3. Ingredient and nutrient composition of diets having varying levels of AME and digestible Lys fed to broilers from 8 to 14 d.

Ingredients, %	High AME			Moderate AME			Low AME		
	High Lys	Moderate Lys	Low Lys	High Lys	Moderate Lys	Low Lys	High Lys	Moderate Lys	Low Lys
Corn	55.80	58.96	62.23	56.80	60.07	63.33	57.81	61.07	64.23
Soybean meal	36.90	34.20	31.50	36.80	34.10	31.40	36.70	34.00	31.30
Soybean oil	3.00	2.60	2.10	2.10	1.60	1.10	1.20	0.70	0.30
Limestone	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Dicalcium phosphate	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Sodium sulfate, 32%	0.26	0.26	0.27	0.26	0.26	0.27	0.26	0.27	0.27
Sodium chloride	0.32	0.31	0.31	0.32	0.31	0.30	0.32	0.31	0.30
Vit. And min. mix[a]	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Choline chloride, 75%	0.06	0.07	0.08	0.06	0.07	0.08	0.06	0.07	0.08
Biolys, 77%[b]	0.35	0.34	0.33	0.35	0.34	0.33	0.36	0.34	0.31
DL-Methionine, 99%	0.38	0.35	0.31	0.38	0.34	0.31	0.38	0.34	0.33
L-Threonine, 98.5%	0.14	0.13	0.12	0.14	0.13	0.12	0.14	0.13	0.11
L-Valine, 96.5%	0.06	0.05	0.05	0.06	0.05	0.03	0.06	0.05	0.03
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Diet cost, R$/kg[c]	2.46	2.39	2.32	2.39	2.32	2.25	2.33	2.26	2.19
Energy and nutrient composition. %									
AME Poultry. kcal/kg	3,130	3,130	3,130	3,080	3,080	3,080	3,030	3,030	3,030
Crude Protein	23.25 (23.42)	22.13 (22.04)	21.06 (21.70)	23.25 (23.27)	22.17 (22.02)	21.09 (20.73)	23.25 (23.07)	22.20 (22.17)	21.10 (20.77)
Calcium	0.93 (0.82)	0.92 (0.80)	0.92 (0.81)	0.93 (0.78)	0.92 (0.77)	0.92 (0.80)	0.93 (0.81)	0.92 (0.79)	0.92 (0.79)
Total Phosphorus	0.65 (0.50)	0.65 (0.50)	0.65 (0.49)	0.65 (0.50)	0.65 (0.50)	0.65 (0.50)	0.65 (0.49)	0.65 (0.51)	0.65 (0.49)
Available phosphorus	0.47	0.47	0.46	0.47	0.47	0.46	0.47	0.47	0.46
Sodium	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Choline, mg/kg	1,697	1,697	1,697	1,700	1,700	1,700	1,700	1,700	1,701
Dig Lysine[d]	1.31	1.24	1.17	1.31	1.24	1.17	1.31	1.24	1.17
Dig TSAA[e]	0.98	0.93	0.88	0.98	0.93	0.88	0.98	0.93	0.88
Dig Threonine	0.87	0.82	0.77	0.87	0.82	0.77	0.87	0.82	0.77
Dig Valine	1.00	0.94	0.89	1.00	0.94	0.89	1.00	0.94	0.89
Total Lysine	1.41 (1.40)	1.34 (1.31)	1.26 (1.25)	1.41 (1.41)	1.34 (1.32)	1.26 (1.24)	1.41 (1.38)	1.34 (1.33)	1.26 (1.23)
Total TSAA	1.06 (1.08)	1.00 (1,00)	0.94 (0.95)	1.06 (1.05)	1.00 (0.99)	0.94 (0.93)	1.06 (1.05)	1.00 (1.00)	0.94 (0.92)
Total Threonine	0.97 (0.96)	0.92 (0.90)	0.87 (0.87)	0.97 (0.95)	0.92 (0.93)	0.87 (0.86)	0.97 (0.97)	0.92 (0.92)	0.87 (0.87)
Total Valine	1.09 (1.05)	1.03 (1.01)	0.97 (0.97)	1.09 (1.05)	1.03 (1.00)	0.97 (0.96)	1.09 (1.09)	1.03 (1.01)	0.97 (0.95)

[a]Mineral and vitamin premix supplied the following per kg of feed: Cu, 10 mg; Zn, 80 mg; Mn, 80 mg; Fe, 50 mg; Se, 0.3 mg; Iodine, 0.7 mg; vitamin A, 9,000 IU; vitamin D3, 2,500 IU; vitamin E, 30 IU; vitamin C, 50 mg; vitamin K3, 2 mg; vitamin B12, 12 µg; thiamine, 2 mg; riboflavin, 6 mg; vitamin B6, 2,5 mg; niacin, 35 mg; pantothenic acid, 15 mg; folic acid, 1 mg; biotin, 0.08 mg; carbohydrate enzyme complex, 1.250 xylanase UV and 860 β-glucanase UV; Phytase, 1000 FYT.
[b]Evonik Industries AG, Hanau, Germany, contains 60% L-Lys as L-Lys sulfate; 0.24% Thr; 0.02% Trp; 0.12% TSAA; 0.2% Cys; 0.5% Leu; 0.61% Arg; 0.24% Ile; 0.33% Val.

[c] Prices (Brazilian Real (R$) per kilogram) used during formulation were: corn: 1.585; SBM: 2.625; soybean oil: 8.575; limestone: 0.334; dicalcium phosphate: 5.660; sodium sulfate 32%: 1.906; sodium chloride: 0.669; vit. and min. mix: 21.47; choline chloride 75%: 8.300; biolys 77%: 11.510; DL-Methionine 99%: 18.390; L-Threonine 98.5%: 13.850; L-valine: 22.23; By the time this paper was written, exchange rate was 4.94 R$ per 1 U$.

[d] Digestible amino acids; minimum ratios to Lys in formulated diets were: TSAA 0.75; Thr 0.66; Val 0.77; Trp 0.19.

[e]Dig. TSAA, digestible total sulphur amino acids.

[f]Analyzed values in parentheses.

Table 4. Ingredient and nutrient composition of diets having varying levels of AME and digestible Lys fed to broilers from 15 to 21 d.

Ingredients, %	High AME			Moderate AME			Low AME		
	High Lys	Moderate Lys	Low Lys	High Lys	Moderate Lys	Low Lys	High Lys	Moderate Lys	Low Lys
Corn	60.00	63.67	67.33	61.00	64.67	68.43	62.11	65.78	69.27
Soybean Meal	33.10	30.00	26.90	33.00	29.90	26.80	32.80	29.80	26.70
Soybean Oil	3.00	2.50	2.00	2.10	1.60	1.00	1.20	0.60	-
Limestone	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Dicalcium phosphate	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Sodium sulfate, 32%	0.23	0.24	0.25	0.23	0.24	0.25	0.23	0.24	0.25
Sodium chloride	0.31	0.31	0.30	0.31	0.31	0.30	0.31	0.31	0.30
Vit. And min. mix[a]	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Choline chloride 75%	0.06	0.07	0.08	0.06	0.07	0.08	0.06	0.07	0.08
Biolys, 77%[b]	0.33	0.32	0.30	0.34	0.32	0.31	0.34	0.32	0.31
DL-Methionine, 99%	0.33	0.29	0.26	0.33	0.29	0.26	0.33	0.29	0.52
L-Threonine, 98.5%	0.11	0.10	0.08	0.11	0.10	0.08	0.11	0.10	0.08
L-Valine, 96.5%	0.04	0.03	0.01	0.04	0.03	0.01	0.04	0.03	0.01
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Diet cost, R$/kg[c]	2.36	2.29	2.21	2.30	2.22	2.14	2.24	2.15	2.11
Energy and nutrient composition, %									
AME Poultry, kcal/kg	3,190	3,190	3,190	3,140	3,140	3,140	3,090	3,090	3,090
Crude Protein	21.66 (21.35)	20.42 (20.04)	19.18(18.82)	21.69 (21.98)	20.45 (20.16)	19.22 (19.36)	21.68 (21.46)	20.49 (20.37)	19.39 (19.38)
Calcium	0.90 (0.76)	0.90 (0.76)	0.90 (0.76)	0.90 (0.75)	0.90 (0.75)	0.90 (0.75)	0.90 (0.74)	0.90 (0.74)	0.90 (0.75)
Total phosphorus	0.60 (0.46)	0.60 (0.46)	0.60 (0.45)	0.60 (0.47)	0.60 (0.46)	0.46 (0.44)	0.60 (0.48)	0.60 (0.49)	0.60 (0.45)
Available phosphorus	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
Sodium	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Choline, mg/kg	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Dig Lysine[d]	1.21	1.13	1.05	1.21	1.13	1.05	1.21	1.13	1.05
Dig TSAA[e]	0.91	0.85	0.80	0.91	0.85	0.80	0.91	0.85	1.06
Dig Threonine	0.79	0.74	0.68	0.79	0.73	0.68	0.79	0.74	0.68
Dig Valine	0.92	0.86	0.80	0.92	0.86	0.80	0.92	0.86	0.80
Total Lysine	1.30 (1.26)	1.21 (1.19)	1.13 (1.15)	1.30 (1.28)	1.21 (1.19)	1.13 (1.13)	1.30 (1.29)	1.21 (1.20)	1.13 (1.12)
Total TSAA	0.97 (0.98)	0.91 (0.90)	0.85 (0.87)	0.97 (0.99)	0.91 (0.92)	0.85 (0.87)	0.97 (0.95)	0.91 (0.90)	0.85 (0.85)
Total Threonine	0.88 (0.86)	0.82 (0.81)	0.76 (0.74)	0.88 (0.87)	0.82 (0.82)	0.76 (0.75)	0.88 (0.87)	0.82 (0.84)	0.76 (0.74)
Total Valine	1.00 (0.98)	0.93 (0.92)	0.86 (0.85)	1.00 (0.98)	0.93 (0.91)	0.86 (0.85)	1.00 (1.00)	0.93 (0.92)	0.86 (0.84)

[a]Mineral and vitamin premix supplied the following per kg of feed: Cu, 10 mg; Zn, 80 mg; Mn, 80 mg; Fe, 50 mg; Se, 0.3 mg; Iodine, 0.7 mg; vitamin A, 9,000 IU; vitamin D3, 2,500 IU; vitamin E, 30 IU; vitamin C, 50 mg; vitamin K3, 2 mg; vitamin B12, 12 µg; thiamine, 2 mg; riboflavin, 6 mg; vitamin B6, 2,5 mg; niacin, 35 mg; pantothenic acid, 15 mg; folic acid, 1 mg; biotin, 0.08 mg; carbohydrate enzyme complex, 1.250 xylanase UV and 860 β-glucanase UV; Phytase, 1000 FYT.

[b]Evonik Industries AG, Hanau, Germany, contains 60% L-Lys as L-Lys sulfate; 0.24% Thr; 0.02% Trp; 0.12% TSAA; 0.2% Cys; 0.5% Leu; 0.61% Arg; 0.24% Ile; 0.33% Val.

[c]Prices (Brazilian Real (R$) per kilogram) used during formulation were: corn: 1.585; SBM: 2.625; soybean oil: 8.575; limestone: 0.334; dicalcium phosphate: 5.660; sodium sulfate 32%: 1.906; sodium chloride: 0.669; vit. and min. mix: 21.47; choline chloride 75%: 8.300; biolys 77%: 11.510; DL-Methionine 99%: 18.390; L-Threonine 98.5%: 13.850; L-valine: 22.23; By the time this paper was written, exchange rate was 4.94 R$ per 1 U$.
[d]Digestible amino acids; minimum ratios to Lys in formulated diets were: TSAA 0.75; Thr 0.66; Val 0.77; Trp 0.19.
[e]Dig. TSAA, digestible total sulphur amino acids.
[f]Analyzed values in parentheses.

Table 5. Ingredient and nutrient composition of diets having varying levels of AME and digestible Lys fed to broilers from 22 to 31 d.

Ingredients, %	High AME			Moderate AME			Low AME		
	High Lys	Moderate Lys	Low Lys	High Lys	Moderate Lys	Low Lys	High Lys	Moderate Lys	Low Lys
Corn	64.73	68.33	72.07	65.83	69.42	73.08	66.83	70.21	73.48
Soybean Meal	29.20	26.20	23.10	29.10	26.10	23.00	29.00	26.00	23.10
Soybean Oil	2.50	2.00	1.40	1.50	1.00	0.50	0.60	0.30	-
Limestone	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Dicalcium phosphate	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Sodium sulfate, 32%	0.21	0.21	0.22	0.21	0.22	0.22	0.21	0.22	0.22
Sodium chloride	0.31	0.30	0.30	0.31	0.30	0.29	0.31	0.30	0.29
Vit. And min. mix[a]	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Choline chloride, 75%	0.06	0.07	0.08	0.06	0.07	0.08	0.06	0.07	0.08
Biolys, 77%[b]	0.33	0.31	0.30	0.33	0.31	0.30	0.33	0.32	0.30
DL-Methionine, 99%	0.30	0.26	0.23	0.30	0.26	0.23	0.30	0.26	0.23
L-Threonine, 98.5%	0.10	0.08	0.07	0.10	0.08	0.07	0.10	0.08	0.07
L-Valine, 96.5%	0.03	0.01	-	0.03	0.01	-	0.03	0.01	-
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Diet cost, R$/kg[c]	2.263	2.182	2.099	2.192	2.111	2.035	2.126	2.059	1.994
Energy and nutrient composition. %									
AME Poultry, kcal/kg	3,210	3,212	3,209	3,157	3,158	3,161	3,109	3,111	3,109
Crude Protein	20.28 (20.02)	19.06 (19.24)	17.82 (17.98)	20.32 (20.40)	19.10 (19.04)	17.85 (18.01)	20.34 (20.04)	19.09 (19.21)	17.88 (17.40)
Calcium	0.83 (0.72)	0.83 (0.74)	0.82 (0.71)	0.83 (0.74)	0.83 (0.72)	0.82 (0.72)	0.83 (0.70)	0.83 (0.72)	0.82 (0.71)
Total phosphorus	0.45 (0.44)	0.44 (0.41)	0.43 (0.43)	0.45 (0.46)	0.44 (0.44)	0.43 (0.45)	0.45 (0.46)	0.44 (0.41)	0.43 (0.41)
Available phosphorus	0.42	0.42	0.41	0.42	0.42	0.41	0.42	0.42	0.41
Sodium	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Choline, mg/kg	1,548	1,548	1,546	1,549	1,551	1,549	1,547	1,551	1,550
Dig Lysine[d]	1.12	1.04	0.96	1.12	1.04	0.96	1.12	1.04	0.96
Dig TSAA[e]	0.84	0.78	0.72	0.84	0.78	0.73	0.84	0.78	0.73
Dig Threonine	0.73	0.68	0.62	0.73	0.68	0.62	0.73	0.68	0.63
Dig Valine	0.85	0.79	0.73	0.85	0.79	0.73	0.85	0.79	0.73
Total Lysine	1.20 (1.20)	1.11 (1.15)	1.02 (1.02)	1.20 (1.19)	1.11 (1.10)	1.02 (1.06)	1.20 (1.20)	1.11 (1.10)	1.02 (1.05)
Total TSAA	0.90 (0.90)	0.84 (0.84)	0.77 (0.75)	0.90 (0.92)	0.84 (0.79)	0.77 (0.72)	0.90 (0.85)	0.84 (0.80)	0.77 (0.77)
Total Threonine	0.82 (0.81)	0.76 (0.75)	0.70 (0.71)	0.82 (0.80)	0.76 (0.75)	0.70 (0.76)	0.82 (0.80)	0.76 (0.78)	0.70 (0.69)
Total Valine	0.92 (0.90)	0.86 (0.85)	0.79 (0.74)	0.92 (0.93)	0.86 (0.83)	0.79 (0.81)	0.92 (0.87)	0.86 (0.84)	0.79 (0.77)

[a]Mineral and vitamin premix supplied the following per kg of feed: Cu, 10 mg; Zn, 80 mg; Mn, 80 mg; Fe, 50 mg; Se, 0.3 mg; Iodine, 0.7 mg; vitamin A, 9,000 IU; vitamin D3, 2,500 IU; vitamin E, 30 IU; vitamin C, 50 mg; vitamin K3, 2 mg; vitamin B12, 12 µg; thiamine, 2 mg; riboflavin, 6 mg; vitamin B6, 2,5 mg; niacin, 35 mg; pantothenic acid, 15 mg; folic acid, 1 mg; biotin, 0.08 mg; carbohydrate enzyme complex, 1.250 xylanase UV and 860 β-glucanase UV; Phytase, 1000 FYT

[b]Evonik Industries AG, Hanau, Germany, contains 60% L-Lys as L-Lys sulfate; 0.24% Thr; 0.02% Trp; 0.12% TSAA; 0.2% Cys; 0.5% Leu; 0.61% Arg; 0.24% Ile; 0.33% Val.

[c]Prices (Brazilian Real (R$) per kilogram) used during formulation were: corn: 1.585; SBM: 2.625; soybean oil: 8.575; limestone: 0.334; kaolin: 0,500; dicalcium phosphate: 5.660; sodium sulfate 32%: 1.906; sodium chloride: 0.669; vit. and min. mix: 21.47; choline chloride 75%: 8.300; biolys 77%: 11.510; MHA: 14.234; L-Threonine 98.5%: 13.850; L-valine: 22.23; By the time this paper was written, exchange rate was 4.94 R$ per 1 U$.
[d]Digestible amino acids; minimum ratios to Lys in formulated diets were: TSAA 0.75; Thr 0.66; Val 0.77; Trp 0.19.
[e]Dig. TSAA, digestible total sulphur amino acids.
[f]Analyzed values in parentheses.

Table 6. Ingredient and nutrient composition of diets having varying levels of AME and digestible Lys fed to broilers from 32 to 38 d.

Ingredients, %	High AME			Moderate AME			Low AME		
	High Lys	Moderate Lys	Low Lys	High Lys	Moderate Lys	Low Lys	High Lys	Moderate Lys	Low Lys
Corn	69.43	72.17	75.00	70.42	73.13	76.00	71.32	73.87	76.10
Soybean Meal	25.40	23.10	20.80	25.30	23.00	20.70	25.20	23.00	20.80
Soybean Oil	2.00	1.60	1.20	1.10	0.70	0.20	0.30	-	-
Limestone	1.10	1.10	1.00	1.10	1.10	1.10	1.10	1.10	1.10
Dicalcium phosphate	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Sodium sulfate, 32%	0.21	0.22	0.23	0.22	0.22	0.23	0.22	0.22	0.23
Sodium chloride	0.30	0.30	0.29	0.30	0.30	0.29	0.30	0.30	0.29
Vit. And min. mix[a]	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Choline chloride, 75%	0.07	0.07	0.08	0.07	0.07	0.08	0.07	0.07	0.08
Biolys, 77%[b]	0.31	0.30	0.29	0.31	0.30	0.29	0.31	0.30	0.29
DL-Methionine, 99%	0.25	0.23	0.21	0.25	0.23	0.21	0.25	0.23	0.21
L-Threonine, 98.5%	0.08	0.07	0.06	0.08	0.07	0.06	0.08	0.07	0.06
L-Valine, 96.5%	0.01	-	-	0.01	-	-	0.01	-	-
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Diet cost, R$/kg[c]	2.131	2.071	2.015	2.067	2.007	1.944	2.007	1.951	1.915
Energy and nutrient composition. %									
AME Poultry. kcal/kg	3,229	3,230	3,230	3,180	3,182	3,180	3,132	3,130	3,132
Crude Protein	18.76 (18.66)	17.83 (18.10)	16.92 (17.01)	18.79 (18.75)	17.86 (17.94)	16.96 (17.05)	18.79 (18.57)	17.89 (17.51)	16.93 (17.06)
Calcium	0.80 (0.68)	0.80 (0.69)	0.79 (0.67)	0.80 (0.70)	0.80 (0.69)	0.79 (0.70)	0.80 (0.69)	0.80 (0.71)	0.79 (0.70)
Total phosphorus	0.41 (0.43)	0.40 (0.41)	0.40 (0.40)	0.41 (0.40)	0.40 (0.41)	0.40 (0.41)	0.41 (0.41)	0.40 (0.40)	0.40 (0.40)
Available phosphorus	0.40	0.39	0.39	0.40	0.39	0.39	0.40	0.39	0.39
Sodium	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Choline, mg/kg	1,499	1,501	1,497	1,501	1,497	1,500	1,502	1,499	1,498
Dig Lysine[d]	1.02	0.96	0.90	1.02	0.96	0.90	1.02	0.96	0.90
Dig TSAA[e]	0.77	0.73	0.69	0.77	0.73	0.69	0.77	0.73	0.69
Dig Thriptofane	0.19	0.18	0.17	0.19	0.18	0.17	0.19	0.18	0.17
Dig Valine	0.78	0.73	0.70	0.78	0.73	0.70	0.78	0.73	0.70
Total Lysine	1.09 (1.08)	1.02 (1.03)	0.96 (0.95)	1.09 (1.07)	1.02 (0.99)	0.96 (0.95)	1.09 (1.10)	1.02 (1.03)	0.96 (0.98)
Total TSAA	0.82 (0.81)	0.78 (0.77)	0.74 (0.75)	0.82 (0.82)	0.78 (0.80)	0.74 (0.74)	0.82 (0.80)	0.78 (0.79)	0.74 (0.74
Total Threonine	0.74 (0.76)	0.70 (0.69)	0.65 (0.66)	0.74 (0.76)	0.70 (0.69)	0.65 (0.61)	0.74 (0.75)	0.70 (0.69)	0.65 (0.63
Total Valine	0.84 (0.84)	0.79 (0.78)	0.75 (0.74)	0.84 (0.84)	0.79 (0.77)	0.75 (0.75)	0.84 (0.85)	0.79 (0.81)	0.75 (0.73)

[a]Mineral and vitamin premix supplied the following per kg of feed: Cu, 10 mg; Zn, 80 mg; Mn, 80 mg; Fe, 50 mg; Se, 0.3 mg; Iodine, 0.7 mg; vitamin A, 9,000 IU; vitamin D3, 2,500 IU; vitamin E, 30 IU; vitamin C, 50 mg; vitamin K3, 2 mg; vitamin B12, 12 µg; thiamine, 2 mg; riboflavin, 6 mg; vitamin B6, 2,5 mg; niacin, 35 mg; pantothenic acid, 15 mg; folic acid, 1 mg; biotin, 0.08 mg; carbohydrate enzyme complex, 1.250 xylanase UV and 860 β-glucanase UV; Phytase, 1000 FYT.

[b]Evonik Industries AG, Hanau, Germany, contains 60% L-Lys as L-Lys sulfate; 0.24% Thr; 0.02% Trp; 0.12% TSAA; 0.2% Cys; 0.5% Leu; 0.61% Arg; 0.24% Ile; 0.33% Val.

[c]Prices [Brazilian Real (R$) per kilogram] used during formulation were: corn: 1.585; SBM: 2.625; soybean oil: 8.575; limestone: 0.334; dicalcium phosphate: 5.660; sodium sulfate 32%: 1.906; sodium chloride: 0.669; vit. and min. mix: 21.47; choline chloride 75%: 8.300; biolys 77%: 11.510; MHA: 14.234; L-Threonine 98.5%: 13.850; L-valine: 22.23; By the time this paper was written, exchange rate was 4.94 R$ per 1 U$.
[d]Digestible amino acids; minimum ratios to Lys in formulated diets were: TSAA 0.75; Thr 0.66; Val 0.77, Trp 0.19.
[e]Dig. TSAA, digestible total sulphur amino acids.
[f]Analyzed values in parentheses.

Table 7. BWG of broilers fed diets having varying levels of AME and dig. Lys, g[1].

Item	1-7 d	1 – 14 d	1 – 21 d	1 – 28 d	1 – 35 d	1 – 38 d
AME[2]						
High	156	603	1,181	1,619[a]	2,529[a]	2,940[a]
Moderate	157	600	1,175	1,575[b]	2,522[a]	2,920[a]
Low	160	603	1,171	1,541[b]	2,456[b]	2,880[b]
Lys[3]						
High	157	607[a]	1,199[a]	1,646[a]	2,596[a]	3,010[a]
Moderate	158	603[ab]	1,176[b]	1,572[b]	2,499[b]	2,898[b]
Low	158	596[b]	1,152[c]	1,508[c]	2,401[c]	2,824[c]
SEM[4]	0.783	1.733	4.246	10.271	15.101	14.137
Probability <						
AME	0.308	0.614	0.596	0.001	0.018	0.049
Lys	0.920	0.027	0.001	0.001	0.001	0.001
AME X Lys	0.898	0.725	0.931	0.296	0.030	0.417

[a>b>c] Means with different letters in the same column indicate significant differences (P < 0.05).
[1]Chick body weight at placement was 45.3g ± 0.25.
[2]AME Moderate: 3,000. 3,080. 3,140. 3,160 and 3,180 kcal/kg for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. Levels with high or low AME were 50 kcal/kg more or less than the moderate level.
[3]PI Moderate: 1.33. 1.24. 1.13. 1.04 and 0.96% digestible lysine for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. The levels with high and low digestible lysine increased or decreased in the pre-starter and starter phases by 0.07% from the moderate level, 0.08% for the grower 1 and grower 2 phases, 0.06% for the withdrawal, with minimum ratios: TSAA 0.75; Thr 0.65; Val 0.76; Trp 0.19%.
[4]SEM= Standard error mean.

Table 8. FCR of broilers fed diets having varying levels of AME and dig. Lys.

Item	1 – 7 d	1 – 14 d	1 – 21 d	1– 28 d	1– 35 d	1 – 38 d
AME[1]						
High	0.966	1.130[c]	1.253[c]	1.442[b]	1.467[c]	1.518[b]
Moderate	0.974	1.152[b]	1.276[b]	1.491[a]	1.504[b]	1.552[a]
Low	0.971	1.166[a]	1.298[a]	1.511[a]	1.528[a]	1.580[a]
Lys[2]						
High	0.954[b]	1.121[c]	1.239[c]	1.420[c]	1.454[c]	1.503[b]
Moderate	0.971[ab]	1.149[b]	1.278[b]	1.490[b]	1.503[b]	1.561[a]
Low	0.986[a]	1.178[a]	1.309[a]	1.541[a]	1.547[a]	1.586[a]
SEM[3]	0.783	0.003	0.004	0.008	0.006	0.006
Probability <						
AME	0.038	0.001	0.001	0.001	0.001	0.001
Lys	0.920	0.001	0.001	0.001	0.001	0.001
AME X Lys	0.898	0.799	0.570	0.060	0.006	0.105

[a>b>c] Means with different letters in the same column indicate significant differences (P < 0.05).
[1]AME Moderate: 3.000. 3.080. 3.140. 3.160 and 3.180 kcal/kg for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. Levels with high or low AME were 50 kcal/kg more or less than the moderate level.
[2]Lys Moderate: 1.33. 1.24. 1.13. 1.04 and 0.96% digestible lysine for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. The levels with high and low digestible lysine increased or decreased in the pre-starter and starter phases by 0.07% from the moderate level, 0.08% for the grower 1 and grower 2 phases, 0.06% for the withdrawal. with minimum ratios: TSAA 0.75; Thr 0.65; Val 0.76; Trp 0.19%.
[3]SEM= Standard error of the mean.
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Table 9. FI of broilers fed diets having varying levels of AME and dig. Lys, g.

Item	1 – 7 d	1 – 14 d	1 – 21 d	1 – 28 d	1– 35 d	1 – 38 d
EMA[1]						
High	151[b]	682[b]	1,478[b]	2,330	3,708	4,461
Moderate	153[ab]	690[b]	1,498[ab]	2,344	3,789	4,528
Low	155[a]	702[a]	1,519[a]	2,326	3,747	4,532
Lys[2]						
High	150[b]	680[b]	1,485[b]	2,336	3,774	4,523
Moderate	153[ab]	692[a]	1,502[ab]	2,342	3,756	4,522
Low	155[a]	701[a]	1,509[a]	2,321	3,710	4,475
SEM[3]	0.721	2.211	4.411	8.441	15.587	15.437
Probability <						
AME	0.008	0.001	0.001	0.674	0.124	0.108
Lys	0.007	0.001	0.041	0.632	0.217	0.352
AME X PI	0.840	0.617	0.789	0.784	0.135	0.749

a>b Means with different letters in the same column indicate significant differences (P < 0.05).
[1]AME Moderate: 3.000, 3.080, 3.140, 3.160 and 3.180 kcal/kg for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. Levels with high or low AME were 50 kcal/kg more or less than the moderate level.
[2]PI Moderate: 1.33, 1.24, 1.13, 1.04 and 0.96% digestible lysine for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. The levels with high and low digestible lysine increased or decreased in the pre-starter and starter phases by 0.07% from the moderate level. 0.08% for the grower 1 and grower 2 phases. 0.06% for the withdrawal. with minimum ratios: TSAA 0.75; Thr 0.65; Val 0.76; Trp 0.19%.
[3]SEM= Standard error of the mean.

Table 10. Interaction of BWG of broilers fed diets varying levels of AME and dig. Lys from 1 to 35 d, g[1].

Item	dig. Lys[3]			SEM	*Probability <*
AME[2]	High	Moderate	Low		
High	2,600	2,479	2,503[a]	23.09	0.062
Moderate	2,616[A]	2,536[A]	2,399[Bab]	25.05	0.001
Low	2,572[A]	2,483[A]	2,311[Bb]	28.16	0.001
SEM[4]	19.661	14.872	26.56		
Probability <	0.678	0.233	0.005		

A>B>C Means with different capital letters in the lines indicate significant difference (P < 0.05).
a>b>c Means with different small letters in the same column indicate significant differences (P < 0.05).
[1]Chick body weight at placement was 45.3g ± 0.25.
[2]AME Moderate: 3,000, 3,080, 3,140, 3,160 and 3,180 kcal/kg for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. Levels with high or low AME were 50 kcal/kg more or less than the moderate level.
[3]PI Moderate: 1.33, 1.24, 1.13, 1.04 and 0.96% digestible lysine for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. The levels with high and low digestible lysine increased or decreased in the pre-starter and starter phases by 0.07% from the moderate level, 0.08% for the grower 1 and grower 2 phases, 0.06% for the withdrawal, with minimum ratios: TSAA 0.75; Thr 0.65; Val 0.76; Trp 0.19%.
[4]SEM= Standard error of the mean.

Table 11. Interaction of FCR of broilers fed diets having varying levels of AME and dig. Lys from 1 to 35 d.

Item	Lys[2]			SEM	*Probability <*
AME[1]	High	Moderate	Low		
High	1.423[Bb]	1.487[A]	1.496[Ac]	0.008	0.001
Moderate	1.455[Bab]	1.516[A]	1.545[Ab]	0.010	0.001
Low	1.485[Ba]	1.506[B]	1.594[Aa]	0.010	0.001
SEM[3]	0.007	0.007	0.010		
Probability <	0.008	0.233	0.001		

[A>B>C]Means with different capital letters in the lines indicate significant difference (P < 0.05).
[a>b>c]Means with different small letters in the same column indicate significant differences (P < 0.05).
[1]AME Moderate: 3,000, 3,080, 3,140, 3,160 and 3,180 kcal/kg for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. Levels with high or low AME were 50 kcal/kg more or less than the moderate level.
[2]Lys Moderate: 1.33, 1.24, 1.13, 1.04 and 0.96% digestible lysine for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. The levels with high and low digestible lysine increased or decreased in the pre-starter and starter phases by 0.07% from the moderate level, 0.08% for the grower 1 and grower 2 phases, 0.06% for the withdrawal, with minimum ratios: TSAA 0.75; Thr 0.65; Val 0.76; Trp 0.19%.
[3]SEM= Standard error of the mean.

Table 12. Carcass yield and commercial cuts of broiler fed diets varying AME and dig. Lys at 38 d, %[1].

Item	Carcass[5]	Abdominal fat	Breast fillets	Breast tenders	Thighs	Drumsticks	Wings	Back
AME[2]								
High	78.4	1.19	25.6	4.8	12.9	17.1	11.1	24.2
Moderate	78.1	1.25	26.0	4.8	12.7	16.9	10.9	24.0
Low	78.2	1.17	26.1	4.9	12.5	16.8	11.1	24.1
Lys[3]								
High	78.3	1.13[b]	26.4[a]	4.9	12.7	16.9	10.9	24.3
Moderate	78.2	1.18[b]	25.8[ab]	4.9	12.7	16.8	11.0	24.1
Low	78.1	1.31[a]	25.5[b]	4.8	12.7	17.2	11.2	24.0
SEM[4]	0.009	0.003	0.008	0.005	0.007	0.009	0.018	0.008
Probability <								
AME	0.374	0.137	0.337	0.588	0.402	0.169	0.313	0.861
Lys	0.572	0.001	0.013	0.799	0.219	0.333	0.274	0.337
AME X Lys	0.624	0.212	0.215	0.238	0.076	0.945	0.278	0.094

[a>b] Means with different letters in the same column indicate significant differences ($P < 0.05$).
[1]Probability presented after transformation to arc sine.
[2]AME Moderate: 3,000. 3,080. 3,140. 3,160 and 3,180 kcal/kg for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. Levels with high or low AME were 50 kcal/kg more or less than the moderate level.
[3]Lys Moderate: 1.33. 1.24. 1.13. 1.04 and 0.96% digestible lysine for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. The levels with high and low digestible lysine increased or decreased in the pre-starter and starter phases by 0.07% from the moderate level, 0.08% for the grower 1 and grower 2 phases, 0.06% for the withdrawal, with minimum ratios: TSAA 0.75; Thr 0.65; Val 0.76; Trp 0.19%.
[4]SEM= Standard error of the mean.
[5]Eviscerated carcass as a percentage of body weight, whereas cuts were proportions of the eviscerated carcass.

Table 13. FCB, FCC of broilers fed diets varying levels of AME and dig. Lys from 1 to 38 d.

Item	FCB	FCC
AME[1]		
High	7.654	1.946[b]
Moderate	7.703	1.995[a]
Low	7.824	2.016[a]
Lys[2]		
High	7.444[b]	1.940[b]
Moderate	7.783[a]	1.998[a]
Low	7.956[a]	2.022[a]
SEM[4]	0.039	0.006
Probability <		
AME	0.167	0.001
Lys	0.001	0.001
AME X Lys	0.141	0.009

[a>b>c] Means with different letters in the same column indicate significant differences (P < 0.05).
[1]AME Moderate: 3,000, 3,080, 3,140, 3,160 and 3,180 kcal/kg for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. Levels with high or low AME were 50 kcal/kg more or less than the moderate level.
[2]Lys Moderate: 1.33, 1.24, 1.13, 1.04 and 0.96% digestible lysine for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. The levels with high and low digestible lysine increased or decreased in the pre-starter and starter phases by 0.07% from the moderate level, 0.08% for the grower 1 and grower 2 phases, 0.06% for the withdrawal, with minimum ratios: TSAA 0.75; Thr 0.65; Val 0.76 Trp 0.19%.
[4]SEM= Standard error of the mean.

Table 14. Feeding cost of broilers fed diets varying AME and dig. Lys. from 1 to 38 d.

Item	Feeding Cost/broiler	Cost/kg body weight	Cost/kg of Carcass	Cost/kg of breast
	U$			
AME[2]				
High	1.90	0.65	0.83	3.22
Moderate	1.87	0.64	0.82	3.17
Low	1.83	0.64	0.81	3.13
Lys[3]				
High	1.92	0.64	0.82	3.13
Moderate	1.87	0.65	0.83	3.19
Low	1.81	0.64	0.82	3.18

[1]AME Moderate: 3,000, 3,080, 3,140, 3,160 and 3,180 kcal/kg for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. Levels with high or low AME were 50 kcal/kg more or less than the moderate level.
[2]Lys Moderate: 1.33, 1.24, 1.13, 1.04 and 0.96% digestible lysine for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. The levels with high and low digestible lysine increased or decreased in the pre-starter and starter phases by 0.07% from the moderate level, 0.08% for the grower 1 and grower 2 phases, 0.06% for the withdrawal, with minimum ratios: TSAA 0.75; Thr 0.65; Val 0.76; Trp 0.19%.

Table 15. Performance and feeding cost of broilers fed diets varying levels of AME and dig. Lys. corrected for 2,950 g of BW[1].

Item	Feed Conversion Ratio	Feed Intake, g	Number of Days	Feeding Cost to 2,950 g of BW
AME[2]				U$
High	1.513[b]	4,403[b]	37.5	1.88
Moderate	1.554[a]	4,467[b]	37.6	1.85
Low	1.579[a]	4,543[a]	37.9	1.83
Lys[3]				
High	1.490[c]	4,348[c]	37.2	1.84
Moderate	1.560[b]	4,485[b]	37.6	1.85
Low	1.603[a]	4,596[a]	38.1	1.84
SEM[4]	0.008	18.369		
Probability <				
AME	0.001	0.001		
Lys	0.001	0.001		
AME X Lys	0.080	0.197		

[a>b>c] Means with different letters in the same column indicate significant differences ($P < 0.05$).

[1]Feed conversion and feed intake of each factor were corrected to 2,950g using linear regression estimated from conversion and consumption data at 35 and 38 days. Factor with High EMA and Low EMA consumed 67 and 73g of feed less and more than the overall mean (4,470g) in 0.1 and 0.3 days less and more than the overall mean (37.6 days), respectively; Factor with High PI and Low PI consumed 122 and 126 g less and more than the general average (4,470g), in 0.4 and 0.5 days less and more than the general average (37.6 days), respectively. Quadratic regressions of the number days of age (Y) of broiler chickens as a function of weight (X): High AME $Y = -0.00000262X^2 + 0.01990753X + 1.58056523$; Moderate AME $Y= -0.00000274X^2 + 0.02032055X + 1.49315758$; Low EMA $Y =-0.00000281X^2 + 0.02063361X + 1.39205602$; High PI $Y= -0.00000256X^2 + 0.01961487X + 1.62206552$; Moderate PI $Y= -0.00000272X^2 + 0.02030620x + 1.47765718$; Low PI $Y = -0.00000291X^2 + 0.02104255X + 1.34563703$.

[2]AME Moderate: 3,000, 3,080, 3,140, 3,160 and 3,180 kcal/kg for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. Levels with high or low AME were 50 kcal/kg more or less than the moderate level.

[3]Lys Moderate: 1.33, 1.24, 1.13, 1.04 and 0.96% digestible lysine for the pre-starter, starter, grower 1, grower 2 and withdrawal phases, respectively. The levels with high and low digestible lysine increased or decreased in the pre-starter and starter phases by 0.07% from the moderate level, 0.08% for the grower 1 and grower 2 phases, 0.06% for the withdrawal, with minimum ratios: TSAA 0.75; Thr 0.65; Val 0.76; Trp 0.19%.

[4]SEM= Standard error of the mean.

CAPÍTULO III

CONSIDERAÇÕES FINAIS

Com base nos resultados obtidos neste estudo, podemos concluir que as dietas com alta densidade de energia e Lisina digestível teve um melhor desempenho zootécnico e de rendimento de peito. Considerar apenas os custos de formulação das rações ou o desempenho, separadamente, pode levar a uma falsa intepretação dos resultados e tornar incorretas as conclusões relativas ao custo-benefício para a produção de carne de frango.

A estratégia necessária para garantir um produto final de qualidade vai implicar diretamente no nível de energia e proteína a ser ofertada na ração. Em dietas com níveis mais altos de energia e proteína se observou uma melhora no desempenho, mas nessas condições, o custo da dieta foi mais alto, já os menores custos foram observados quando as aves foram alimentadas a partir de dietas mais pobres, ou seja, com níveis mais baixos de proteína e energia, mas nessa condição as aves perderam em desempenho. Portanto, além de considerar o preço dos ingredientes, que é volátil, pois o mercado é muito dinâmico, se faz necessário a análise do custo-benefício para melhor tomada de decisão.

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Apêndice 1: Normas para publicação de artigos no periódico Journal of Applied Poultry Research

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Article:

Bagley, L. G., and V. L. Christensen. 1991. Hatchability and physiology of turkey embryos incubated at sea level with increased eggshell permeability. Poult. Sci. 70:1412-1418. Bagley, L. G., V. L. Christensen, and R. P. Gildersleeve. 1990. Hematological indices of turkey embryos incubated at high altitude as affected by oxygen and shell permeability. Poult. Sci. 69:2035- 2039. Witter, R. L., and I. M. Gimeno. 2006. Susceptibility of adult chickens, with and without prior vaccination, to challenge with Marek's disease virus. Avian Dis. 50:354-365. doi:10.1637/7498-010306R.1

Book: Metcalfe, J., M. K. Stock, and R. L. Ingermann. 1984. The effects of oxygen on growth and development of the chick embryo. Pages 205- 219 in Respiration and Metabolism of Embryonic Vertebrates. R. S. Seymour, ed. Dr. W. Junk, Dordrecht, the Netherlands.

National Research Council. 1994. Nutrient Requirements of Poultry. 9th rev. ed. Natl. Acad. Press, Washington, DC.

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Department of Agriculture, Plant and Animal Health Inspection Service. 2004. Blood and tissue collection at slaughtering and rendering establishments, final rule. 9CFR part 71. Fed. Regis. 69:10137-10151.

Other:

Choct, M., and R. J. Hughes. 1996. Long-chain hydrocarbons as a marker for digestibility studies in poultry. Proc. Aust. Poult. Sci. Symp. 8:186. (Abstr.)

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Hruby, M., J. C. Remus, and E. E. M. Pierson. 2004. Nutritional strategies to meet the challenge of feeding poultry without antibiotic growth promotants. Proc. 2nd Mid-Atlantic Nutr. Conf., Timonium, MD. Univ. Maryland, College Park.

Luzuriaga, D. A. 1999. Application of computer vision and electronic nose technologies for quality assessment of color and odor of shrimp and salmon. PhD Diss. Univ. Florida, Gainesville.

Peak, S. D., and J. Brake. 2000. The influence of feeding program on broiler breeder male mortality. Poult. Sci. 79 (Suppl. 1):2. (Abstr.)

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The following abbreviations may be used without definition in JAPR:

ADF acid detergent fiber

ADFI average daily feed intake

ADG average daily gain

AME apparent metabolizable energy

AMEn nitrogen-corrected apparent metabolizable energy

ANOVA analysis of variance AOAC Association of Official Analytical Chemists

BSA bovine serum albumin

BW body weight

°C Celsius

cDNA complementary DNA

CF crude fiber

cfu colony-forming units (following a numeral)

CI confidence interval

CP crude protein

cpm counts per minute

CV coefficient of variation

d day

df degrees of freedom

DM dry matter

DNA deoxyribonucleic acid

EDTA ethylenediaminetetraacetate

EE ether extract

ELISA enzyme-linked immunosorbent assay

°F Fahrenheit

FCR feed conversion ratio

FE feed efficiency

ft foot

g gram

gal gallon

G:F gain-to-feed ratio

GLM general linear model

h hour

HEPES N-(2-hydroxyethyl)piperazine-N'-2-ethanesulfonic acid

HPLC high-performance (high-pressure) liquid chromatography

ICU international chick units

Ig immunoglobulin

IL interleukin

i.m. intramuscular

in. inch

i.p. intraperitoneal

IU international units

i.v. intravenous

kcal kilocalorie

L liter (also capitalized with any combination, e.g., mL)

lb pound

L:D hours of light:hours of darkness in a photoperiod

LSD least significant difference

m meter

μ micro

M molar

ME metabolizable energy

MEn nitrogen-corrected metabolizable energy

MHC major histocompatibility complex

mRNA messenger ribonucleic acid

min minute

mo month

MS mean squares

n number of observations

NADH reduced form of NAD

NDF neutral detergent fiber

NRC National Research Council

NS not significant

PBS phosphate-buffered saline

PCR polymerase chain reaction

ppm parts per million

r correlation coefficient

r2 coefficient of determination, simple

R2 coefficient of determination, multiple

RH relative humidity

RIA radioimmunoassay

RNA ribonucleic acid

rpm revolutions per minute

s second

SAS Statistical Analysis System

s.c. subcutaneous

SD standard deviation

SE standard error

SEM standard error of the mean

SNP single nucleotide polymorphism

SRBC sheep red blood cells

TBA thiobarbituric acid

T cell thymic-derived cell

TME true metabolizable energy

TMEn nitrogen-corrected true metabolizable energy

TSAA total sulfur amino acids

USDA United States Department of Agriculture

UV ultraviolet

vol/vol volume to volume

vs. versus

wt/vol weight to volume

wt/wt weight to weight

wk week

yr year

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