UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
FACULDADE DE AGRONOMIA
PROGRAMA DE PÓS-GRADUAÇÃO EM ZOOTECNIA

# ESTRATÉGIAS PARA REDUÇÃO PROTÉICA DE DIETAS PARA FRANGOS DE CORTE

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Tese apresentada como um dos requisitos à obtenção do Grau de Doutor em Zootecnia
Área de Concentração Nutrição Animal

Porto Alegre (RS), Brasil
Fevereiro de 2010

Folha de homologação

# AGRADECIMENTOS

A Deus pela vida, em toda sua expressão.

Aos meus pais Pedro e Arsicia e irmãs Viviane, Rosilene e Priscila por serem a base da minha vida, acreditarem no meu potencial e me incentivarem na busca pelos meus objetivos.

Ao Professor Sergio Luiz Vieira pela dedicação e paciência na orientação de seus alunos.

Aos colegas e amigos Dimitri, Jaime, André, Diogo, Maria, Rafael, Fúlvio, Jolvane, Pedro, Jorge, Joaquim, Cibele, Fabrício, Natacha e todos os que passaram pelo Aviário de Ensino e Pesquisa, pela união na superação dos desafios.

Ao Miguel, ao Lauro, à Ione e ao quadro de funcionários da Universidade Federal do Rio Grande do Sul pela acessibilidade e colaboração.

À Universidade Federal do Rio Grande do Sul e aos professores do Programa de Pós-Graduação em Zootecnia por disponibilizarem ensino gratuito e de qualidade.

Ao CNPq pela concessão da bolsa de estudos.

À FAPERGS e ao CNPq pela disponibilização de recursos para os presentes projetos através de editais.

À empresa Ajinomoto Biolatina Ltda pela parceria na condução dos experimentos e aminogramas.

A todos aqueles que de alguma forma contribuíram para a realização desta tese, muito obrigado!

# SUPLEMENTAÇÃO DE AMINOÁCIDOS NÃO TRADICIONAIS PARA MELHORAR A EFICIÊNCIA PRODUTIVA DE FRANGOS DE CORTE[1]

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## RESUMO

A presente tese foi realizada com o objetivo de estudar as relações entre valina (VAL) e isoleucina (ILE), determinar as exigências de valina e a razão pela qual dietas de baixo conteúdo protéico tendem a causar queda no desempenho de frangos de corte. Desta forma, três experimentos foram conduzidos utilizando dietas a base de milho e farelo de soja e linhagens de frangos de corte comercialmente disponíveis. No primeiro estudo foram avaliadas deficiências de VAL e ILE em dietas práticas para frangos de 14 a 35 dias de idade. Tanto VAL quanto ILE foram limitantes para o ganho de peso dos frangos, não sendo possível identificar com precisão a ordem de limitação destes dois aminoácidos, o que sugere uma co-limitação entre eles. No segundo experimento, foram determinadas as exigências de VAL para frangos entre 21 e 42 dias de idade. Os níveis de VAL digestível considerados ideais por meio de regressão linear foram de 0,82 e 0,81% para ganho de peso e conversão alimentar. Entretanto, quando utilizado o método de linha-quebrada o platô para estas mesmas respostas foi obtido com 0,81 e 0,76% de VAL digestível. No terceiro experimento, a suplementação de L-VAL, L-ILE, Glicina (GLY) e/ou L-Ácido glutâmico (L-GLU) (PB) em níveis idênticos aos apresentados por uma dieta controle tida como padrão da indústria indicou influência do nível de nitrogênio sobre o desempenho das aves. Glicina e ácido glutâmico melhoraram o ganho de peso e conversão alimentar das aves. Os benefícios no crescimento devidos ao fornecimento de GLY foram majoritariamente observados em fases iniciais do crescimento das aves enquanto a suplementação de GLU monstrou-se vantajosa ao longo de todo o período experimental. Adições de VAL, ILE, GLU e GLY resultaram em maior deposição de carne de peito em relação as dietas suplementadas somente com valina. Conclui-se que o fornecimento de dietas de reduzido conteúdo protéico fica restrito a utilização de relações precisas entre VAL, ILE e LYS, além do fornecimento adequado de glicina em fases iniciais. O fornecimento de L-GLU como fonte de nitrogênio em dietas de reduzido conteúdo protéico é uma alternativa para a obtenção de desempenho similar ao apresentado por frangos alimentados com dietas de maior conteúdo protéico.

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[1] Tese de Doutorado em Zootecnia – Nutrição Animal, Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil. (143 p.) Fevereiro, 2010.

# NON-TRADITIONAL AMINO ACID SUPPLEMENTATION TO IMPROVE THE BROILERS PRODUCTION EFFICIENCY[2]

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## ABSTRACT

This thesis was carried out to understand the relationships between valine (VAL) and isoleucine (ILE), to determine the requirements of valine and why low protein diets tend to cause drop in broilers performance. Thus, three experiments were conducted using corn and soybean meal diets and broilers strain crosses commercially available. In first study were assessed deficiencies of VAL and ILE in practical diets for broilers from 14 to 35 days of age. VAL and ILE showed limitations on the body weight gain of broilers and it was impossible identify precisely the order of limitation of these two amino acids, suggesting a co-limitation between them. In the second experiment VAL requirements were determined for broilers between 21 and 42 days of age. Ideal digestible levels of VAL considering linear adjustments were 0.82 and 0.81% for body weight gain and feed conversion ratio. However, when used the method of broken-line linear model the plateau for these same responses were obtained with 0.81 and 0.76% of digestible VAL level. In the third experiment, the supplementation of VAL, ILE, Glycine (GLY) and/or Glutamic acid (GLU) as crude protein source at levels similar to those presented by a standard industry diet indicated a strong influence of nitrogen level on the performance of birds. GLY and GLU improved body weight gain and feed conversion of birds. The benefits in growth due to the supply of GLY were mostly observed in early stages of birds growth while the supplementation of GLU showed advantage throughout the experimental period. Additions of VAL, ILE, GLU and GLY showed a higher deposition of breast meat for diets supplemented only with valine. It is concluded that the provision of low protein content diets is restricted to the use of precise relationships between VAL, ILE and LYS, and providing adequate glycine in the early stages. The supply of L-GLU as a source of nitrogen in diets of low protein content is an alternative for obtaining similar performance presented by broilers fed diets of higher protein content.

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[2] Doctoral thesis in Animal Nutrition, Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil. (143 p.) February, 2010.

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# RELAÇÃO DE ABREVIATURAS E SÍMBOLOS

| | |
|---|---|
| Aminoácido(s) | AA |
| Aminoácidos de cadeia ramificada | AACR |
| Aminoácidos essenciais | AAE |
| Aminoácidos não-essenciais | AANE |
| Arginina | ARG |
| Conversão alimentar | CA |
| Cistina | CYS |
| Gordura abdominal | GA |
| Ácido glutâmico | GLU |
| Glicina | GLY |
| Glicina+Serina | GLY+SER |
| Ganho de peso | GP |
| Isoleucina | ILE |
| Leucina | LEU |
| Lisina | LYS |
| Metionina | MET |
| Metionina+Cistina | MET+CYS |
| Pontos percentuais | p.p |
| Prolina | PRO |
| Proteína bruta | PB |
| Serina | SER |
| Treonina | THR |
| Triptofano | TRP |
| Valina | VAL |

# CAPÍTULO I

# Introdução

Alterações no mercado mundial como a proibição do uso de ingredientes de origem animal e normas relacionadas a poluição ambiental, bem-estar animal e qualidade do produto final elevam os custos de produção em comparação à sistemas de produção sem estas exigências. Considerando a alta participação da ração nestes custos, é natural que esta seja foco de pesquisas.

Através da manipulação nutricional das rações não só é possível reduzir custos como modular respostas relacionadas a uma menor excreção de elementos potencialmente poluidores, como o nitrogênio. A obrigatoriedade do uso de dietas exclusivamente vegetais para frangos exportados para países da União Européia e Arábia Saudita passou a determinar a impossibilidade da reciclagem de ingredientes de origem animal dentro da própria indústria, anteriormente tida como uma alternativa de redução de custos. Dentre as fontes vegetais de proteína disponíveis no mercado brasileiro o farelo de soja destaca-se por ser o de maior inclusão nas dietas. Entretanto, este ingrediente apresenta como desvantagens o custo relativamente alto, a alta concentração de polissacarídeos não-amiláceos e de potássio, os quais aumentam a viscosidade da dieta e elevam o consumo e eliminação de água pelas aves. Estes fatores, em última análise, contribuem para o desenvolvimento de condições adversas ao crescimento dos frangos através do aumento da proliferação de patógenos e fermentação da cama.

Desta forma, a redução do nível de proteína bruta da dieta por meio da diminuição da inclusão de farelo de soja nas dietas e menor excreção de nitrogênio pelas aves, sem perdas em desempenho zootécnico são pontos essenciais na busca por alternativas viáveis. Grandes avanços foram alcançados até a suplementação de treonina, o terceiro aminoácido limitante em dietas para frangos de corte. Contudo, a identificação do quarto aminoácido limitante e suas exigências carece de maiores estudos e aprofundamento. Da mesma forma, a redução acentuada do nível de proteína bruta das dietas geralmente leva à queda de desempenho. A busca do entendimento das causas desta perda de desempenho é atual e fundamental para que os custos de produção possam ser reduzidos.

Ante o exposto, para a realização da presente tese foram conduzidos três experimentos buscando determinar as relações entre valina e isoleucina, as exigências de valina e o efeito da suplementação de aminoácidos valina, isoleucina, glicina e ácido glutâmico em dietas a base de milho e farelo de soja sobre o desempenho de frangos de corte.

# Revisão bibliográfica

## Necessidades protéicas das aves

É geralmente aceito que o nível protéico ótimo de uma dieta é aquele suficiente para atender às exigências de aminoácidos (AA) das aves sendo o resultado da mistura heterogênea de diferentes matérias-primas. O crescimento dos animais depende da síntese protéica, a qual tem sua eficiência de utilização relacionada a quantidade de AA a serem catabolizados. As exigências de AA em uma determinada idade variam diretamente com a taxa de crescimento da ave. Portanto, as exigências de AA, como proporção do total de nutrientes consumidos por dia, diminuem em paralelo à redução do crescimento com a idade (Han & Baker, 1991).

A utilização dos AA presentes nas matérias-primas para síntese de proteína no organismo animal depende de fatores além da sua concentração na dieta. As proteínas dos alimentos são digeridas em taxas diversas e, assim, os AA são disponibilizados também em diferentes concentrações na mucosa intestinal para absorção. Vários fatores podem afetar a velocidade de digestão das proteínas, entre eles os inibidores das proteases, tais como: inibidores de tripsinas, lectinas, compostos polifenólicos e saponinas (Bryden, 1996; Hughes & Choct, 1999). Os vários polissacarídeos não amiláceos presentes em ingredientes protéicos vegetais, como os grãos e farelos de leguminosas alteram a viscosidade intestinal e, portanto, a digestibilidade da dieta (Vieira & Lima, 2005).

A fixação de um nível mínimo de proteína bruta na formulação, como critério para assegurar níveis mínimos de AA e ótimo desempenho dos animais, continua sendo adotada por muitos nutricionistas. Isto eleva os custos de produção das rações e desconsidera o balanço aminoacídico e eventuais excessos destes nutrientes nas rações.

Além da grande influência sobre parâmetros de desempenho zootécnico e de rendimentos de cortes, o consumo de proteína e AA influencia o crescimento e desenvolvimento das penas de aves em crescimento. A maior parte da estrutura da pena é composta por queratina que é sintetizada na pena formando células da epiderme. Embora a estrutura da queratina seja muito rica em cistina e níveis marginais de metionina+cistina prejudiquem o desenvolvimento normal das penas, a deficiência de AA como a valina (VAL) também podem afetar o desenvolvimento destas (Farran e Thomaz, 1992ab).

Excessos de proteína das dietas são degradados e incorporados ao ácido úrico sintetizado por reações comuns às purinas, componentes do DNA. A glicina é parte integral do ácido úrico e, portanto, a eliminação desta é paralela à excreção urinária (Scott *et al.*, 1982). Portanto, supõe-se que a exigência de glicina seja maior em aves de rápido crescimento e em dietas com excesso ou desequilíbrio protéico. A treonina, sendo precursora da glicina, pode também ter suas exigências alteradas nestas condições. Da mesma forma, a excreção do ácido úrico demanda energia e o excesso de nitrogênio na dieta constitui desperdício de nitrogênio e de energia (McLeod, 1997).

As exigências de proteína das aves são, na verdade, exigências de aminoácidos. Todavia, esta afirmação está baseada na necessidade de degradação das proteínas até os compostos típicos de absorção para posterior utilização nos processos de síntese no metabolismo animal. Independentemente da proteína original ingerida, AA, di- e tripeptídeos, são as unidades realmente absorvidas pelo animal. Da mesma forma, assume-se que do “pool” de AA em trânsito para os processos de síntese, preocupações com a demanda de aminoácidos não-essenciais (AANE) seriam irrelevantes, pois em dietas usuais estes apresentam-se em excesso. Assim, apenas a riqueza em AA essenciais é levada em consideração na formulação de rações comerciais. A menos que o conteúdo protéico das dietas seja reduzido de forma a restringir o suprimento de nitrogênio total da dieta considera-se desnecessária a quantificação dos AA não-essenciais.

A manipulação do conteúdo protéico das dietas também foi estudada em relação a temperatura ambiente. Altas temperaturas ambientes reduzem o consumo de alimento e a taxa de crescimento (Cemigua et al., 1983; Reece and Lott, 1983). Cheng et al. (1996) reportaram que o fornecimento de dietas de alta PB para frangos sob estresse por calor tem um efeito prejudicial no ganho de peso e composição da carcaça, bem como na eficiência de utilização do alimento, proteína e energia. Faria Filho et al. (2006) relataram ainda que dietas de baixa proteína bruta para frangos sob estresse por calor além de reduzir a proteína também aumentou a deposição de gordura em cortes. Segundo os autores a utilização destas dietas não é recomendada para frangos entre 43 e 49 dias de idade criados sob temperatura de 32 ºC. Todavia, para temperaturas entre 20 e 25 ºC sua utilização é benéfica.

Dietas de alto conteúdo protéico foram descritas como responsáveis pelo aumento da resistência ao rompimento da pele de frangos, muito embora a razão esteja pouco elucidada. Uma quantidade maior de proteína bruta provê maior quantidade do AANE glicina, o qual representa cerca de 30% dos AA constituintes do colágeno, o que poderia explicar este fato (Leeson & Summers, 2001).

As concentrações relativas dos AA entre si também exercem efeito sobre a absorção e o metabolismo de síntese e degradação protéica do organismo animal, sendo comum a existência de antagonismos entre estes no momento de sua absorção. A disponibilidade comercial dos AA metionina, lisina (LYS), e treonina (THR) têm propiciado redução nos custos das dietas. Estes são, na prática, os três primeiros AA limitantes em dietas para frangos de corte. Contudo, a formulação de dietas com redução acentuada no conteúdo de proteína bruta das rações para frangos de corte permanece motivo de indagações e conjecturas.

### Redução protéica

A adequação das dietas com os mais diversos ingredientes às exigências dos animais é muito difícil de ser realizada sem que ocorra a administração excessiva de alguns nutrientes. Comum é o caso dos AA, em que aqueles não suplementados individualmente nas dietas, geralmente excedem os níveis considerados suficientes para maximizar respostas de desempenho zootécnico, imunidade e rendimentos pós-abate. Neste contexto, a redução protéica das dietas ganha ênfase e relações mais precisas entre os

AA passam a ser requeridas. Segundo Kidd & Kerr (1996), reduzindo-se a proteína bruta da dieta, é possível melhorar a eficiência de utilização do nitrogênio diminuindo sua excreção, aumentar a tolerância dos frangos a altas temperaturas ambiente e reduzir o nível de amônia na cama. Ishibashi & Yonemochi (2002) afirmaram que a eficiência de utilização da proteína pode ser melhorada em níveis superiores a 50% pelo correto balanço aminoacídico da dieta e que para melhorar a conversão alimentar e reduzir a excreção de nitrogênio é necessário elucidar o conteúdo em aminoácidos das matérias-primas utilizadas na alimentação animal e sua disponibilidade além, é claro, de determinar as exigências dos animais. Todavia, a redução do conteúdo protéico em dietas para frangos de corte merece maior atenção que no caso de suínos, por exemplo. Reduções de 3 a 4 pontos percentuais (p.p.) no conteúdo protéico de rações para suínos são perfeitamente possíveis quando utilizada a suplementação de AA sintéticos, sem qualquer perda em desempenho zootécnico ou qualidade de carcaça (Hansen *et al.*, 1993; Ferreira *et al.*, 2006). Entretanto, quando reduções desta magnitude são realizadas em dietas para frangos estes resultados nem sempre são alcançados suplementando-se AA na forma sintética (Fancher and Jensen, 1989ab; Pinchasov et al., 1990; Thornton *et al.*, 2005; Aftab et al., 2006; Berres *et al.*, 2007).

Quando reduções desta magnitude são realizadas para o nível de proteína bruta, aminoácidos além da metionina, lisina e treonina passam a apresentar-se limitantes e a prejudicar o aproveitamento destes três primeiros AA para conversão em proteína corporal. É o caso da valina, isoleucina (ILE), arginina (ARG), triptofano (TRP) e para fases iniciais, mesmo da glicina (GLY).

O balanço entre os aminoácidos essenciais é de grande importância na otimização do crescimento animal e o uso de aminoácidos sintéticos permite uma nutrição mais precisa, sem excessos de proteína bruta. De acordo com Kidd (2001), a disponibilidade econômica dos aminoácidos industriais, assim como a melhor avaliação dos ingredientes e das exigências nutricionais permitem aos nutricionistas formularem rações com menores níveis protéicos.

Por outro lado, a adição de AA industriais em rações pode resultar em redução no consumo de alimento (Han and Baker, 1993; Carew et al., 1998; Si et al., 2004). O metabolismo dos AA envolve síntese e degradação de proteínas, incorporação do nitrogênio dos AA no ácido úrico, conversão dos esqueletos de carbono dos AA em glicose, gordura, energia ou $CO_2$ e $H_2O$ e ainda formação de derivados não protéicos (Kidd & Kerr, 1996). Os esqueletos de carbono resultantes do catabolismo de AA podem gerar piruvato para produção de glicose ou energia e AANE para necessidades metabólicas tais como a síntese de proteína, creatina, serina, ácido úrico, sais biliares e glutationa, por exemplo. Alguns autores (Kumta and Harper, 1962; Peng and Harper, 1970) propuseram a hipótese aminostática, pela qual os níveis de aminoácidos presentes no plasma serviriam como um sinal para um mecanismo controlador do apetite. É possível que não somente níveis de aminoácidos mas também de seus metabólitos serviriam como sinal para regular o consumo de alimento. De acordo com Namroud et al. (2008) o retardo no crescimento e consumo de alimento em frangos alimentados com dietas de reduzida PB e suplementadas com grandes quantidades de AA é devido aos efeitos negativos do aumento da concentração sanguinea e excretória de amônia no metabolismo tecidual. A amônia é inevitavelmente liberada no metabolismo da proteína, mas é extremamente tóxica para células vivas, e os mecanismos sensíveis a mantem em níveis não tóxicos. Excessos ou desbalanços de AA originam esqueletos de carbono e amônia, a qual é posteriormente convertida em ácido úrico e excretada pelas aves.

Diminuir o consumo de ração para limitar a absorção e o catabolismo do excesso de aminoácidos pode ser um mecanismo para diminuir a concentração intracelular de amônia. Outra forma é a indução de atividades de enzimas envolvidas na desintoxicação de amônia. Segundo Noda (1975), o nível de amônia no sangue é um fator importante na regulação do apetite em ratos, mas não há nenhuma pesquisa confiável para investigar o mecanismo de controle em frangos de corte ou os fatores dietéticos eficazes sobre o nível de amônia no sangue.

O insucesso na obtenção de desempenho de frangos alimentados com dietas de reduzida PB semelhante ao apresentado por frangos que consomem dietas controle pode ser atribuído a insuficiência de nitrogênio para a síntese de AANE, especialmente GLY, SER, PRO, e GLU; a um decréscimo no nível de potássio ou alteração no balanço iônico; e a desbalanços entre aminoácidos. Contudo, a maioria destes fatores não explicam completamente essa queda no desempenho. Discrepâncias entre os efeitos da suplementação de AAE e AANE em dietas com reduzida PB podem ser atribuídas principalmente a severidade da redução do nível de PB, aos ingredientes utilizados nas dietas e a adequação da suplementação a ordem de limitação dos aminoácidos nestas dietas. Ainda assim, estas manipulações nas dietas podem não demonstrar sucesso na obtenção de crescimento similar ao apresentado por aves alimentadas com uma dieta controle positivo.

### Aminoácidos essenciais

A determinação do conteúdo de PB de um alimento é bastante simplista e geralmente é obtida através da multiplicação do percentual de nitrogênio deste pelo fator de correção 6,25, o qual na realidade varia de uma matéria-prima para outra. Portanto, parece mais apropriado considerar-se como nível protéico ótimo da ração aquele suficiente para atender às exigências das aves em aminoácidos. Quando o nível de PB da ração não apresenta restrições no momento da formulação este é determinado estritamente pelo nível do último aminoácido essencial fixo na fórmula, geralmente a treonina, e pela presença deste aminoácido nas fontes protéicas disponíveis.

A ordem de limitação dos AA das dietas é usualmente estudada por meio de experimentos com adição ou remoção dos mesmos das dietas (Edmonds *et al*., 1985; Baker, 1989). Nos experimentos com adição, os AA são adicionados individualmente e em várias combinações a uma dieta com baixo conteúdo protéico ou AA-deficiente, enquanto em experimentos com remoção, os AA são removidos sequencialmente de uma dieta contendo os AA em níveis satisfatórios. Os experimentos com adição são mais diretos e apresentam menos excessos de AA, mas requerem muitos tratamentos. Os experimentos de remoção de AA são muito simples e mais eficientes do ponto de vista de desenho experimental, mas seus resultados podem ser confundidos pelos excessos de AA. Fernandez *et al*. (1994) demonstraram que o problema de excessos de AA no método de remoção pode ser minimizado peso uso do conceito de proteína ideal na formulação das dietas.

Para a síntese protéica, os AA estão relacionados entre si de forma a sustentar as exigências de mantença e crescimento. Portanto, inadequações na oferta do primeiro limitante levam ao catabolismo dos próximos em ordem de limitação. Na nutrição de AA, mantença refere-se ao estado no qual a proteína não é depositada para crescimento, reprodução ou substituição de penas (D'Mello, 1994). Normalmente, estas são devidas a perdas obrigatórias e são relativamente baixas comparadas àquelas necessárias para o crescimento. Por exemplo, frangos em crescimento têm 94% das exigências de valina utilizadas para suportar o crescimento e apenas 6% são exigidos para repor as perdas obrigatórias (Baker *et al.*, 1996).

Uma das primeiras definições de AAE foi a de que são aqueles que não podem ser sintetizados pelo organismo animal, a partir do material disponível às células, em velocidade suficiente para atender as exigências para um crescimento normal (Borman et al., 1946). Cada AAE é único em seu catabolismo e a carência de um deles (limitante) geralmente acarreta o catabolismo parcial dos demais. A resposta das aves pode variar com os níveis de aminoácidos essenciais, com a magnitude da carência de algum deles, e com as relações entre os remanescentes (NRC, 1994). Exigências de AA são usualmente determinadas para ganho de peso e conversão alimentar. Entretanto, pela importância quantitativa na demanda a partir de AA da dieta, a composição corporal é relevante, permanecendo inalterada mesmo com alterações nos demais fatores que afetam as exigências protéicas das aves.

Muitos fatores podem influenciar as exigências de AA para frangos de corte durante o crescimento. Entre estes, fatores comuns são os níveis de proteína e energia e a presença de inibidores de proteases nas dietas, desafios microbiológicos, densidade de alojamento, disponibilidades de equipamentos, estresse por calor ou frio, bem como a composição corporal (Baker & Han, 1994) e sua taxa de crescimento. Concentrações inadequadas de um determinado AA levam ao catabolismo de outros. Antagonismos entre AA de cadeias laterais similares são reconhecidos, sendo que excessos de um afetam as necessidades dos demais. São reconhecidos os antagonismos entre leucina-isoleucina-valina, arginina-lisina, e treonina-triptofano (NRC, 1994). Outros efeitos indiretos, entretanto, existem. Por exemplo, excesso de MET causa deficiência de THR devido ao aumento da oxidação da mesma pela elevação da atividade da enzima treonina desidratase. Da mesma forma, o excesso de LYS pode causar deficiência de treonina (Kidd & Kerr, 1996). Um problema na avaliação do efeito de diferentes AA fornecidos através da dieta sobre o desempenho é que muitos fatores mudam simultaneamente, incluindo consumo de alimento (Denbow, 1989; Kuenzel, 1994) e síntese protéica (Kang *et al.*, 1985; Klasing *et al.*, 1987). Num contexto experimental, a mudança de um único AA pode ser usada para determinar a exigência para aqueles AA, entretanto quando são alterados os níveis de mais de um AA, interações entre eles acontecem e as interpretações das respostas obtidas tornam-se mais difíceis. Dificuldades associadas com a análise de AA podem ser a maior fonte de variação de um experimento com AA e estas são freqüentemente negligenciadas (Ravindran & Bryden, 1999).

Os AA apresentam uma larga variedade de funções, ainda que a sua participação no crescimento seja preponderante para os animais domésticos. As aves apresentam maior demanda dos AA sulfurados metionina (MET) e cistina (CYS) para deposição de penas e estes influenciam diretamente o desempenho zootécnico das aves além do rendimento de carcaça. A MET, além de participar da síntese protéica, é precursora da CYS e doadora de grupos metil (Warnick & Anderson, 1968). A LYS é utilizada quase que exclusivamente para síntese protéica (também atua na síntese de carnitina), enquanto a THR além de participar na formação de proteínas estruturais como o músculo participa da formação da GLY, faz parte das enzimas digestivas e de outras secreções intestinais como o muco, as células da mucosa e as proteínas do sistema imunológico (Fernandez *et al.*, 1994; *Kidd et al.*, 1998). O conhecimento das exigências destes 3 primeiros aminoácidos limitantes para frangos é alicerçado em um grande volume de informações científicas. Reduções nos níveis de proteína bruta das dietas além das usuais são dependentes da correta identificação do quarto AA limitante bem como de sua relação com os demais AA presentes na dieta. Nesta perspectiva, uma vez determinado, espera-se que em futuro próximo seja corriqueiro o uso do quarto, e talvez do quinto AA limitantes a partir de fontes industriais em dietas para frangos.

### Quarto aminoácido limitante

A ordem de limitação dos AAE tem sido fonte de preocupação e área prioritária de estudo há décadas. Um número considerável de pesquisas tem sido conduzido para definir a ordem de limitação dos AA em dietas com milho e farelo de soja (Schwartz & Bray, 1975; Edmonds *et al*., 1985; Han *et al*., 1992; Fernandez *et al*., 1994, Corzo *et al.*, 2008), amplamente utilizadas nas rações de frangos de corte atualmente.

Sem dúvida, a suplementação de AA sintéticos é uma alternativa para a redução na inclusão de farelo de soja nas rações. No entanto, reduções protéicas com correspondentes suplementações de AAE, a partir de fontes industriais, nem sempre resultam em recuperação do desempenho animal. Diferentemente dos três primeiros, o quarto limitante é altamente dependente dos ingredientes usados nas dietas. Valina, isoleucina, arginina e triptofano são potenciais candidatos. Entre os AA referenciados na literatura como possível quarto limitante, a valina vem demonstrando maior importância em dietas exclusivamente vegetais baseadas apenas em milho e farelo de soja (Schwartz & Bray, 1975; Edmonds *et al*., 1985; Han *et al*., 1992; Fernandez *et al*., 1994; Kidd & Hackenhaar, 2006). Simulações de formulação deste tipo de dieta para frangos em crescimento apresentam relações entre valina e lisina abaixo de 77%, relação considerada ótima por alguns autores recentemente (Rostagno *et al.*, 2005). Por outro lado, teoricamente e baseando-se nas relações entre AA determinadas até o momento, quando as dietas são baseadas em milho ou trigo, farelo de soja e farinha de carne de frango ou quando trigo, farelo de soja e farinha de carnes são utilizados em uma mesma dieta, ILE passa a ser o quarto limitante. Em dietas baseadas em milho, farelo de soja e farinha de carnes, TRP é o aminoácido limitante após treonina. Quando o sorgo é utilizado no lugar do milho, ARG torna-se o quarto AA limitante para frangos de corte (Kidd and Hackenhaar, 2006).

Mack *et al.* (1999) usaram dietas a base de milho e farelo de soja com baixa proteína (17,2%) para avaliar as exigências para vários aminoácidos. As dietas experimentais foram fornecidas de 20 a 40 dias de idade. Entretanto, à exceção de TRP e ILE, o ganho de peso e conversão alimentar foram questionáveis, não permitindo uma boa base para o estabelecimento das exigências de TRP e ILE ou das relações TRP:LYS e ILE:LYS. Estes autores também obtiveram resultados sugerindo que a relação ideal THR:LYS foi de 59%, inferior a de 67% encontrada no estudo de Baker (1997). Estes estudos claramente demonstram a importância da realização de novos experimentos, a partir dos quais relações entre os AA possam ser calculadas.

As recomendações de VAL do NRC (1994) são majoritariamente baseadas em modelagem e ausência de desbalanços entre os AA de cadeia ramificada (AACR) VAL, ILE e leucina (LEU). A limitação de VAL é particularmente aparente a idades avançadas quando a proteína da dieta é reduzida e a participação dos grãos, especialmente milho, têm sua contribuição elevada. As proporções relativamente baixas de VAL e ILE na proteína do milho são acompanhadas por alta concentração de leucina. Dietas com alto conteúdo de leucina têm sido relatadas como responsáveis por um aumento das exigências de VAL e ILE em frangos e perus em crescimento (D'Mello & Lewis, 1970; Allen & Baker, 1972; Tuttle & Balloun, 1976). Dietas inadequadas no conteúdo de VAL não somente impactam negativamente sobre o ganho de peso e conversão alimentar, mas também causam anormalidades no desenvolvimento de penas e pernas (Anderson & Warnick, 1967; Robel, 1977;

Farran & Thomas, 1992ab). Níveis extremamente elevados de leucina também ocasionam problemas de empenamento similares aos descritos para a carência de valina em dietas para frangos de corte (Penz *et al.*, 1984). Leclercq (1998) também observou redução no desempenho zootécnico de frangos consumindo dietas reconhecidamente deficientes em valina. Entretanto, não foram mencionadas anormalidades no desenvolvimento de penas e pernas. Desta forma, diferenças na expressão de uma deficiência de valina podem ser associadas à matéria-prima e ao nível de leucina empregados.

A deficiência dos AACR foi descrita por Konashi *et al.* (2000) como sendo responsável pela redução do peso de timo e bursa de Fabricius quando comparados com todos os outros grupos de AA essenciais. A degradação de VAL, ILE e LEU em animais inicia com uma transaminação seguida por descarboxilação oxidativa dos respectivos cetoácidos. Esta reação é conduzida pelo complexo *α*-cetoácido desidrogenase de cadeia ramificada (Mathews & Van Holde, 1990). Embora o metabolismo da ILE seja majoritariamente conhecido, poucos estudos avaliando seus efeitos sobre o desempenho de frangos de corte foram conduzidos. Antagonismos entre estes três AA têm sido demonstrados em várias espécies animais como ratos, suínos, perus e frangos de corte (Sauberlich, 1961; Allen & Baker, 1972; Oestemer *et al.*, 1973; Tuttle & Balloun, 1976; Smith & Austic, 1978; Taylor *et al.*, 1984). Burnham *et al.* (1991) demonstraram que a elevação dos níveis de LEU em dietas de frangos alivia o efeito depressivo do fornecimento excessivo de isoleucina.

A mistura de ingredientes em uma ração que resultem em quantidades de AAs essenciais muito próximas das exigências para crescimento e mantença dos frangos minimiza as inadequações entre os AACR e a excreção de nitrogênio (Mack *et al.*, 1999). Isoulecina também compete com o TRP para sua transferência no cérebro através da barreira sangue-cérebro (Wurtman, 1980; Tackman *et al.*, 1990). O triptofano tem um papel importante no cérebro como precursor do neutrotransmissor serotonina que, entre suas muitas funções, destaca-se por seu maior efeito no comportamento do animal em relação à regulação do apetite e do ritmo circadiano (Blundell & Latham, 1978; Tackman *et al.*, 1990; Mullen & Martin, 1992). Como excessos de ILE na dieta são associados a uma redução marcada em consumo de alimento, talvez, então, este efeito também possa ser associado a uma deficiência secundária de triptofano no cérebro.

Existem evidências de participação de AA na modulação da resposta imunológica em aves e mamíferos. Deficiências de proteína na dieta ou de AA alteram a resposta imunológica (Bhargava *et al*., 1970, 1971; Glick *et al*., 1981, 1983; Klasing, 1988; Payne *et al.* 1990; Umezawa *et al*., 1990). Glick *et al.* (1981; 1983) demonstraram diferenças entre a resposta imunológica de frangos alimentados com uma dieta deficiente para todos os AA essenciais e outra controle.

As funções do sistema imunológico podem ser afetadas pelo ambiente, nutrição ou fatores estressantes. O fornecimento de dietas com desbalanços entre os AA pode prejudicar a habilidade da ave de montar uma resposta imunológica efetiva. Isto pode ocorrer em frangos alimentados com dietas limitantes em valina ou isoleucina e com excessos de leucina. Pesquisas com ratos demonstraram efeitos imunossupressivos de altas concentrações de leucina na dieta, sendo estes efeitos revertidos através do aumento dos níveis de VAL e ILE nestas dietas (Aschkenasy, 1979). Deficiências de ILE e VAL apresentaram efeitos imunossupressores em ratos (Petro & Bhattacharjee, 1981). Desta forma, pode-se afirmar que devido a similaridades estruturais, LEU pode antagonizar a absorção e retenção de VAL e ILE, ou ambos, e este pode ser o mecanismo envolvido na imunossupressão leucina-induzida (Benton *et al.*, 1956).

Dependendo do perfil de ingredientes utilizado para compor uma dieta, a ordem de limitação de desempenho apresentada para os aminoácidos tende a ser diferente. Além disso, a medida que outros aminoácidos, menos limitantes, tem suas exigências atendidas com precisão, ou seja, sem excessos, o conceito de co-limitância ganha espaço, especificamente entre VAL e ILE (Corzo et al., 2009).

### Aminoácidos não-essenciais

Poucos trabalhos têm considerado a suplementação de VAL e ILE e de AANE em dietas para frangos de corte, principalmente no Brasil. Dentre os AANE, os que apresentam potencial para serem utilizados sinteticamente em dietas para frangos de corte são a glicina, o ácido glutâmico e o ácido aspártico. Todavia, também existem estudos que avaliaram a suplementação de outros AANE como a prolina e a alanina. Embora a glicina possa ser sintetizada pelas aves, a taxa de síntese não é adequada para suportar crescimento máximo (Featherston, 1976). Há muitas funções no metabolismo intermediário nas quais a glicina está envolvida, mas esta é exigida primariamente para a formação de ácido úrico e excreção de nitrogênio (Coon et al., 1975; Corzo et al., 2004). O ácido glutâmico é essencial para a manutenção da mucosa intestinal por ser fonte de energia para o *turnover* da mucosa, por intermédio do ATP produzido a partir do ciclo de Krebs; fonte de nitrogênio para síntese de aminoácidos e outros compostos nitrogenados; precursor da glutationa, antioxidante intracelular, que auxilia na manutenção da integridade intestinal. Han *et al*. (1992) demonstraram que pintos com idade entre 1 e 21 dias, consumindo rações à base de milho e farelo de soja, com 19% de proteína bruta e suplementadas com metionina, lisina, treonina, arginina e valina, bem como o aminoácido não essencial ácido glutâmico, tiveram um desempenho equivalente àqueles alimentados com a dieta controle com 23% de proteína bruta. Já entre os 22 e os 42 dias de idade as aves que receberam 16% de proteína bruta e suplementação com estes aminoácidos, tiveram um desempenho semelhante àquelas que receberam uma dieta com 20% de proteína bruta. Não houve diferença no teor de gordura corporal entre as aves que receberam dietas de baixa proteína bruta suplementadas com aminoácidos e aquelas que receberam a dieta controle. Porém outros estudos (Pinchasov *et al*., 1990; Colnago *et al*., 1991) indicaram desempenhos inferiores em aves alimentadas com dietas à base de milho e farelo de soja em que se usou baixa proteína e suplementação com aminoácidos limitantes.

O grau de limitação de muitos AANE, quando a PB da dieta é reduzida, é desconhecido para frangos de corte. Trabalhos referentes à administração de AANE em dietas com baixo conteúdo protéico têm apresentado resultados promissores. É o caso do estudo de Corzo *et al.* (2005), em que frangos de corte machos dos 5 aos 21 dias de idade foram submetidos a dietas com baixo nível de PB e suplementação de AANE em comparação a uma dieta controle positivo (convencional), sendo o nível de PB da dieta controle 4 p.p. maior em relação a dieta suplementada com AANE. Neste estudo, verificou-se ganho de peso semelhante entre a dieta controle e a dieta com baixa PB suplementada com glicina, alanina, ácido aspártico, ácido glutâmico e prolina, sendo ambas superiores a dieta com baixa PB sem suplementação dos AANE. Estes resultados indicam a necessidade de suplementação de AANE em dietas iniciais com 4 p.p. a menos de PB.

Hussein *et al.* (2001) avaliando a suplementação não só de AANE como de treonina, triptofano e arginina em dois experimentos, encontraram resultados contraditórios. Em um primeiro experimento, a adição de arginina, triptofano e treonina à dietas com 17,3% de PB foram capazes de imprimir ganho de peso semelhante ao obtido por frangos consumindo uma dieta de alta PB (22,6%), o que não ocorreu com a suplementação de isoleucina ou ácido glutâmico. Contudo, em um segundo experimento, os pesquisadores obtiveram efeito positivo da suplementação de AANE ou energia extra em conjunto com arginina, triptofano e treonina sobre respostas de desempenho zootécnico. Os autores destacaram a limitação de treonina das dietas com baixo conteúdo protéico.

Quando consideradas a retenção de nitrogênio e gordura bruta na carcaça de frangos consumindo dietas com baixa PB, ainda que suplementadas com glutamina e asparagina, comparativamente às daqueles que consumiram dietas convencionais, observou-se menor e maior retenção de nitrogênio e gordura, respectivamente, em carcaças de frangos que consumiram as dietas de baixo valor protéico. Da mesma forma, as aves que consumiram dietas com baixa PB, excretaram menos nitrogênio e apresentaram pior conversão alimentar (Bregendahl *et al.*, 2002).

De modo semelhante, Kerr & Kidd (1999) observaram que a adição única de ácido glutâmico (GLU) em dietas de baixo conteúdo protéico proporcionou ganho de peso e rendimento de carcaça inferior em relação à dieta controle. Contudo, quando estes pesquisadores adicionaram além de GLU, AAE, as respostas de rendimento de carcaça, percentual de gordura abdominal e rendimento de carne de peito foram similares às apresentadas por frangos consumindo a dieta controle. Em uma seqüência de estudos realizada por Dean *et al.* (2006), foi avaliada a suplementação de glicina em dietas com baixo conteúdo protéico. Os autores demonstraram ganho significativo sobre o desempenho das aves que consumiram dietas com baixa PB com níveis bastante superiores de GLY+SER aos comumente recomendados pelas tabelas de exigências de frangos de corte. Embora os resultados encontrados tenham sido semelhantes aos apresentados por frangos consumindo dietas controle com maior conteúdo protéico, a dieta de 16% de PB não teve aplicação prática em razão da alta quantidade de aminoácidos cristalinos ainda não disponíveis comercialmente. Corzo et al. (2005) reportaram que frangos alimentados com dietas contendo 18% de PB suplementada com GLY ou L-LEU tiveram conversão alimentar igual a de frangos alimentados com uma dieta controle com 22% de PB.

Waldroup et al. (2005) reportaram que a suplementação de GLY em uma dieta de baixa PB melhoraram significativamente o ganho de peso, apesar de não restaurar completamente o desempenho obtido por frangos alimentados com dietas de 22 ou 24% de PB. Schutte et al. (1997) recomendaram 1.9% de GLY+SER total quando frangos foram alimentados com dietas de baixa PB fortificadas com aminoácidos essenciais. Por outro lado, alguns pesquisadores sugeriram que o grande fornecimento de aminoácidos essenciais em relação aos não essenciais em dietas de baixa PB tendem a melhorar o desempenho e prevenir o excesso de deposição de gordura, (Yamazaki et al., 1998); embora, outros achados rejeitem esta influência positiva (Yamazaki et al., 2006).

De acordo com a revisão de Pesti (2009), apesar do aumento dos níveis protéicos da maioria dos estudos resultar em melhora no ganho de peso e conversão alimentar, a decisão sobre os níveis adequados de PB ou da soma de AAE e AANE da dieta fica dependente de uma série de fatores relacionados ao retorno econômico.

### Proteína ideal

Proposto por Mitchell (1964), o conceito de proteína ideal baseia-se em otimizar a utilização da proteína da dieta melhorando o desempenho das aves (Waldroup *et al*., 1976; Baker, 1994; Mack *et al*., 1999) e minimizando a excreção de nitrogênio (de Lange, 1993). Os nutricionistas de suínos foram os primeiros a focalizar esse problema, expressando as exigências de aminoácidos como relativas à LYS para diferentes categorias de peso (Wang & Fuller, 1989; Chung & Baker, 1992). Embora as exigências para aminoácidos mudem por uma série de motivos, entre os quais a taxa de crescimento, as relações ideais permanecem similares e, uma vez determinadas, somente exigências precisas de LYS precisariam ser estabelecidas para os animais em diferentes condições ambientais (Baker, 1997).

A proteína ideal nada mais é que a mistura de aminoácidos ou proteínas capaz de atender as exigências dos animais para mantença e crescimento com a máxima eficiência ou o menor desperdício possível. A LYS é o AA referência por ser usado quase que exclusivamente para deposição protéica, por ser um aminoácido essencial limitante em dietas para frangos e por sua determinação laboratorial ser bastante precisa (Baker, 1997). A utilização deste conceito facilita a inclusão de ingredientes alternativos na fórmula sem alteração no desempenho das aves e com redução nos custos de produção.

Quando utilizado o conceito de proteína ideal na formulação sem que níveis mínimos de proteína bruta sejam fixados é natural que ocorra uma redução do conteúdo de proteína bruta até que o nível mínimo do aminoácido limitante, geralmente um aminoácido não provido de forma sintética, seja obtido. Desta forma, a excreção de nitrogênio pelas aves é reduzida, e desde que a redução protéica não seja exacerbada o desempenho pode ser mantido similar a dietas de maior nível de proteína bruta.

## Hipóteses e objetivos

### Hipóteses

A alteração das relações VAL:LYS e ILE:LYS das dietas afetará o desempenho zootécnico e rendimentos de carcaça e cortes de frangos de corte e haverá uma ordem de limitação entre estes dois aminoácidos;

A alteração do nível de VAL das dietas afetará o desempenho zootécnico e rendimentos de carcaça e cortes de frangos de corte;

A alteração do nível protéico e do perfil aminoacídico das dietas afetará o desempenho zootécnico e rendimentos de carcaça e cortes de frangos de corte.

### Objetivos

#### Geral

O objetivo da presente tese foi o de explorar possibilidades em virtude da necessidade de redução protéica das dietas.

#### Específicos

Entender a importância das relações entre VAL e ILE;

Determinar as exigências de VAL;

Determinar a razão pela qual o nível de proteína bruta das dietas, quando reduzido, determina respostas inferiores de desempenho e rendimentos de carcaça e cortes em frangos de corte.

# CAPÍTULO II[1]

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[1] Artigo submetido ao Journal of Applied Poultry Research em Agosto de 2009

# Supplementing L-Valine and L-Isoleucine in low protein corn-soybean meal all vegetable diets for broilers

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Key words: branched chain amino acids; ideal protein; protein; isoleucine; valine

Section: Metabolism and Nutrition

Running title: Valine and Isoleucine for broilers

Primary audience: Nutritionists

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## SUMMARY

One study was conducted to evaluate performance and carcass yields of broilers fed diets having increased VAL and ILE to LYS ratios from 14 to 35 d. One thousand seven hundred and seventy-five Cobb x Cobb 500 male broilers were fed a corn-soybean meal all vegetable diets having 1.10% digestible LYS. This diet was formulated without crude protein restriction to attain the lowest digestible ILE to LYS ratio and without synthetic AA besides MET, LYS and THR. MET+CYS and THR to LYS ratios were kept at 75 and 65%. Crude protein was 18.7%, whereas VAL and ILE reached at 70 and 65% of LYS. Graded increases in ratios of VAL and ILE to LYS were created using the basal feed supplemented with L-VAL and L-ILE at the expense of kaolin as follow: 75 and 65, 80 and 65, 70 and 68, 70 and 71, 75 and 68, 80 and 71%. Treatments had 9 replications of 25 male broilers each. Performance differences were detected mainly from 14 to 21 d of age; feed intake was lower for broilers fed the basal diet, whereas body weight gain and feed conversion ratio were improved by increases in VAL and ILE to LYS ratios. From 14 to 35 d, low levels of VAL and ILE led to lower body weight gain but did not influence feed conversion ratio. No differences were found among treatments for mortality, carcass, cuts and abdominal fat yields. In general, digestible ratios of VAL and ILE to LYS between 70 and 75 and 65 and 68, respectively, should be sufficient for Cobb 500 birds from 14 to 35 d of age.

## DESCRIPTION OF PROBLEM

The use of synthetic (MET sources) and crystalline (L-LYS sources and L-THR) amino acids (AA) in broiler feeds is well established as successfully attaining the needs of the first limiting amino acids. As amino acids follow in the limiting order of deficiency, the fourth limiting AA becomes more sensitive to the overall allowances of AA in macro ingredients. For instance, corn-soybean meal all vegetable diets, diets containing animal by-products, or even diets with other cereals such as sorghum have VAL, ILE, TRP or ARG as fourth limiting amino acids [1]. However, actual deficiencies of the fourth limiting amino acid in broiler diets are usually not seen in practical production even when frequent modifications in feed formulation potentially change the dietary AA profile. This is the consequence of CP safety margins adopted during linear formulation, which prevent the appearance of AA deficiencies after THR.

The use of ratios between essential amino acids and lysine has gained importance as a method to supply balanced protein in feeds for broilers. Diets formulated using this principle have been proposed by scientists to optimize animal utilization of dietary protein [2, 3, 4]. The literature has been presenting a progressive number of investigations directed to establish the ideal ratios between essential amino acids and lysine; however, information on this matter regarding the fourth limiting amino acid is still missing.

The use of synthetic amino acids has allowed a significant reduction in the dietary CP contents for broilers along the years. Further reductions are theoretically possible as long as identification of the fourth limiting amino acid is routinely performed as ingredients change during feed formulation.

Recent publications have indicated that ILE and VAL in broiler feeds are optimized at the ratio to LYS of 65 and 78%, when corn-soybean meal diets containing blood cells or corn-peanut meal were respectively used [5, 6]. The use of all vegetable diets to feed animals destined for human consumption has been mandatory in some countries for a few years [7]. Presently, a considerable amount of broiler feeds produced in the world towards these markets is based on corn and soybeans as the only sources of protein besides synthetic amino acids. This type of diet has VAL and ILE as fourth and fifth limiting amino acids [1, 8, 9]. However, differences between supplemental needs of these amino acids are very small. Since VAL and ILE are branched chain amino acids, which present a known antagonism in broilers, excesses of one that can negatively affect the other can potentially occur if requirements of both are not assessed simultaneously. The objective of this investigation was to evaluate the performance and carcass yields of broilers fed all vegetable diets based on corn and soybean meal supplemented with VAL and ILE, individually or combined, simulating the practical feed formulation presently done for the international market requiring all vegetable feeds.

## MATERIALS AND METHODS

### ***Broiler Husbandry***

One thousand five hundred and seventy-five one-day-old Cobb X Cobb 500 male broiler chicks were placed in 63 pens, 1.70 x 1.65 m each. Chicks averaged 45 ± 0.42 g and were previously vaccinated for Infectious Bronchitis and Marek´s disease at the hatchery. Temperature was 32 °C at placement, being reduced with age to provide comfort temperature throughout the study. Lighting was continuous until 10 d of age with natural day light to provide 12h of light thereafter. Water and feeds were provided *ad libitum*. All birds were fed the same commercial crumbled starter diet from 1 to 14 d (3,000 kcal/kg ME; 23.3% CP; and 1.27, 1.07, 0.82, 0.93, and 0.87% of dig LYS, MET+CYS, THR, VAL, and ILE, respectively). Amino acid analyses were conducted for corn and soybean meal prior to feed formulation using High Performance Liquid Chromatography auto analyzer according to 914.12 AOAC Official Method [10]; and Near Infrared Spectroscopy System for CYS and TRP determination.

### *Experimental Diets*

Treatments were applied from 14 to 35 d of age. A basal diet was formulated to attain the lowest digestible ILE to LYS ratio without a CP minimum value restriction and also without synthetic AA supplementation other than DL-MET, L-LYS and L-THR. Digestible LYS was fixed at 1.10% and ratios between essential AA and digestible LYS were as shown in Table 1. These ratios were based on Rostagno et al. [4], with exception of MET+CYS which was based on the Illinois University recommendation [2]. Through this feed formulation, ratios of VAL and ILE to LYS of 70 and 65% were obtained, whereas all other essential AA requirements were attended or slightly excessive. Six other treatments were then produced with graded increases of 5 and 3 percentage points in the ratios of VAL and ILE to LYS, respectively. These two AA were increased individually or simultaneously using L-VAL and L-ILE at the expense of kaolin [11] as formulated in the basal feed. Therefore, supplementations of VAL and ILE produced treatments with simultaneous ratios of VAL and ILE to LYS of 75 and 65, 80 and 65, 70 and 68, 70 and 71, 75 and 68, 80 and 71%, respectively.

### *Measurements*

Feed intake, body weight gain and feed conversion corrected for the weight of dead birds were weekly evaluated. At 35 d of age, ten birds per pen were randomly taken from each pen following an 8h fasting and being then individually weighted.

Birds were then stunned by electric narcosis, bled for 3 minutes through a jugular vein cut, scalded at 60 ºC for 45 seconds and de-feathered. Birds were manually eviscerated and then chilled in slush ice for 3 h and hung for 3 min to draw off water excess. Carcasses were then weighed and abdominal fat was collected and weighed. Commercial cuts were performed by skilled industry personnel producing deboned breast meat, thighs, drumsticks, wings, and cages, which were immediately weighed. Carcass yield was expressed relatively to live body weight whereas abdominal fat and cuts were expressed relatively to carcass weight. Birds were not submitted to any unnecessary discomfort.

### *Statistical Analyses*

Seven treatments with nine replications were distributed in a randomized complete block design. The experimental unit was a pen with 25 birds and pen location was the blocking factor. Data were submitted to analysis of variance at a 5% of significance using the GLM procedure of SAS [12]. Significant differences were separated using Tukey test ($P<0.05$). Mortality data were submitted to arcsine transformation prior statistic analysis.

## RESULTS AND DISCUSSION

Resulting dietary treatments demonstrated slight deviations between analyzed and expected AA. These differences were considered acceptable since analyzed values followed expected trends for each treatment (Table 2).

Live performance results are shown in Table 3. From the body weight gain data, it was observed that the diets without VAL and ILE supplementation produced lower numerical means, which were statistically different ($P<0.05$) from VAL and ILE supplementation at 75 and 68% ratios to LYS from 14 to 21 d but also to any level of supplementation of both AA from 21 to 28 d. There were no differences in the last week of observation, but the accumulated body weight gain from 14 to 35 d showed benefits of VAL or ILE ratios to LYS individually added to the feeds at 75 and 65, and 70 and 68%, respectively. Feed conversion from 14 to 21 d, was worse when not supplemented with VAL and supplemented at the ratio of 71% ILE. On the overall period, feed intake and feed conversion were not affected by the treatments, whereas body weight gain showed improvements when any supplementation of VAL or ILE was used.

Carcass evaluation performed at 35 d was not able to detect any differences due to the treatments. Feather abnormalities were not observed and leg problems were not related with the treatments ($P>0.05$).

Data presented in this study showed supplementation effects of VAL and ILE in body weight gain and feed conversion; however, they failed to present any improvement in carcass evaluation. Requirements for maximum gain are generally lower than those for breast meat yield, which is lower than the requirement for feed conversion; and lastly, the requirement for minimum abdominal fat percentage is the highest [13].

However, this order of responses may be dependent of the studied AA, as shown by Schutte and Pack [14] for sulfur amino acids. Broiler performance and carcass composition responses are expected to be less affected when AA supplementation becomes increasingly apart from MET and lysine. Muscle synthesis is not dependent of VAL and ILE compared to LYS and MET. Kidd et al. [15] related an increase in breast meat yield ($P<0.08$) when branched chain amino acids were increased from deficient to adequate levels. In the present study, the impact of supplementing either VAL or ILE, were similar and without additive effects. Besides, responses were already maximized at the first level of supplementation.

Valine has been previously shown to be first limiting when compared to ILE in diets based on corn and soybean meal [6, 8, 9]. It is generally expected that increases in one essential amino acid leads to the need of further increasing the other essential AA to avoid limitation in animal protein synthesis and, therefore, limitation in growth. In the present study, VAL could have been limiting when ILE was increased, which then explains the worse feed conversion from 14 to 21 days when 70 and 71 VAL and ILE to LYS digestible ratios were used. In parallel, the lack of additive effects for VAL and ILE concomitantly supplemented, as well as discrepancies with higher levels of supplementation can also be attributed to interactions between branched-chain amino acids. Since VAL and ILE are branched chain amino acids, which present a known antagonism in broilers, individual excesses can negatively affect their counterpart [16, 17, 18]. In the case of VAL and ILE in corn-soybean meal all vegetable diets, this issue becomes relevant because these AA are almost co-limiting, i.e., they appear as fourth and fifth limiting at about the same dietary protein level.

Abnormalities on legs and feather have been related in the past when broilers were fed under the requirement [19, 20, 21, 22]. Severities of VAL deficiency in those early studies were likely to be more extensive than those in this work and, therefore, could explain the unnoticeable appearance of these characteristics in the present study.

Imbalances of AA in diets lead to abdominal fat increases in broilers and rats [23, 24]. However differences for this characteristic were not detected at levels studied in this work. The range of variation of VAL and ILE from the control diet to the highest supplementations was not capable of inducing such a change in the evaluated carcasses in this study.

Previous results or recommendations for VAL and ILE ratios to LYS for broilers have been based in diets formulated with a varied range of ingredients and studying individual VAL or ILE increases. In the present study, not only individual as well as associated supplementations of these two AA were evaluated. This fact associated to the natural interactions between them makes it more difficult to interpret the results. Early recommendations of VAL and ILE from NRC [25] allow present calculations of total ratios to LYS of 82% for VAL and 73% for ILE in diets from 21 to 42 d of age. Mack et al. [26] showed optimum responses with ideal VAL to LYS ratio of 81% and ILE to LYS of 71% for broilers from 20 to 40 d of age. Baker et al. [3] recommended ideal ratios of VAL to LYS and ILE to LYS of 77.5 and 61.4%, respectively. Rostagno et al. [4] currently suggest digestible ratios of VAL to LYS of 77 and ILE to LYS of 67% from 21 to 42 d and Corzo et al. [6] attributed optimum performance responses to VAL to LYS ratio of 78% from 21 to 42 days. Responses evaluated in the present study indicate that VAL and ILE ratios of 75 and 65%, respectively were able to optimize broiler performance but without affecting carcass characteristics. Reductions in protein towards deficiencies of VAL and ILE, lead to a parallel reduction in LEU, also a branched chain AA. Therefore, VAL and ILE increases from supplemented sources can potentially interact with LEU and affect protein synthesis.

## CONCLUSIONS AND APPLICATIONS

1. Supplementation of VAL or ILE positively influenced broiler live performance responses.
2. VAL and ILE were both limiting in the test diets to support body weight gain.
3. In general, digestible ratios of VAL and ILE to LYS of 70 and 65% were sufficient for most parameters in Cobb 500 birds from 14 to 35 d of age, but to maximize body weight gain a VAL and ILE to LYS ratios of 75 and 65 or 70 and 68% must be provided, respectively.

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*Acknowledgments:* Grants from FAPERGS, CNPq, and Ajinomoto Biolatina are recognized.

**Table 1.** Basal experimental diet composition (as-fed)

| **Ingredients** | **%** |
|---|---|
| Corn, 7.5% | 62.72 |
| Soybean meal, 46% | 28.70 |
| Soybean oil | 3.61 |
| Dicalcium phosphate | 1.90 |
| Limestone | 1.27 |
| Sodium bicarbonate | 0.41 |
| Vitamin and mineral premix[a] | 0.26 |
| Common salt | 0.20 |
| Choline chloride, 75% | 0.07 |
| DL-Methionine, 99% | 0.32 |
| L-Lysine HCl, 78% | 0.25 |
| L-Threonine, 98% | 0.10 |
| Kaolin[b] | 0.19 |
| | |
| **Calculated composition** | |
| Apparent metabolizable energy, kcal/kg | 3,100 |
| Crude protein, % | 18.70 |
| Dig. LYS, % | 1.10 |
| Ca, % | 0.98 |
| Av. P, % | 0.48 |
| Na, % | 0.21 |
| Choline, ppm | 1,700 |
| Dig. AA to LYS, % | |
| MET+CYS | 75 |
| THR | 65 |
| VAL | 70 |
| ILE | 65 |
| ARG | 106 |
| TRP | 18 |
| His | 42 |
| LEU | 142 |
| Phe+Tyr | 134 |

[a] Supplied per kg of feed: Vitamin A: 8,000 IU; Vitamin D3: 2,000 IU; Vitamin E: 30 IU; Vitamin K: 2 mg; Thiamine: 2 mg; Riboflavin: 6 mg; Pyridoxine: 2.5 mg; Cyanocobalamin: 0.012 mg; Pantothenic acid: 15 mg; Niacin: 35 mg; Folic acid: 1 mg; Biotin: 0.08 mg; Fe: 40 mg; Zn: 80 mg; Mn: 80 mg; Cu: 10 mg; I: 0.7 mg; Se: 0.3 mg; Sodium monensin (Coban™ 40%, Elanco Animal Health, Division of Eli Lilly and Company): 0.275 g

[b] Other treatments were composed by partial or total kaolin replacement with L-VAL 99% and/or L-ILE 99%

**Table 2.** Calculated and analyzed crude protein and total amino acids values of experimental diets, %

| **Calculated** | Dig. AA to LYS, % | | | | | | |
|---|---|---|---|---|---|---|---|
| | VAL 70 | VAL 75 | VAL 80 | VAL 70 | VAL 70 | VAL 75 | VAL 80 |
| Crude protein | 18.70 | 18.75 | 18.79 | 18.72 | 18.75 | 18.77 | 18.84 |
| Methionine+Cysti | | | | 0.91 | | | |
| Lysine | | | | 1.17 | | | |
| Threonine | | | | 0.80 | | | |
| Valine | 0.86 | 0.92 | 0.98 | 0.86 | 0.86 | 0.92 | 0.98 |
| Isoleucine | 0.77 | 0.77 | 0.77 | 0.80 | 0.84 | 0.80 | 0.84 |
| Arginine | | | | 1.21 | | | |
| Triptophan | | | | 0.22 | | | |
| Leucine | | | | 1.59 | | | |
| **Analyzed** | | | | | | | |
| Crude protein | 18.50 | 18.00 | 18.60 | 19.10 | 18.90 | 19.00 | 18.60 |
| Methionine+Cysti | 0.91 | 0.92 | 0.90 | 0.92 | 0.89 | 0.90 | 0.94 |
| Lysine | 1.16 | 1.20 | 1.17 | 1.20 | 1.21 | 1.19 | 1.19 |
| Threonine | 0.78 | 0.81 | 0.79 | 0.82 | 0.78 | 0.80 | 0.80 |
| Valine | 0.86 | 0.90 | 0.99 | 0.87 | 0.87 | 1.00 | 0.94 |
| Isoleucine | 0.77 | 0.75 | 0.79 | 0.80 | 0.84 | 0.79 | 0.80 |
| Arginine | 1.22 | 1.21 | 1.25 | 1.27 | 1.27 | 1.27 | 1.19 |
| Leucine | 1.60 | 1.55 | 1.61 | 1.58 | 1.59 | 1.60 | 1.52 |

**Table 3.** Feed intake, body weight gain and feed conversion ratio of male broilers fed diets having different valine and isoleucine to lysine digestible ratios from 14 to 35 days of age

| Digestible ratios to LYS, % | | Feed intake, g | | | | Body weight gain, g | | | | Feed conversion | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VAL | ILE | 14-21d | 21-28d | 28-35d | 14-35d | 14-21d | 21-28d | 28-35d | 14-35d | 14-21d | 21-28d | 28-35d | 14-35d |
| 70 | 65 | 719 | 1,096 | 1,511 | 3,323 | 484$^{b}$ | 712$^{b}$ | 889 | 2,084$^{b}$ | 1.486$^{ab}$ | 1.541 | 1.700 | 1.595 |
| 75 | 65 | 725 | 1,127 | 1,564 | 3,410 | 501$^{ab}$ | 751$^{a}$ | 891 | 2,142$^{a}$ | 1.449$^{a}$ | 1.502 | 1.756 | 1.592 |
| 80 | 65 | 737 | 1,132 | 1,539 | 3,403 | 502$^{ab}$ | 756$^{a}$ | 875 | 2,133$^{ab}$ | 1.466$^{ab}$ | 1.498 | 1.761 | 1.595 |
| 70 | 68 | 736 | 1,143 | 1,541 | 3,418 | 502$^{ab}$ | 754$^{a}$ | 888 | 2,144$^{a}$ | 1.467$^{ab}$ | 1.517 | 1.736 | 1.595 |
| 70 | 71 | 744 | 1,118 | 1,543 | 3,402 | 495$^{ab}$ | 752$^{a}$ | 889 | 2,137$^{ab}$ | 1.503$^{b}$ | 1.486 | 1.737 | 1.592 |
| 75 | 68 | 736 | 1,138 | 1,526 | 3,397 | 508$^{a}$ | 740$^{a}$ | 875 | 2,123$^{ab}$ | 1.449$^{a}$ | 1.539 | 1.745 | 1.600 |
| 80 | 71 | 724 | 1,111 | 1,527 | 3,353 | 489$^{ab}$ | 744$^{a}$ | 890 | 2,123$^{ab}$ | 1.481$^{ab}$ | 1.495 | 1.716 | 1.580 |
| S.E.M. | | 3.05 | 4.78 | 6.40 | 10.82 | 1.99 | 3.49 | 3.42 | 5.44 | 0.005 | 0.006 | 0.008 | 0.003 |
| P< | | 0.32 | 0.07 | 0.50 | 0.16 | 0.01 | 0.01 | 0.77 | 0.05 | 0.02 | 0.08 | 0.41 | 0.71 |

$^{a, b}$ Means with different letters in the same column are different (Tukey, P≤0.05)

**Table 4.** Carcass, abdominal fat, and commercial cuts yields of male broilers with diets varying valine and isoleucine to lysine ratios at 35 days of age, %

| Digestible ratios to LYS, % | | Carcass | Abdominal fat | Breast meat[1] | Leg quarters[2] | Wings |
|---|---|---|---|---|---|---|
| VAL | ILE | | | | | |
| 70 | 65 | 74.7 | 1.88 | 29.8 | 32.3 | 11.1 |
| 75 | 65 | 74.1 | 1.89 | 29.2 | 32.8 | 11.0 |
| 80 | 65 | 74.4 | 1.82 | 29.4 | 32.5 | 11.1 |
| 70 | 68 | 74.8 | 1.80 | 29.3 | 32.7 | 11.0 |
| 70 | 71 | 74.3 | 1.88 | 29.1 | 32.3 | 11.0 |
| 75 | 68 | 74.2 | 1.87 | 29.4 | 32.5 | 11.1 |
| 80 | 71 | 74.1 | 1.91 | 29.2 | 32.5 | 11.1 |
| S.E.M. | | 0.70 | 0.186 | 0.52 | 0.46 | 0.21 |
| *P-value* | | 0.18 | 0.87 | 0.10 | 0.32 | 0.69 |

[1] *Pectoralis major* plus *P. minor*

[2] Thighs plus drumsticks

# CAPÍTULO III[1]

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[1] Artigo submetido à revista Poultry Science em Fevereiro de 2010

# Digestible Valine Requirements of Cobb × Cobb 500 Male Broilers From Twenty-One to Forty-Two Days of Age

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## ABSTRACT

Valine is the fourth limiting amino acid (AA) for broilers fed diets having ingredients from vegetable origin. The present study evaluated live performance and processing yields of broilers fed corn-soybean meal diets with graded levels of L-VAL. One thousand five hundred and seventy-five male Cobb × Cobb 500 broilers were fed a corn-soybean meal diet with 23.2% CP; 1.25 % digestible (dig) LYS; 0.94% dig VAL; 0.92% Ca; and 0.46% non-pytate P, from placement to 21 d of age. At 21 d of age, broilers were fed 7 experimental diets until 42 d of age with 9 replicate pens (25 birds per pen). The basal diet was formulated to contain 0.64% dig VAL and were all other essential AA at least 105% of their requirements. Valine was added to the basal diet at the expense of cornstarch to create 7 digestible VAL concentrations ranging from 0.64 to 0.98% in increments of 0.06%. The basal diet negatively affected body weight gain (BWG), and feed conversion ratio (FCR). No differences among dietary treatments were observed for parts yields. Digestible VAL requirements were 0.82 and 0.81, and 0.81 and 0.76 for BWG and FCR, respectively when using regression and broken-line models, respectively.

# INTRODUCTION

Dietary amino acid (**AA**) supplements (MET, LYS, and THR) are used extensively in broiler production to lower diet cost without compromising the efficiency of growth. The inclusion of VAL to diets fed to broilers may further reduce production costs without altering performance objectives. Valine is considered the 4th limiting AA for broilers fed diets containing major ingredients only from vegetable origin (Kidd and Hackenhaar, 2005; Corzo et al., 2007). Valine deficiency results in decreased body weight gain (**BWG**), poor feed conversion, and reduced meat yields, as well as legs and feathers abnormalities (Anderson and Warnick, 1967; Robel, 1977; Farran and Thomas, 1992a,b; Corzo et al., 2004). Digestible (**dig**) VAL requirements estimates are limited for the modern broiler.

Corzo et al. (2008) evaluated dig VAL requirement of Ross × Ross 308 male broilers from 0 to 42 d of age. Determined dig VAL requirements were 0.91, 0.86, and 0.78% from 0 to 14, 14 to 28, and 28 to 42 d of age, respectively. From 28 to 42 d of age, dig VAL requirements ranged from 0.75 to 0.78% with growth responses having a higher need for VAL than meat yield estimates. Corzo et al. (2007) examined the dig VAL requirement of Ross × Ross 708 male broilers from 21 to 42 d of age and found that the values for BWG ranged from 0.69 to 0.74%. The VAL requirements for increased BWG were higher than those for increased breast meat yield.

Broiler strains have distinct growth curves, and it is expected that they have different nutrient requirements (Dozier et al., 2001, 2002). Studies estimating digestible VAL requirements of modern broilers have been mostly conducted with late-developing strains (Thornton et al., 2006; Corzo et al., 2007, 2008). Supposedly, requirements may be different with early-developing broilers due to differences in feed intake, growth rate, and carcass yield and composition. The present study was designed to determine the dig VAL requirement of male Cobb × Cobb 500 broilers from 21 to 42 d of age based on growth performance and carcass yields.

## MATERIALS AND METHODS

### *Broiler husbandry*

One thousand five hundred and seventy-five one-day-old Cobb × Cobb 500 male broiler chicks were placed in 63 pens (1.70 × 1.65 m) in an open-sided house having built up litter. Pens were equipped with a tube feeder, and a drinker line with 3 nipples. Temperature at placement was 32 °C being reduced at 0.5 ºC per day until 23 ºC and lighting was continuous to 14 d with natural day light being used thereafter. Water and feed were provided *ad libitum*. Birds were managed according to the directives of Ethics and Research Committee of the Universidade Federal do Rio Grande do Sul.

### *Treatments*

Broilers were fed a common corn-soybean meal mash diet from 1 to 21 d of age (3,020 kcal AME/kg; 23.2% CP; 1.25% dig LYS; 0.94% dig VAL; 0.92% Ca; 0.46% non-phytate P). Amino acid analyses were conducted for corn and soybean meal previously to the feed formulation using High Performance Liquid Chromatography auto analyzer according to 914.12 and crude protein values according to 954.01 Official Methods (AOAC, 1998). A basal diet with 0.33% of cornstarch and a summit diet with 0.33% of L-VAL were manufactured to contain 0.64 and 0.97% of dig VAL, respectively. Synthetic MET, crystalline LYS, THR, ILE, ARG and TRP were added to ensure that performance would not be limited (Emmert and Baker, 1997; Rostagno et al., 2005) (Table 1). These two mash diets were mixed at different proportions to produce other 5 treatments having intermediate VAL concentrations ranging from 0.70

to 0.92%, by 0.06% increments. Composite samples of dietary treatments were submitted to these same analyzes carried out for corn and soybean meal to ensure that formulated diets were in agreement with the calculated values, except to TRP (Table 2).

### ***Measurements***

The overall body weight of birds from at 21 d was 1,055 g. Feed intake, BWG, feed conversion ratio (**FCR**) corrected for the weight of dead birds, and the mortality were determined from 21 to 42 d. Feed intake data did not take in consideration any possibly feed wastage. At 42 d, 10 birds were randomly selected from each pen, fasted for 8 h, individually weighed, for on line processing. Slaughter followed electrical stunning at 45 V for 3 s. Birds were then bled for 3 min after jugular vein cut, scalded at 60 ºC for 45 s, and then had the feathers plucked. After manual evisceration, the carcasses were chilled in slush ice for 3 h. After chilling, carcasses with abdominal fat, lungs and kidneys, but without viscera and adjacent fats, feets, neck, and head were weighted. Abdominal fat were then removed from carcasses, and weighed. Carcasses were deboned to obtain weights of breast meat with skin (*Pectoralis major* plus *Pectoralis minor* muscles), thighs, drumsticks and wings with bone and skin, and cage.

### ***Statistical analyses***

Seven treatments with 9 replications each were distributed in a randomized complete block design. Pen was considered the experimental unit with pen location being the blocking factor. Mortality data were submitted to arcsine transformation prior to statistic analysis. Data were analyzed using the GLM procedure (SAS, 2001). Digestible VAL requirements were determined using: 1) Linear regression analysis when a significant ($P<0.05$) response occurred 95% of the plateau, and 2) Broken-line methodology (Robbins et al., 2006).

# RESULTS AND DISCUSSION

Analyzed Val in the experimental feeds followed a graded increasing sequence, however, Val analyzed values were higher than expected in the three first diets. Therefore, broilers may have received more dig Val than planned and this may explain the results obtained when birds were fed at 0.70% calculated dig Val.

Significant quadratic responses were observed for BWG and FCR (Figure 1 and 2). Estimations of digestible Val requirements following the quadratic equations for body weight gain and feed conversion were: 0.85% [$BWG = -1126.80\,(\text{dig Val})^2 + 2021.2892\,(\text{dig Val}) + 1246.4463$; $r^2 = 0.89$]; and 0.84% [$FCR = 0.70474\,(\text{dig Val})^2 - 1.24\,(\text{dig Val}) + 2.23534$; $r^2 = 0.91$]. Estimations using the broken-line methodology for the same responses were: 0.81% [$BWG = 2150.2 - 408.6\,(0.8106 - \text{dig Val})$; $r^2 = 0.92$]; and 0.80% [$FCR = 1.6921 + 0.2321\,(0.7972 - \text{dig Val})$; $r^2 = 0.88$]. Feed intake, mortality, and carcass yields were not affected by the dietary treatments (Table 3). General means for thighs, drumsticks, wings and cage yields were 12.8, 19.4, 10.3, and 23.4%, respectively.

In the present study, dig Val requirements were observed at 0.85 and 0.84% for BWG and FCR, respectively, but a valid equation to estimate carcass and breast meat yields requirements was not found. Corzo et al. (2007) reported dig Val requirements ranging from 0.69 to 0.74% for Ross 708 broilers from 21 to 42 d of age. Requirement estimates were determined at 0.74, 0.73, and 0.70% for BWG, total breast weight, and total breast yield, respectively. Corzo et al. (2008) reported dig Val requirements at 0.77, 0.78, 0.77, 0.75, and 0.75%, for BWG, feed intake, FCR, carcass weight, and total breast weight, respectively.

Digestible Val requirements for BWG and FCR were higher in the present study than in previous published research (Corzo et al., 2007, 2008). Rostagno et al. (2005)

reported that AA requirements were influenced by broiler growth rate. The BWG from 21 to 42 d of age was approximately 2.1 kg in the current research whereas it was 1.4 kg in the Corzo et al. (2007) study. Different strain crosses show distinct growth curves, and therefore, is expected that it have distinct nutrient requirements. The Cobb × Cobb 500 strain cross have an accelerated growth and respond better than Ross × Ross 308 to the higher dietary AA concentration with a higher breast meat and lower abdominal fat yields (Coneglian et al., 2010). As the plateau in the growth curve is reached is expected that muscle and bone accretion go lower and the fat tissue continues increasing. The increase in carcass fat content affects cuts yields negatively. In this way, for different body weights, differences between post-slaughter measures are expected. However, at a similar body weight, no differences between strain crosses are expected in carcass composition and quality. In this work, it became evident the higher development of birds in relation to this work. Thus, the highest recommendation of dig Val provided in the current study in relation to other researches carried out with Ross strain crosses makes sense. Amino density may also have contributed to differences with dig Val requirement estimates between studies. For example, the current research was designed to determine dig Val requirement, whereas other research was conducted to estimate a dig Val to dig Lys ratio (Corzo et al., 2007, 2008). Diet formulation to determine AA requirements utilizes a dig Lys concentration that will not limit growth performance, whereas designing a ratio study will utilize a dig Lys level that is sub-marginal to ensure that broilers do not over consume Lys so that an accurate ratio can be determined. Although some AA as Met, Lys, and yet Thr frequently exhibit effects on post-slaughter responses, less limiting AA as Val tend to not affect this responses, unless a very low level is used (Leclercq, 1998). This, possibly associated with the higher analyzed values than calculated of the three lower Val levels diets can explain the lack of effects in post-slaughter responses in the present study. In order, a dig Val level of 0.81% is recommended to maximize male Cobb × Cobb 500 broilers performance from 21 to 42 days of age.

## Acknowledgments

Grants from FAPERGS, Porto Alegre, RS, Brazil; CNPq, Brasília, DF, Brazil; and Ajinomoto Biolatina, São Paulo, SP, Brazil, are recognized.

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**Table 1.** Ingredient and nutrient composition of the experimental diets, % “as- is”[1]

| Ingredients | Basal | | Summit |
|---|---|---|---|
| | Without L-VAL | | 0.33% of L-VAL |
| Corn | | 67.03 | |
| Soybean meal 45.8% CP | | 23.91 | |
| Soybean oil | | 2.97 | |
| Dicalcium phosphate | | 2.05 | |
| Limestone | | 0.97 | |
| Sodium bicarbonate | | 0.73 | |
| Premix[2] | | 0.26 | |
| Choline chloride 75% | | 0.07 | |
| Salt | | 0.04 | |
| DL-MET 99% | | 0.42 | |
| L-LYS HCl | | 0.49 | |
| L-THR | | 0.20 | |
| L-ILE | | 0.18 | |
| L-ARG | | 0.31 | |
| L-TRP | | 0.04 | |
| L-VAL | - | | 0.33 |
| Cornstarch | 0.33 | | - |
| Calculated composition | | | |
| AME, kcal/kg | | 3,150 | |
| CP, % | 17.57 | | 17.83 |
| Ca, % | | 0.95 | |
| Non-phytate P, % | | 0.48 | |
| Na, % | | 0.23 | |
| Calculated true ileal digestible amino acids, % | | | |
| MET+CYS | | 0.85 | |
| LYS | | 1.10 | |
| THR | | 0.74 | |
| VAL | 0.64 | | 0.97 |
| ILE | | 0.76 | |
| ARG | | 1.16 | |
| TRP | | 0.21 | |
| His | | 0.41 | |
| LEU | | 1.28 | |
| Phe+Tyr | | 1.26 | |
| Total GLY+SER | | 1.42 | |

[1] Values standing done in the center of the table are common for all diets

[2] Supplied per kg of feed: Vitamin A: 8,000 IU; Vitamin $D_3$: 2,000 IU; Vitamin E: 30 IU; Vitamin $K_3$: 2 mg; Thiamine: 2 mg; Riboflavin: 6 mg; Pyridoxine: 2.5 mg; Vitamin $B_{12}$: 0.012 mg; Pantothenic acid: 15 mg; Niacin: 35 mg; Folacin: 1 mg; Biotin: 0.08 mg; Fe: 40 mg; Zn: 80 mg; Mn: 80 mg; Cu: 10 mg; I: 0.7 mg; Se: 0.3 mg; Monensin sodium (Coban$^{TM}$ 40%, Elanco Animal Health, Division of Eli Lilly and Company): 0.275 g

**Table 2**. Calculated and analyzed composition for crude protein and total amino acids of the experiment diets, % "as-is"

| CP or total amino acids | Digestible VAL, %[1] | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0.64 | 0.70 | 0.75 | 0.81 | 0.86 | 0.92 | 0.97 |
| | Calculated values[2] | | | | | | |
| CP | 17.57 | 17.61 | 17.66 | 17.70 | 17.75 | 17.79 | 17.83 |
| MET+CYS | | | | 0.90 | | | |
| LYS | | | | 1.17 | | | |
| THR | | | | 0.82 | | | |
| VAL | 0.72 | 0.78 | 0.83 | 0.89 | 0.94 | 1.00 | 1.05 |
| ILE | | | | 0.82 | | | |
| ARG | | | | 1.21 | | | |
| TRP | | | | 0.23 | | | |
| LEU | | | | 1.38 | | | |
| | Analyzed values | | | | | | |
| CP | 17.43 | 17.56 | 17.73 | 17.78 | 17.87 | 17.90 | 17.97 |
| MET+CYS | 0.99 | 1.06 | 1.01 | 0.99 | 1.06 | 1.09 | 1.07 |
| LYS | 1.18 | 1.17 | 1.17 | 1.15 | 1.18 | 1.17 | 1.13 |
| THR | 0.83 | 0.81 | 0.78 | 0.79 | 0.78 | 0.79 | 0.78 |
| VAL | 0.80 | 0.83 | 0.87 | 0.89 | 0.96 | 1.00 | 1.05 |
| ILE | 0.84 | 0.88 | 0.86 | 0.82 | 0.81 | 0.82 | 0.82 |
| ARG | 1.43 | 1.37 | 1.38 | 1.37 | 1.32 | 1.34 | 1.34 |
| LEU | 1.45 | 1.46 | 1.43 | 1.39 | 1.39 | 1.38 | 1.37 |

[1] Obtained values correspond to total AA analyzed in ingredients multiplied by the digestibility coefficients presented by Rostagno et al. (2005)

[2] Values standing done in the center of the table are common for all diets

**Table 3.** Performance of Cobb × Cobb 500 broiler males fed graded increases on the VAL to LYS ratio from 21 to 42 d and post-slaughter yields at 42 days of age

| Digestible VAL level, % | BWG[1], g/bird | FCR[2], g/g | Feed intake, g | Mortality, % | Carcass and parts yields, % | | |
|---|---|---|---|---|---|---|---|
| | | | | | Carcass | Breast meat | Abdominal fat |
| 0.64 | 2,081$^{b}$ | 1.733$^{b}$ | 3,607 | 0.67 | 78.59 | 31.64 | 2.10 |
| 0.70 | 2,111$^{ab}$ | 1.704$^{ab}$ | 3,610 | 1.00 | 78.62 | 31.46 | 1.94 |
| 0.75 | 2,112$^{ab}$ | 1.709$^{ab}$ | 3,610 | 1.11 | 78.74 | 31.92 | 1.83 |
| 0.81 | 2,156$^{a}$ | 1.691$^{a}$ | 3,646 | 1.22 | 79.14 | 31.67 | 1.86 |
| 0.86 | 2,159$^{a}$ | 1.691$^{a}$ | 3,650 | 0.56 | 78.78 | 31.30 | 1.88 |
| 0.92 | 2,143$^{ab}$ | 1.691$^{a}$ | 3,624 | 1.00 | 78.68 | 31.32 | 1.85 |
| 0.97 | 2,149$^{ab}$ | 1.695$^{a}$ | 3,642 | 0.67 | 79.02 | 31.54 | 1.80 |
| Pooled SEM | 7.37 | 0.003 | 11.20 | 0.12 | 0.11 | 0.09 | 0.03 |
| ANOVA *P-value* | 0.02 | 0.01 | 0.77 | 0.74 | 0.81 | 0.62 | 0.13 |
| | | | | | | | |
| Regressions | | | | | | | |
| Linear *P-value* | 0.02 | 0.03 | - | - | - | - | - |
| Linear $r^2$*-value* | 0.70 | 0.64 | - | - | - | - | - |
| Quadratic *P-value* | 0.01 | 0.01 | - | - | - | - | - |
| Quadratic $r^2$*-value* | 0.89 | 0.91 | - | - | - | - | - |
| Broken-line $r^2$*-value* | 0.01 | 0.01 | - | - | - | - | - |
| | 0.92 | 0.88 | - | - | - | - | - |
| Requirements, % | | | | | | | |
| Quadratic regression[3] | | | | | | | |
| Broken-line | 0.85 | 0.84 | - | - | - | - | - |

[1] Body weight gain

[2] Feed conversion ratio

[3] 95% of the maximum or minimum value

**Figure 1.** Body weight gain of male broilers fed diets varying in digestible VAL from 21 to 42 d of age. Digestible VAL requirement was determined at 0.81% by broken-line analysis [BWG = 2,146 – 305.8 (0.81 – dig VAL level); $r^2 = 0.55$]. Quadratic regression [BWG = –1,185.19497 (dig VAL level)$^2$ + 2,048.06293 (dig VAL level) + 1,264.79868; $r^2 = 0.56$] estimated the dig VAL requirement at of 0.86% to maximize body weight gain, with 95% of this value (upper value) being 0.82%

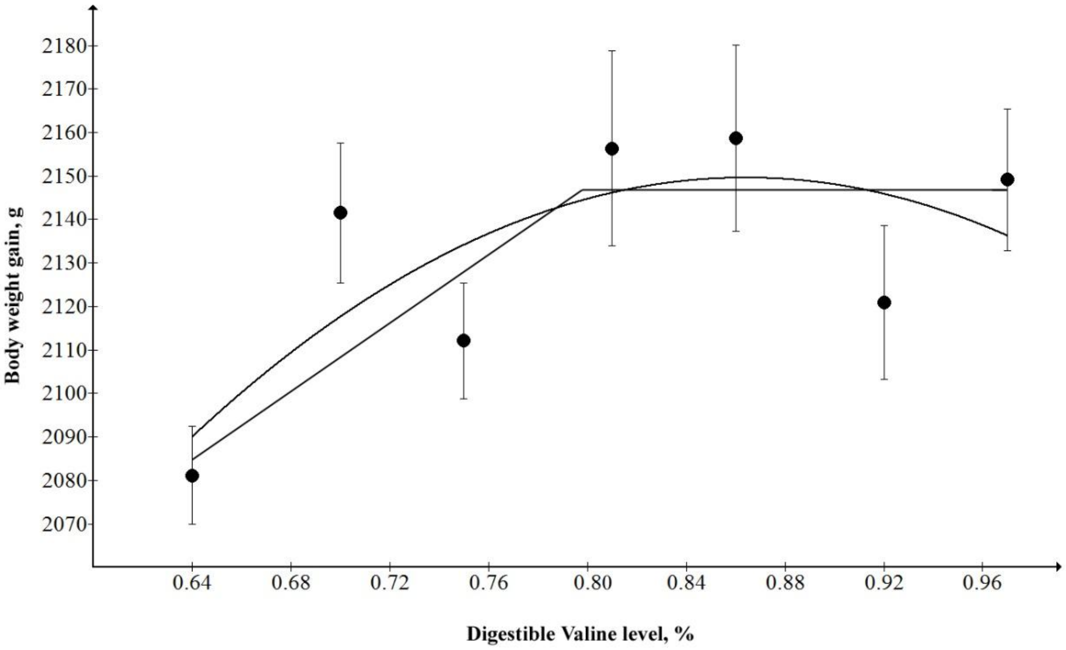
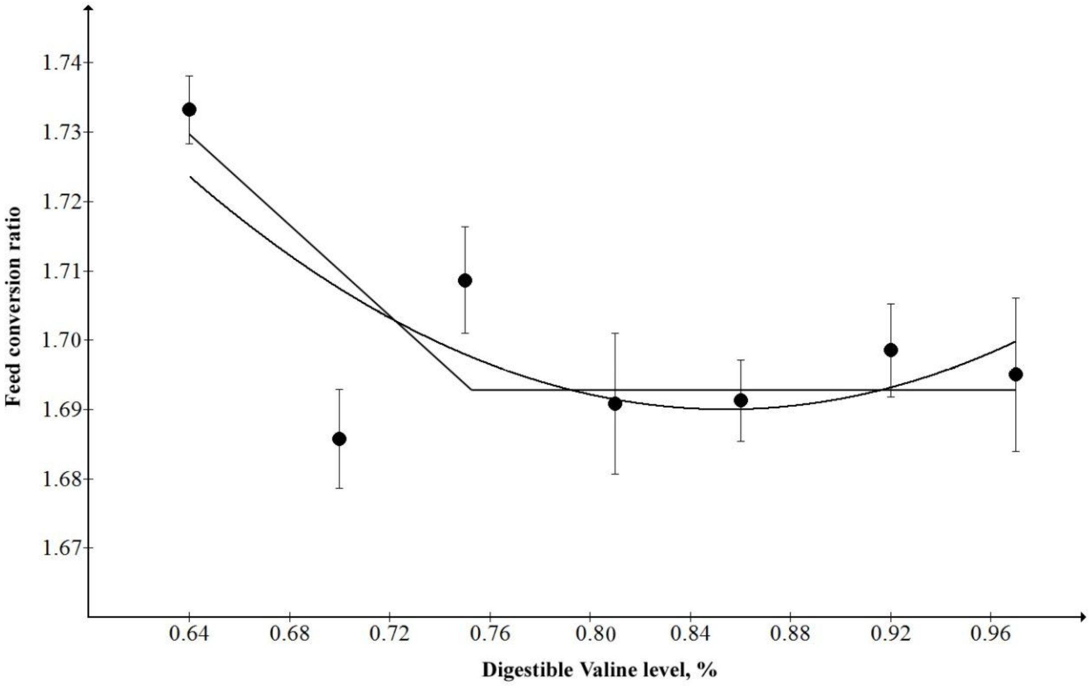


**Figure 2.** Feed conversion ratio of male broilers fed diets varying in digestible VAL from 21 to 42 d of age. Digestible VAL requirement determined at 0.76% by broken-line analysis [FCR = 1.6939 + 0.2423 (0.7598 - dig VAL level); $r^2 = 0.48$]. Quadratic regression [FCR $= 0.73365$ (dig VAL level)$^2$ – 1.25343 (dig VAL level) + 2.22534; $r^2 = 0.53$] estimated the dig VAL requirement at 0.85% to maximize FCR, with 95% of this value (lower value) being 0.81%



# CAPÍTULO IV[1]

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[1] Artigo submetido ao Journal of Applied Poultry Research em Novembro de 2009 e aprovado em Janeiro de 2010

# Broiler Responses to Reduced Protein Diets Supplemented with Valine, Isoleucine, Glycine and Glutamic Acid

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Primary Audience: Nutritionists, Researchers, Production Managers

Running title: VAL, ILE, GLY, and GLU in broiler diets

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## SUMMARY

Reduced performance is eventually observed when broilers are fed low protein diets even when industrial AA are provided to reach requirement levels. The reason for this detrimental effect is not precisely determined, but it is possible that non essential AA become limiting. The objective of this study was to evaluate the effects of individual or combined VAL, ILE, GLY and GLU supplementations at the same levels of these AA or CP content of a practical diet on live performance and meat yields of broilers. Two thousand and sixteen Ross × Ross 308 male broilers were fed 8 treatments with 9 replications (28 birds per pen) during a 42 d production period. Overall care of animals complied with animal welfare directives from Universidade Federal do Rio Grande do Sul. The control diet (Treatment 1) was formulated without CP restriction and maintaining a GLY + SER to LYS ratio of 155 or 158%; Other treatments, when not supplemented with L-GLU, had the CP content dependent of the AA to LYS fixed ratios in formulation, and this generated diets with lower crude protein contents than the control diet. Treatment 2 was formulated with L-VAL; Treatment 3 was formulated with L-VAL and GLY; Treatment 4 was formulated with L-VAL + L-GLU; Treatment 5 was formulated with L-VAL + GLY + L-GLU; Treatment 6 was formulated with L-VAL + L-ILE; Treatment 7 was formulated with L-VAL + L-ILE + GLY; Treatment 8 was formulated with L-VAL + L-ILE + GLY + L-GLU. Dietary CP varied with feeding phase and treatment, but reached 2.5 percentage points as the greatest obtained reduction. Glycine and GLU supplementation improved BW gain and feed conversion. Benefits in growth due to GLY supplementation were mainly observed in early phases of growth. Conversely, broilers fed diets supplemented with GLU exhibited advantages in growth throughout experimentation. Additions of ILE, GLU, and GLY increased breast meat yield compared with broilers fed diets supplemented with only L-VAL. Isoleucine supplementation improved breast meat yield. Good broiler growth and meat yield can be obtained with GLY and GLU supplementation in reduced CP diets, which infers a need for nitrogen for the synthesis of non-essential amino acids.

**Key words:** amino acid, broiler growth, crude protein

## DESCRIPTION OF PROBLEM

Investigations conducted with low CP diets fed to broilers have generally led to poor performance when comparison is made with broilers having adequate amino acids (AA) and non-essential nitrogen [1-3]. However, when formulation is based on an AA basis [4], a reasonable reduction in CP may produce acceptable growth performance [5]. Commercial availability of industrial AA has reduced dietary cost without compromising broiler performance. Threonine usage in broiler diets is a common practice and its inclusion is often dictated by corn, soybean meal, and fat prices. Diet costs can be eventually reduced with L-THR supplementation when large price spreads occur between soybean meal and fat.

L-Valine supplementation could potentially provide further reductions in diet cost without negatively influencing broiler performance. The order of limitation with VAL and ILE is dependent on ingredients used in diet formulation [6,7]. For example, VAL is the fourth limiting AA with corn and soybean meal being the primary ingredients [6, 8,9], whereas when animal protein meals are included in the diet VAL and ILE may be co-limiting [10]. L-Valine supplementation has not yielded strong evidence to provide it as a commercially available supplement [11]. Inadequacy of non-essential AA may limit performance when low CP diets containing L-VAL are fed.

Glycine has been shown to limit broiler performance in starter diets formulated without animal by-products [12] because its rate of endogenous synthesis cannot support maximum growth [13]. Glycine functions to support synthesis of uric acid and excretion of nitrogen [14,15]. The requirement for GLY seems to be higher in low CP diets than in high CP diets [16,17]. Glutamic acid has been included in the diet to provide a nitrogen source for synthesis of non- essential AA. However, most of the studies with GLU addition with low CP diets have not been successful in reproducing similar performance compared with broilers fed diets having higher CP [1,17,18].

Research is warranted on the feasibility of L-VAL supplemented diets on broiler growth and meat yield. The addition of other than the three first limiting AA to corn-soybean meal diets containing L-VAL may improve performance of broilers. The objective of this study was to evaluate the effects of individual or combined VAL, ILE, GLY and GLU supplementations at the same levels of these AA or CP content of a practical diet on live performance and meat yields of broilers.

## MATERIALS AND METHODS

### *Bird Husbandry*

Two thousand and sixteen 1-d-old Ross × Ross 308 male broiler chicks were randomly distributed in 72 pens (1.70 × 1.65 m; 28 birds per pen). Each pen had reused pine shavings after one flock and was equipped with 1 tube feeder and 3 nipple drinkers. Chicks were vaccinated for Infectious Bronchitis and Marek´s disease at the hatchery. Temperature was maintained at 32 ºC at placement and gradually reduced to ensure comfort using a thermostatically controlled heater, fans and foggers. Birds were reared under a continuous lighting program from placement to 14 d and then it was gradually reduced to a 12:12 h L:D lighting schedule. Feed was provided in mash form and birds had free access to feed and water. Amino acid analyses were conducted for corn and soybean meal prior to feed formulation and on samples of experimental diets using accepted methodology [19]. Digestible AA values for corn and soybean meal were calculated using digestibility coefficients [20] and analyzed total AA composition. Calculated digestible AA values for corn and soybean meal were used in diet formulation.

### *Treatments*

Treatments were distributed in a 4 phase feeding program: 1 to 7, 8 to 21, 22 to 35 and 36 to 42 d of age. A corn-soybean meal all vegetable control diet (Treatment1) was formulated without CP restriction to meet or exceed Ideal AA recommendations [20]. Treatments 2 to 8 were formulated with individual or combined inclusions of industrial VAL, ILE, GLY and/or GLU to meet these same AA and/or CP levels of the control diet as showed in Table 1. These treatments, when not supplemented with L-GLU, had the CP content dependent of the AA to LYS fixed ratios in formulation, and this generated diets with lower crude protein contents than the control diet. Ingredient and nutrient composition of experimental diets are provided in Tables 2, 3, 4 and 5. These diets were individually mixed in 350 kg batches in a horizontal mixer, afterwards minor ingredients and corn pre-mix in 50 kg batches. Similar analyses were conducted on all experimental diets. Calculated and analyzed total AA and CP of diets were in good agreement (Table 6).

### *Measurements*

Birds were not submitted to any unnecessary discomfort and followed directives of Ethics and Research Committee of the Universidade Federal do Rio Grande do Sul.

Body weight gain, feed intake and feed conversion were determined from 1 to 7, 7 to 21, 21 to 35 and 35 to 42 d of age. Mortality was recorded daily and causes of death were classified as sudden death, ascites, leg abnormalities and other. At 42 d, 10 birds per pen were randomly selected and subjected to an 8 h pre-slaughter fasting but had access to water. Subsequently, birds were individually weighed, hung on shackles, stunned by electric narcosis, bled for 3 min through a jugular vein cut until death, scalded at 60 ºC for 45 s and then de-feathered. Processing followed with manual evisceration and chilling whole carcasses in slush ice for 3 h after which carcasses were hung for 3 min to remove water excess. Carcasses and abdominal fat were weighed. Then, carcasses were deboned by industry personnel to obtain breast meat (*Pectoralis major* plus *Pectoralis minor*), thighs, drumsticks, wings and cage weights. Yields of breast meat (*Pectoralis major* plus *Pectoralis minor* muscles), thighs, drumsticks, wings and cage were determined. Carcass weights were expressed as a proportion to live BW whereas meat parts were expressed relative to the whole carcass.

### *Statistical Analysis*

Data were evaluated by the analysis of variance procedure using a randomized complete block design [21] with pen location within the experimental house being the blocking factor. Eight treatments with 9 replications were used and each pen was an experimental unit. Significant differences were separated using Tukey's multiple range tests. Mortality data were subjected to arcsine transformation for statistic analysis. Statistical significance was considered $P \leq 0.05$.

## RESULTS

### *Live Performance*

Live performance data is presented on Table 7. From 1 to 7 d of age, only broilers fed reduced CP diets supplemented with VAL and ILE had lower ($P \leq 0.05$) BW gain compared to broilers provided diets supplemented with VAL, VAL + GLY, VAL + GLU, VAL + ILE + GLY and VAL + ILE + GLY + GLU, but had the same BW compared with broilers fed the control diet or the diets supplemented with VAL and VAL + GLY + GLU. Dietary treatments did not affect feed intake. Broilers fed diets supplemented with VAL + GLU, VAL + ILE + GLY, and VAL + ILE + GLY + GLU had better ($P \leq 0.05$) feed conversion compared with birds receiving diets containing VAL + ILE which had a similar feed conversion of birds fed the control diet and the diets supplemented with VAL + GLY and VAL + GLY + GLU.

From 1 to 21 d of age, dietary treatments did not alter BW gain or feed intake. Diets having added VAL + ILE + GLY exhibited similar feed conversion to the VAL + ILE treatment, which is in contrast to the previous period. Only birds fed diets supplemented with VAL and VAL + ILE + GLY had a similar feed conversion provided by the diet VAL + ILE. Other treatments had better feed conversions in relation to this diet. Broilers fed low CP diets supplemented with VAL, VAL + GLY, VAL + GLU, VAL + GLY + GLU, VAL + ILE + GLY and VAL + ILE + GLY + GLU had a similar feed conversion compared with the bird fed the Control diet supplemented with MET, LYS and THR.

From 1 to 35 and from 1 to 42 d of age dietary treatments did not alter BW gain or feed intake. Broilers fed diets supplemented with VAL + ILE and VAL + ILE + GLY had poorer feed conversion compared with the Control treatment or VAL + GLU fed birds from 1 to 35 d of age. Broilers fed low CP diets supplemented with VAL, VAL + GLY, VAL + GLU, VAL + GLY + GLU and VAL + ILE + GLY + GLU had a similar feed conversion compared with the bird fed the Control diet supplemented with MET, LYS and THR. Broilers fed the Control diet, VAL + GLU and VAL + ILE + GLY + GLU supplemented diets had improved feed conversion compared with diets supplemented with VAL + ILE in birds from 1 to 42 d of age whatever did not differ from the broilers fed with diets containg VAL, VAL + GLY, VAL + GLY + GLU or VAL + ILE + GLY.

Dietary treatments did not influence the incidence of mortality (Table 8).

### *Carcass measurements*

Dietary treatments did not affect carcass, wings or cage yields (Table 9). Only broilers fed the VAL + ILE + GLY + GLU supplemented diet had lower abdominal fat percentage than birds fed diets having added VAL + ILE. All other treatments resulted in similar abdominal fat percentage compared with VAL + ILE + GLY + GLU or VAL + ILE. Supplementing the diet with VAL + ILE + GLY + GLU increased breast meat yield compared with broilers fed diets having only added VAL, but the birds fed this diet had similar breast meat yield compared with all other treatments. All other treatments resulted in equal breast meat yield compared with birds fed diets supplemented with VAL + ILE + GLY + GLU In contrast, birds fed diets supplemented with VAL and VAL + GLY had similar leg quarter yields to broilers given the control diet. Broilers receiving control diet had higher leg quarters yield than all treatments except those birds fed VAL or VAL + GLY supplemented diets.

## DISCUSSION

Adding industrial MET, LYS and THR without fixing CP level on formulation lowers concentration of less limiting AA which can result in sub-marginal performance. This occurs due to the reduction of the intact protein source in diet. The next limiting AA should determine the level of CP. The reduction in CP and less limiting AA with the diet supplemented with VAL + ILE treatment led to poor cumulative feed conversion. One possible explanation is that the reduced CP diets did not contain adequate amounts of non-essential AA or nitrogen. Glycine supplementation can be recommended for the initial stages, i.e. up to 21 d of age based on feed conversion responses. Glutamic acid supplementation produced similar responses with cumulative feed conversion compared with the control fed birds.

Broilers fed the control diet exhibited better feed conversion compared with birds fed diets supplemented with VAL + ILE throughout experimentation but did not differ compared with the other amino acids supplemented diets. Optimum broiler performance is dependent on less limiting AA or non-essential nitrogen, particular for the young chick from 1 to 7 d of age. The amount of less limiting AA and/or non-essential nitrogen affected abdominal fat percentage. Nitrogen excretion is an energy dependent process [22], and broilers fed diets with excess nitrogen will result in less energy for fat deposition [23]. In the present research, the diet supplemented with VAL + ILE did not alter breast meat yield. ILE adequacy is known to influence breast meat yield [7].

Non-essential AA supplementation to low CP diets has been shown not to improve broiler performance [1,24-26]. However, Dean et al. [15] concluded that the addition of GLY to an AA-supplemented 16% CP diet supported growth and feed efficiency equal to broilers fed a 22% CP diet. Corzo et al. [27] also found positive effects with non-essential AA supplementation to diets with reduced CP content. Deschepper and Groote [28] reported that broilers fed a reduced CP diet supplemented with non-essential and essential AA grew as well as those fed a high-CP diet, but not when essential AA were included to the low CP diet. Moran and Stilborn [18] reported a response to GLU supplementation of reduced CP diets for broilers during the starter period. Broiler chicks need both essential AA and non-essential AA supplementation with low CP diets. Glycine may be utilized more efficiently than GLU [28] when supplemented to low CP diets fed to young chicks. Essentially, differences in evaluated responses attributed to these two amino acids can reside in their metabolic route and in the age of broilers. Glutamic acid is known as a nitrogen source to form other amino acids, whereas its carbon skeleton is utilized to form carbohydrates. However, GLY is directly associated to nitrogen excretion because it is basically utilized in uric acid composition. Therefore, a higher protein diet typically required in the starter phases potentially leads to a higher proportion needs for nitrogen excretion and requires more GLY to form uric acid. This may explain a higher need for GLY in starter phases and the lower requirement of this amino acid in subsequent phases.

Han et al. [29] observed that low protein diets fortified with MET, LYS, THR, VAL, ARG and amino nitrogen from GLU, resulted in bird performance comparable to a high protein diet. In the present research, additions of L-VAL, L-ILE, GLY and L-GLU to the same levels supplied by a practical diet provided similar broiler growth rates. We suggest that GLY and GLU levels were sufficient to meet nitrogen needs for non-essential AA synthesis. Amino acid supplementation of low CP diets has not always resulted in bird performance comparable to those fed higher CP diets [30,31]. Discrepancies between the results may be attributed to the severity of dietary protein reduction, to the age of broilers, to the amino acid basis (as total or digestible) used in formulation and also to dietary designs.

## CONCLUSIONS AND APPLICATIONS

1. Broilers fed diets supplemented with industrial amino acids had the same cumulative body weight gain, feed intake and feed conversion, and carcass, wings, cage and abdominal fat compared with the birds fed the Control diet, except the cumulative feed conversion of birds fed diets supplemented with VAL + ILE.

2. Higher cumulative feed conversion of broilers fed diets supplemented only with VAL + ILE was a consequence of poor performance occurring from 1 to 7 and 1 to 21 d of age, which provides evidence for adequate amino nitrogen being needed during the early growth phases.

## ACKNOWLEDGMENTS

Grants from CNPq, FAPERGS, and Ajinomoto Biolatina are recognized.

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**Table 1.** Outline of dietary treatments (T1-T8) fed to male broilers throughout a 42 d production period[1]

| AA supplementation | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|
| L-VAL | – | + | + | + | + | + | + | + |
| L-ILE | – | – | – | – | – | + | + | + |
| GLY | – | – | + | – | + | – | + | + |
| L-GLU | – | – | – | + | + | – | – | + |

[1] DL-MET, L-LYS and L-THR were supplemented in all diets; other amino acids shown were supplemented to obtain the same ratio with LYS and/or crude protein of the control diet; – Not supplemented; + Supplemented.

**Table 2.** Ingredient and nutritional composition of the experimental diets (T1-T8) fed to male broilers from 1 to 7 d of age

| Ingredients, % | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|
| Corn | 44.32 | 48.53 | 48.33 | 45.52 | 45.67 | 52.60 | 52.21 | 47.11 |
| Soybean meal 48% CP | 47.29 | 43.51 | 43.53 | 43.83 | 43.82 | 39.81 | 39.85 | 40.38 |
| Soybean oil | 4.10 | 3.33 | 3.38 | 3.61 | 3.63 | 2.52 | 2.62 | 3.09 |
| Monodicalcium phosphate | 1.65 | 1.66 | 1.66 | 1.67 | 1.67 | 1.68 | 1.68 | 1.69 |
| Calcium carbonate | 1.27 | 1.28 | 1.28 | 1.27 | 1.27 | 1.29 | 1.29 | 1.28 |
| Sodium chloride | 0.51 | 0.42 | 0.42 | 0.42 | 0.42 | 0.33 | 0.32 | 0.32 |
| Sodium bicarbonate | 0.01 | 0.14 | 0.14 | 0.15 | 0.15 | 0.28 | 0.28 | 0.29 |
| Additives[1] | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| DL-MET 99% | 0.33 | 0.36 | 0.36 | 0.36 | 0.36 | 0.39 | 0.39 | 0.40 |
| L-LYS 78% | 0.14 | 0.25 | 0.25 | 0.25 | 0.25 | 0.36 | 0.36 | 0.35 |
| L-THR 98.5% | 0.06 | 0.11 | 0.11 | 0.11 | 0.11 | 0.16 | 0.16 | 0.16 |
| L-VAL 98.5% | - | 0.06 | 0.06 | 0.06 | 0.06 | 0.12 | 0.12 | 0.12 |
| L-ILE 98.5% | - | - | - | - | - | 0.12 | 0.12 | 0.12 |
| GLY 97% | - | - | 0.13 | - | 0.13 | - | 0.25 | 0.26 |
| L-GLU 99.4% | - | - | - | 2.40 | 2.12 | - | - | 4.07 |
| Premixes[2] | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| Choline 75% | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 |
| Nutrients, energy and electrolytic balance, % or otherwise noted | | | | | | | | |
| CP | 26.20 | 24.90 | 25.04 | 26.20 | 26.20 | 23.70 | 23.99 | 26.20 |
| AME, kcal/kg | 2,950 | | | | | | | |
| Ca | 0.94 | | | | | | | |
| Non-phytate P | 0.47 | | | | | | | |
| Na+K-Cl, mEq/kg | 250 | | | | | | | |
| Choline, ppm | 1,750 | | | | | | | |
| Digestible LYS | 1.33 | | | | | | | |
| Digestible amino acid ratios to LYS, % | | | | | | | | |
| MET+CYS | 71 | | | | | | | |
| THR | 65 | | | | | | | |
| VAL | 75 | | | | | | | |
| ILE | 69 | 65 | 65 | 65 | 65 | 69 | 69 | 69 |
| TRP | 22 | 21 | 21 | 21 | 21 | 19 | 19 | 19 |
| ARG | 120 | 113 | 113 | 113 | 113 | 105 | 105 | 105 |
| MET | 47 | 48 | 48 | 49 | 48 | 49 | 49 | 50 |
| LEU | 133 | 127 | 127 | 126 | 126 | 120 | 120 | 119 |
| His | 44 | 42 | 42 | 42 | 42 | 40 | 40 | 39 |
| Phe | 84 | 79 | 79 | 79 | 79 | 74 | 74 | 74 |
| Phe+Tyr | 144 | 136 | 136 | 135 | 135 | 127 | 127 | 127 |
| GLY+SER | 155 | 146 | 155 | 146 | 155 | 138 | 155 | 155 |

[1] Adsorbent (MT.x +, Olmix S.A.): 0.1%; Sodium monensin (Coban™ 40%, Elanco Animal Health, Division of Eli Lilly and Company): 0.0275%; Bacitracin methylene disalicilate (BMD 11%, Alpharma do Brasil Ltda.): 0.05%; Colistin sulphate 8% (Indukern do Brasil Química Ltda.): 0.0125%.

[2] Supplied per kg of diet: Vitamin A: 9,800 IU; Vitamin $D_3$: 2,520 IU; Vitamin E: 70 IU; Vitamin $K_3$: 3 mg; Thiamine: 2.5 mg; Riboflavin: 7 mg; Pyridoxine: 4 mg; Vitamin $B_{12}$: 0.025 mg; Pantothenic acid: 12 mg; Niacin: 50 mg; Folacin: 1.5 mg; Biotin: 0.15 mg; Phytase: 0.14 g; Fe: 50 mg; Zn: 50 mg; Mn: 80 mg; Cu: 10 mg; I: 1 mg; Co: 1 mg; Se: 0.3 mg.

**Table 3.** Ingredient and nutritional composition of the experimental diets (T1-T8) fed to male broilers from 8 to 21 d of age

| Ingredients, % | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|
| Corn | 54.14 | 57.02 | 56.88 | 54.94 | 55.04 | 60.35 | 60.04 | 56.12 |
| Soybean meal 48% CP | 38.48 | 35.88 | 35.90 | 36.10 | 36.09 | 32.75 | 32.79 | 33.19 |
| Soybean oil | 3.18 | 2.66 | 2.69 | 2.85 | 2.86 | 2.03 | 2.10 | 2.46 |
| Monodicalcium phosphate | 1.55 | 1.57 | 1.57 | 1.57 | 1.57 | 1.58 | 1.58 | 1.59 |
| Calcium carbonate | 1.22 | 1.23 | 1.23 | 1.22 | 1.22 | 1.24 | 1.24 | 1.23 |
| Sodium chloride | 0.27 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| Sodium bicarbonate | 0.32 | 0.41 | 0.41 | 0.42 | 0.42 | 0.52 | 0.53 | 0.53 |
| Additives[1] | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| DL-MET 99% | 0.27 | 0.29 | 0.29 | 0.29 | 0.29 | 0.31 | 0.31 | 0.32 |
| L-LYS 78% | 0.16 | 0.23 | 0.23 | 0.23 | 0.23 | 0.32 | 0.32 | 0.32 |
| L-THR 98.5% | 0.06 | 0.09 | 0.09 | 0.09 | 0.09 | 0.13 | 0.13 | 0.13 |
| L-VAL 98.5% | - | 0.04 | 0.04 | 0.04 | 0.04 | 0.09 | 0.09 | 0.09 |
| L-ILE 98.5% | - | - | - | - | - | 0.09 | 0.09 | 0.09 |
| GLY 97% | - | - | 0.09 | - | 0.09 | - | 0.19 | 0.20 |
| L-GLU 99.4% | - | - | - | 1.66 | 1.46 | - | - | 3.13 |
| Premixes[2] | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| Choline 75% | 0.04 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.06 |
| Nutrients, energy and electrolytic balance, % or otherwise noted | | | | | | | | |
| CP | 22.66 | 21.77 | 21.87 | 22.66 | 22.66 | 20.74 | 20.96 | 22.66 |
| AME, kcal/kg | 3,000 | | | | | | | |
| Ca | 0.88 | | | | | | | |
| Non-phytate P | 0.44 | | | | | | | |
| Na+K-Cl, mEq/kg | 250 | | | | | | | |
| Choline, ppm | 1,700 | | | | | | | |
| Digestible LYS | 1.15 | | | | | | | |
| Digestible amino acid ratios to LYS, % | | | | | | | | |
| MET+CYS | 71 | | | | | | | |
| THR | 65 | | | | | | | |
| VAL | 75 | | | | | | | |
| ILE | 69 | 65 | 65 | 65 | 65 | 69 | 69 | 69 |
| TRP | 22 | 21 | 21 | 21 | 21 | 19 | 19 | 19 |
| ARG | 119 | 113 | 113 | 113 | 113 | 105 | 105 | 105 |
| MET | 46 | 47 | 47 | 47 | 47 | 48 | 48 | 49 |
| LEU | 137 | 132 | 132 | 131 | 131 | 125 | 125 | 124 |
| His | 45 | 43 | 43 | 43 | 43 | 41 | 41 | 40 |
| Phe | 84 | 80 | 80 | 80 | 80 | 75 | 75 | 75 |
| Phe+Tyr | 144 | 138 | 138 | 137 | 137 | 129 | 129 | 129 |
| GLY+SER | 155 | 148 | 155 | 148 | 155 | 139 | 155 | 155 |

[1] Adsorbent (MT.x +, Olmix S.A.): 0.1%; Sodium monensin (Coban$^{\text{TM}}$ 40%, Elanco Animal Health, Division of Eli Lilly and Company): 0.0275%; Bacitracin methylene disalicilate (BMD 11%, Alpharma do Brasil Ltda.): 0.05%; Colistin sulphate 8% (Indukern do Brasil Química Ltda.): 0.0125%.

[2] Supplied per kg of diet: Vitamin A: 9,800 IU; Vitamin D$_3$: 2,520 IU; Vitamin E: 70 IU; Vitamin K$_3$: 3 mg; Thiamine: 2.5 mg; Riboflavin: 7 mg; Pyridoxine: 4 mg; Vitamin B$_{12}$: 0.025 mg; Pantothenic acid: 12 mg; Niacin: 50 mg; Folacin: 1.5 mg; Biotin: 0.15 mg; Phytase: 0.14 g; Fe: 50 mg; Zn: 50 mg; Mn: 80 mg; Cu: 10 mg; I: 1 mg; Co: 1 mg; Se: 0.3 mg.

**Table 4.** Ingredient and nutritional composition of experimental diets (T1-T8) fed to male broilers from 22 to 35 d of age

| Ingredients, % | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|
| Corn | 55.06 | 57.41 | 57.30 | 55.66 | 55.74 | 61.97 | 61.63 | 57.18 |
| Soybean meal 48% CP | 36.56 | 34.38 | 34.39 | 34.56 | 34.55 | 30.10 | 30.14 | 30.60 |
| Soybean oil | 4.50 | 4.08 | 4.11 | 4.25 | 4.26 | 3.26 | 3.31 | 3.72 |
| Monodicalcium phosphate | 1.43 | 1.43 | 1.44 | 1.44 | 1.44 | 1.45 | 1.45 | 1.47 |
| Calcium carbonate | 1.14 | 1.15 | 1.15 | 1.14 | 1.14 | 1.16 | 1.16 | 1.15 |
| Sodium chloride | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.20 | 0.20 | 0.21 |
| Sodium bicarbonate | 0.39 | 0.47 | 0.47 | 0.47 | 0.47 | 0.62 | 0.62 | 0.63 |
| Additives[1] | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| DL-MET 99% | 0.24 | 0.26 | 0.26 | 0.26 | 0.26 | 0.29 | 0.29 | 0.30 |
| L-LYS 78% | 0.12 | 0.18 | 0.18 | 0.18 | 0.18 | 0.31 | 0.31 | 0.30 |
| L-THR 98.5% | 0.04 | 0.07 | 0.07 | 0.07 | 0.07 | 0.12 | 0.12 | 0.12 |
| L-VAL 98.5% | - | 0.03 | 0.04 | 0.04 | 0.04 | 0.10 | 0.10 | 0.11 |
| L-ILE 98.5% | - | - | - | - | - | 0.10 | 0.10 | 0.10 |
| GLY 97% | - | - | 0.07 | - | 0.08 | - | 0.22 | 0.23 |
| L-GLU 99.4% | - | - | - | 1.40 | 1.24 | - | - | 3.54 |
| Premixes[2] | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Choline 75% | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 |
| Nutrients, energy and electrolytic balance, % or otherwise noted | | | | | | | | |
| CP | 21.75 | 20.99 | 21.08 | 21.75 | 21.75 | 19.57 | 19.83 | 21.75 |
| AME, kcal/kg | 3,100 | | | | | | | |
| Ca | 0.82 | | | | | | | |
| Non-phytate P | 0.41 | | | | | | | |
| Na+K-Cl, mEq/kg | 250 | | | | | | | |
| Choline, ppm | 1,600 | | | | | | | |
| Digestible LYS | 1.07 | | | | | | | |
| Digestible amino acid ratios to LYS, % | | | | | | | | |
| MET+CYS | 72 | | | | | | | |
| THR | 65 | | | | | | | |
| VAL | 77 | | | | | | | |
| ILE | 70 | 67 | 67 | 67 | 67 | 70 | 70 | 70 |
| TRP | 22 | 21 | 21 | 21 | 21 | 19 | 19 | 19 |
| ARG | 122 | 116 | 116 | 116 | 116 | 105 | 105 | 105 |
| MET | 47 | 47 | 47 | 48 | 48 | 49 | 49 | 49 |
| LEU | 141 | 136 | 136 | 136 | 136 | 127 | 127 | 125 |
| His | 46 | 45 | 45 | 45 | 45 | 41 | 41 | 41 |
| Phe | 86 | 82 | 82 | 82 | 82 | 75 | 75 | 75 |
| Phe+Tyr | 148 | 142 | 142 | 142 | 142 | 130 | 130 | 129 |
| Total GLY+SER:LYS | 158 | 152 | 158 | 152 | 158 | 140 | 158 | 158 |

[1] Adsorbent (MT.x +, Olmix S.A.): 0.1%; Sodium monensin (Coban™ 40%, Elanco Animal Health, Division of Eli Lilly and Company): 0.0275%; Bacitracin methylene disalicilate (BMD 11%, Alpharma do Brasil Ltda.): 0.05%; Colistin sulphate 8% (Indukern do Brasil Química Ltda.): 0.0125%.

[2] Supplied per kg of diet: Vitamin A: 8,400 IU; Vitamin $D_3$: 2,160 IU; Vitamin E: 60 IU; Vitamin $K_3$: 2.57 mg; Thiamine: 2.14 mg; Riboflavin: 6 mg; Pyridoxine: 3.43 mg; Vitamin $B_{12}$: 0.02 mg; Pantothenic acid: 10.29 mg; Niacin: 42.86 mg; Folacin: 1.29 mg; Biotin: 0.13 mg; Phytase: 0.12 g; Fe: 40 mg; Zn: 40 mg; Mn: 64 mg; Cu: 8 mg; I: 0.8 mg; Co: 0.8 mg; Se: 0.26 mg.

**Table 5**. Ingredient and nutritional composition of experimental diets (T1-T8) fed to male broilers from 36 to 42 d of age

| Ingredients, % | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
|---|---|---|---|---|---|---|---|---|
| Corn | 57.70 | 59.69 | 59.59 | 58.21 | 58.28 | 63.99 | 63.68 | 59.64 |
| Soybean meal 48% CP | 33.87 | 32.02 | 32.03 | 32.18 | 32.17 | 27.99 | 28.02 | 28.44 |
| Soybean oil | 4.75 | 4.40 | 4.42 | 4.54 | 4.55 | 3.59 | 3.67 | 4.04 |
| Monodicalcium phosphate | 1.29 | 1.30 | 1.30 | 1.31 | 1.31 | 1.32 | 1.32 | 1.33 |
| Calcium carbonate | 1.06 | 1.07 | 1.07 | 1.07 | 1.07 | 1.08 | 1.08 | 1.08 |
| Sodium chloride | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.19 | 0.19 | 0.19 |
| Sodium bicarbonate | 0.48 | 0.54 | 0.55 | 0.55 | 0.55 | 0.69 | 0.69 | 0.69 |
| Additives[1] | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 | 0.18 |
| DL-MET 99% | 0.22 | 0.24 | 0.24 | 0.24 | 0.24 | 0.27 | 0.27 | 0.28 |
| L-LYS 78% | 0.13 | 0.18 | 0.18 | 0.18 | 0.18 | 0.30 | 0.30 | 0.29 |
| L-THR 98.5% | 0.04 | 0.06 | 0.06 | 0.06 | 0.06 | 0.11 | 0.11 | 0.12 |
| L-VAL 98.5% | - | 0.03 | 0.03 | 0.03 | 0.03 | 0.09 | 0.09 | 0.10 |
| L-ILE 98.5% | - | - | - | - | - | 0.09 | 0.09 | 0.09 |
| GLY 97% | - | - | 0.06 | - | 0.06 | - | 0.20 | 0.21 |
| L-GLU 99.4% | - | - | - | 1.18 | 1.04 | - | - | 3.22 |
| Premixes[2] | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| Choline 75% | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.04 | 0.04 |
| | | | | | | | | |
| Nutrients, energy and electrolytic balance, % or otherwise noted | | | | | | | | |
| CP | 20.64 | 20.00 | 20.08 | 20.64 | 20.64 | 18.66 | 18.89 | 20.64 |
| AME, kcal/kg | 3,150 | | | | | | | |
| Ca | 0.76 | | | | | | | |
| Non-phytate P | 0.38 | | | | | | | |
| Na+K-Cl, mEq/kg | 250 | | | | | | | |
| Choline, ppm | 1,500 | | | | | | | |
| Digestible LYS | 1.02 | | | | | | | |
| | | | | | | | | |
| Digestible amino acid ratios to LYS, % | | | | | | | | |
| MET+CYS | 72 | | | | | | | |
| THR | 65 | | | | | | | |
| VAL | 77 | | | | | | | |
| ILE | 70 | 67 | 67 | 67 | 67 | 70 | 70 | 70 |
| TRP | 22 | 21 | 21 | 21 | 21 | 19 | 19 | 19 |
| ARG | 121 | 116 | 116 | 116 | 116 | 105 | 105 | 105 |
| MET | 46 | 47 | 47 | 47 | 47 | 49 | 49 | 49 |
| LEU | 143 | 138 | 138 | 138 | 138 | 129 | 129 | 127 |
| His | 47 | 45 | 45 | 45 | 45 | 42 | 42 | 41 |
| Phe | 86 | 83 | 83 | 83 | 83 | 76 | 76 | 75 |
| Phe+Tyr | 148 | 143 | 143 | 143 | 143 | 131 | 131 | 130 |
| GLY+SER | 158 | 153 | 158 | 153 | 158 | 141 | 158 | 158 |

[1] Adsorbent (MT.x +, Olmix S.A.): 0.1%; Sodium monensin (Coban™ 40%, Elanco Animal Health, Division of Eli Lilly and Company): 0.0275%; Bacitracin methylene disalicilate (BMD 11%, Alpharma do Brasil Ltda.): 0.05%.

[2] Supplied per kg of diet: Vitamin A: 4,200 IU; Vitamin $D_3$: 1,080 IU; Vitamin E: 30 IU; Vitamin $K_3$: 1.29 mg; Thiamine: 1.07 mg; Riboflavin: 3 mg; Pyridoxine: 1.71 mg; Vitamin $B_{12}$: 0.01 mg; Pantothenic acid: 5.14 mg; Niacin: 21.43 mg; Folacin: 0.64 mg; Biotin: 0.06 mg; Phytase: 0.06 g; Fe: 30 mg; Zn: 30 mg; Mn: 48 mg; Cu: 6 mg; I: 0.6 mg; Co: 0.6 mg; Se: 0.13 mg.

**Table 6**. Calculated (C) and analyzed (A) values (%) of crude protein (CP) and total amino acids of experimental diets (T1-T8) fed to male broilers during a 42 d production period[1]

| | T1 | | T2 | | T3 | | T4 | | T5 | | T6 | | T7 | | T8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | A | C | A | C | A | C | A | C | A | C | A | C | A | C | A |
| 1 to 7 d | | | | | | | | | | | | | | | | |
| CP | 26.2 | 25.8 | 24.9 | 24.8 | 25.0 | 24.5 | 26.2 | 26.4 | 26.2 | 26.0 | 23.7 | 23.1 | 24.0 | 24.4 | 26.2 | 25.7 |
| LYS | 1.43 | 1.60 | 1.43 | 1.53 | 1.43 | 1.32 | 1.43 | 1.46 | 1.43 | 1.29 | 1.42 | 1.29 | 1.42 | 1.51 | 1.42 | 1.51 |
| VAL | 1.09 | 1.13 | 1.09 | 1.16 | 1.09 | 1.01 | 1.09 | 1.12 | 1.09 | 0.99 | 1.08 | 1.01 | 1.08 | 1.15 | 1.08 | 1.12 |
| ILE | 1.00 | 1.08 | 0.94 | 1.00 | 0.94 | 0.87 | 0.94 | 0.95 | 0.94 | 0.84 | 0.99 | 0.91 | 0.99 | 1.10 | 0.99 | 1.01 |
| GLY+SER | 2.22 | 2.45 | 2.09 | 2.22 | 2.21 | 2.05 | 2.08 | 2.13 | 2.21 | 1.96 | 1.96 | 1.82 | 2.20 | 2.34 | 2.20 | 2.24 |
| GLU | 4.24 | 4.74 | 3.99 | 4.32 | 3.98 | 3.78 | 6.36 | 6.17 | 6.09 | 5.12 | 3.74 | 3.58 | 3.74 | 4.14 | 7.77 | 7.48 |
| 8 to 21 d | | | | | | | | | | | | | | | | |
| CP | 22.7 | 22.9 | 21.8 | 22.7 | 21.9 | 21.5 | 22.7 | 23.2 | 22.7 | 21.4 | 20.7 | 20.2 | 21.0 | 20.5 | 22.7 | 22.1 |
| LYS | 1.24 | 1.30 | 1.23 | 1.23 | 1.23 | 1.17 | 1.23 | 1.28 | 1.23 | 1.31 | 1.23 | 1.27 | 1.23 | 1.24 | 1.23 | 1.21 |
| VAL | 0.94 | 0.99 | 0.94 | 0.94 | 0.94 | 0.91 | 0.94 | 0.97 | 0.94 | 1.02 | 0.94 | 0.95 | 0.94 | 0.98 | 0.94 | 0.89 |
| ILE | 0.85 | 0.87 | 0.81 | 0.80 | 0.81 | 0.77 | 0.81 | 0.83 | 0.81 | 0.88 | 0.85 | 0.86 | 0.85 | 0.92 | 0.85 | 0.79 |
| GLY+SER | 1.91 | 1.99 | 1.82 | 1.79 | 1.90 | 1.80 | 1.82 | 1.87 | 1.90 | 2.03 | 1.71 | 1.74 | 1.90 | 1.99 | 1.90 | 1.79 |
| GLU | 3.65 | 3.85 | 3.48 | 3.51 | 3.48 | 3.37 | 5.12 | 4.92 | 4.93 | 5.00 | 3.27 | 3.31 | 3.27 | 3.36 | 6.37 | 6.06 |
| 22 to 35 d | | | | | | | | | | | | | | | | |
| CP | 21.7 | 21.9 | 21.0 | 20.6 | 21.1 | 20.8 | 21.7 | 21.2 | 21.7 | 19.9 | 19.6 | 18.1 | 19.8 | 19.6 | 21.7 | 21.3 |
| LYS | 1.16 | 1.19 | 1.16 | 1.20 | 1.16 | 1.16 | 1.16 | 1.20 | 1.16 | 1.16 | 1.15 | 1.15 | 1.15 | 1.13 | 1.15 | 1.15 |
| VAL | 0.91 | 0.93 | 0.90 | 0.93 | 0.90 | 0.92 | 0.90 | 0.95 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.86 | 0.90 | 0.88 |
| ILE | 0.82 | 0.85 | 0.78 | 0.81 | 0.78 | 0.82 | 0.78 | 0.83 | 0.78 | 0.76 | 0.81 | 0.82 | 0.81 | 0.79 | 0.81 | 0.81 |
| GLY+SER | 1.84 | 1.86 | 1.76 | 1.80 | 1.83 | 1.84 | 1.76 | 1.84 | 1.83 | 1.78 | 1.61 | 1.55 | 1.82 | 1.73 | 1.82 | 1.74 |
| GLU | 3.51 | 3.55 | 3.36 | 3.41 | 3.36 | 3.42 | 4.75 | 4.62 | 4.59 | 4.74 | 3.08 | 3.01 | 3.08 | 2.92 | 6.59 | 5.84 |
| 36 to 42 d | | | | | | | | | | | | | | | | |
| CP | 20.6 | 20.8 | 20.0 | 19.3 | 20.1 | 19.6 | 20.6 | 19.9 | 20.6 | 20.2 | 18.7 | 18.6 | 18.9 | 18.4 | 20.6 | 20.9 |
| LYS | 1.10 | 1.11 | 1.10 | 1.13 | 1.10 | 1.16 | 1.10 | 1.22 | 1.10 | 1.18 | 1.09 | 1.18 | 1.09 | 1.16 | 1.09 | 1.19 |
| VAL | 0.86 | 0.91 | 0.86 | 0.89 | 0.86 | 0.93 | 0.86 | 0.91 | 0.86 | 0.94 | 0.85 | 0.93 | 0.85 | 0.89 | 0.85 | 0.92 |
| ILE | 0.77 | 0.84 | 0.74 | 0.78 | 0.74 | 0.81 | 0.74 | 0.80 | 0.74 | 0.84 | 0.77 | 0.85 | 0.77 | 0.81 | 0.77 | 0.83 |
| GLY+SER | 1.74 | 1.77 | 1.67 | 1.73 | 1.73 | 1.86 | 1.67 | 1.83 | 1.73 | 1.85 | 1.53 | 1.67 | 1.72 | 1.76 | 1.72 | 1.85 |
| GLU | 3.33 | 3.47 | 3.20 | 3.34 | 3.20 | 3.45 | 4.37 | 4.35 | 4.24 | 4.30 | 2.93 | 3.20 | 2.93 | 2.94 | 6.13 | 6.87 |

[1] Values were performed in duplicate by standard procedures [19].

**Table 7**. Body weight gain, feed intake and feed conversion of Ross 308 male broilers fed control diets or diets supplemented with different industrial AA to provide these same ratios to LYS or CP levels during a 42 d production period[1]

| Body weight gain, g/bird | 1 to 7d | 1 to 21d | 1 to 35d | 1 to 42d |
|---|---|---|---|---|
| Control | 136 $^{ab}$ | 984 | 2,520 | 3,120 |
| VAL | 135 $^{ab}$ | 973 | 2,489 | 3,100 |
| VAL + GLY | 140 $^{a}$ | 993 | 2,508 | 3,122 |
| VAL + GLU | 140 $^{a}$ | 976 | 2,495 | 3,123 |
| VAL + GLY + GLU | 136 $^{ab}$ | 981 | 2,500 | 3,108 |
| VAL + ILE | 131 $^{b}$ | 962 | 2,472 | 3,096 |
| VAL + ILE + GLY | 142 $^{a}$ | 979 | 2,476 | 3,072 |
| VAL + ILE + GLY + GLU | 140 $^{a}$ | 993 | 2,506 | 3,110 |
| SD | 6.27 | 28.22 | 44.09 | 53.76 |
| *P*= | 0.01 | 0.37 | 0.34 | 0.53 |
| Feed intake, g/bird | | | | |
| Control | 144 | 1,264 | 3,557 | 4,675 |
| VAL | 142 | 1,264 | 3,551 | 4,686 |
| VAL + GLY | 145 | 1,280 | 3,587 | 4,717 |
| VAL + GLU | 142 | 1,248 | 3,504 | 4,656 |
| VAL + GLY + GLU | 141 | 1,261 | 3,547 | 4,676 |
| VAL + ILE | 141 | 1,272 | 3,572 | 4,741 |
| VAL + ILE + GLY | 146 | 1,280 | 3,562 | 4,660 |
| VAL + ILE + GLY + GLU | 143 | 1,274 | 3,553 | 4,638 |
| SD | 5.66 | 38.89 | 72.53 | 94.57 |
| *P*= | 0.50 | 0.68 | 0.50 | 0.40 |
| Feed conversion, g:g | | | | |
| Control | 1.060 $^{ab}$ | 1.285 $^{a}$ | 1.412 $^{a}$ | 1.498 $^{a}$ |
| VAL | 1.048 $^{ab}$ | 1.299 $^{ab}$ | 1.427 $^{ab}$ | 1.511 $^{ab}$ |
| VAL + GLY | 1.038 $^{ab}$ | 1.289 $^{a}$ | 1.430 $^{ab}$ | 1.511 $^{ab}$ |
| VAL + GLU | 1.018 $^{a}$ | 1.278 $^{a}$ | 1.404 $^{a}$ | 1.490 $^{a}$ |
| VAL + GLY + GLU | 1.040 $^{ab}$ | 1.286 $^{a}$ | 1.419 $^{ab}$ | 1.504 $^{ab}$ |
| VAL + ILE | 1.079 $^{b}$ | 1.324 $^{b}$ | 1.445 $^{b}$ | 1.531 $^{b}$ |
| VAL + ILE + GLY | 1.024 $^{a}$ | 1.307 $^{ab}$ | 1.439 $^{b}$ | 1.517 $^{ab}$ |
| VAL + ILE + GLY + GLU | 1.019 $^{a}$ | 1.283 $^{a}$ | 1.418 $^{ab}$ | 1.491 $^{a}$ |
| SD | 0.029 | 0.021 | 0.019 | 0.021 |
| *P*= | 0.01 | 0.01 | 0.01 | 0.01 |

[1] Values are least-square means of 9 replicate pens with each pen having 28 birds at 1 d of age.

[a, b] Means within an age and measured characteristic followed by differing letters are statistically different ($P \leq 0.05$).

**Table 8**. Mortality (%) of Ross 308 male broilers fed control diets or diets supplemented with different industrial AA to provide these same ratios to LYS or CP levels during a 42 d production period[1]

| Treatment | Ascites | Sudden death | Legs abnormalities | Others | All |
|---|---|---|---|---|---|
| Control | 0.00 | 1.59 | 0.00 | 0.40 | 1.98 |
| VAL | 0.00 | 0.79 | 0.00 | 1.19 | 1.98 |
| VAL + GLY | 0.00 | 1.19 | 0.79 | 1.59 | 3.57 |
| VAL + GLU | 0.00 | 1.36 | 0.40 | 3.21 | 4.96 |
| VAL + GLY + GLU | 0.40 | 0.79 | 0.40 | 0.79 | 2.38 |
| VAL + ILE | 0.00 | 1.43 | 0.52 | 0.15 | 2.03 |
| VAL + ILE + GLY | 0.00 | 1.19 | 0.79 | 0.79 | 2.78 |
| VAL + ILE + GLY + GLU | 0.00 | 2.38 | 0.40 | 1.19 | 3.97 |
| SD | 0.43 | 2.20 | 1.52 | 2.26 | 3.38 |
| *P*= | 0.46 | 0.78 | 0.93 | 0.22 | 0.53 |

[1] Values are least-square means of 9 replicate pens with each pen having 28 birds at 1 d of age.

**Table 9**. Carcass, abdominal fat, and parts yields of Ross 308 male broilers fed diets with different amino acid profiles during a 42 d production period[1], %

| Treatment | Carcass | Abdominal fat | Breast meat[2] | Leg quarters[3] | Wings | Cage |
|---|---|---|---|---|---|---|
| Control | 78.62 | 1.88 [ab] | 29.04 [ab] | 33.51 [a] | 10.51 | 24.63 |
| VAL | 78.73 | 2.04 [ab] | 28.99 [b] | 33.29 [ab] | 10.57 | 24.54 |
| VAL + GLY | 78.69 | 1.94 [ab] | 29.22 [ab] | 33.11 [ab] | 10.55 | 24.69 |
| VAL + GLU | 78.53 | 1.83 [ab] | 29.33 [ab] | 32.91 [b] | 10.66 | 24.62 |
| VAL + GLY + GLU | 78.45 | 1.93 [ab] | 29.32 [ab] | 32.96 [b] | 10.49 | 24.73 |
| VAL + ILE | 78.60 | 2.06 [b] | 29.27 [ab] | 32.93 [b] | 10.47 | 24.43 |
| VAL + ILE + GLY | 79.09 | 2.03 [ab] | 29.52 [ab] | 32.88 [b] | 10.42 | 24.52 |
| VAL + ILE + GLY + GLU | 78.50 | 1.81 [a] | 29.73 [a] | 32.76 [b] | 10.62 | 24.45 |
| SD | 0.72 | 0.17 | 0.50 | 0.36 | 0.17 | 0.41 |
| *P* = | 0.67 | 0.01 | 0.04 | 0.01 | 0.09 | 0.72 |

[1] Values are least-square means of 9 replicate pens with 10 birds per pen.

Carcass yield expressed relative to live weight, whereas other data are relative to carcass weight.

[2] *Pectoralis major* plus *Pectoralis minor* muscles.

[3] Thighs plus drumsticks.

[a, b] Means followed by differing letters are statistically different ($P \leq 0.05$).

# CAPÍTULO V

## Considerações finais

Ainda que existam certas discrepâncias, resultados promissores têm sido demonstrados. A perspectiva de redução dos níveis protéicos das formulações, têm impulsionado novos estudos na área, abrangendo além dos AAE menos limitantes valina, isoleucina, triptofano e arginina, os AANE glicina e ácido glutâmico. Respostas positivas à utilização destes AA propiciarão, a médio prazo, sua produção sintética em escala industrial com conseqüente queda dos custos e maximização na utilização das novas formulações.

Não só as exigências de cada aminoácido devem ser atendidas como o equilíbrio entre eles, principalmente lisina, aminoácidos sulfurados, treonina e, num futuro próximo, valina, isoleucina e mesmo glicina. Desta forma, a excreção de nitrogênio pelas aves será minimizada, economizando energia para os processos de mantença e crescimento.

A tendência é que os nutricionistas e formuladores passem a utilizar relações fixas entre os AA e lisina nas fórmulas, conforme a fase de desenvolvimento das aves, alterando somente o nível de lisina das dietas em função das respostas esperadas sob as mais diversas condições ambientais. Novos estudos avaliando as interações de VAL, ILE e LEU devem ser conduzidos.

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# APÊNDICES

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

# Apêndice 2. Normas para publicação de artigos no periódico Poultry Science

Apêndice 3. Ganho de peso (GP, g), conversão alimentar (CA), consumo de ração (Cons, g) e mortalidade de 14 a 35 dias de idade (referente ao artigo do Capítulo II).

| VAL:lys | ILE:lys | Bloco | GP | | | | CA | | | | Cons | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 14-21 d | 21-28 d | 28-35 d | 14-35 d | 14-21 d | 21-28 d | 28-35 d | 14-35 d | 14-21 d | 21-28 d | 28-35 d | 14-35 d | Mort |
| 70 | 65 | I | 465 | 690 | 868 | 2022 | 1,511 | 1,532 | 1,680 | 1,591 | 702 | 1057 | 1458 | 3218 | 0 |
| 70 | 65 | II | 471 | 661 | 886 | 2018 | 1,490 | 1,598 | 1,656 | 1,597 | 701 | 1056 | 1467 | 3222 | 8 |
| 70 | 65 | III | 477 | 720 | 914 | 2111 | 1,456 | 1,514 | 1,695 | 1,573 | 694 | 1090 | 1549 | 3320 | 0 |
| 70 | 65 | IV | 482 | 728 | 909 | 2119 | 1,519 | 1,511 | 1,690 | 1,588 | 733 | 1100 | 1537 | 3366 | 4 |
| 70 | 65 | V | 485 | 712 | 884 | 2081 | 1,480 | 1,489 | 1,712 | 1,581 | 718 | 1060 | 1514 | 3290 | 4 |
| 70 | 65 | VI | 482 | 729 | 863 | 2074 | 1,467 | 1,509 | 1,729 | 1,591 | 706 | 1100 | 1493 | 3299 | 0 |
| 70 | 65 | VII | 482 | 747 | 886 | 2114 | 1,488 | 1,502 | 1,723 | 1,592 | 717 | 1122 | 1527 | 3365 | 0 |
| 70 | 65 | VIII | 504 | 728 | 892 | 2124 | 1,473 | 1,550 | 1,755 | 1,618 | 743 | 1129 | 1565 | 3437 | 0 |
| 70 | 65 | IX | 506 | 690 | 898 | 2094 | 1,494 | 1,660 | 1,662 | 1,621 | 755 | 1146 | 1493 | 3394 | 0 |
| 75 | 65 | I | 503 | 740 | 887 | 2130 | 1,498 | 1,503 | 1,795 | 1,618 | 754 | 1111 | 1593 | 3447 | 8 |
| 75 | 65 | II | 498 | 730 | 893 | 2121 | 1,331 | 1,480 | 1,763 | 1,564 | 662 | 1081 | 1574 | 3318 | 0 |
| 75 | 65 | III | 493 | 761 | 884 | 2138 | 1,486 | 1,425 | 1,791 | 1,589 | 733 | 1084 | 1583 | 3399 | 0 |
| 75 | 65 | IV | 498 | 736 | 893 | 2128 | 1,470 | 1,520 | 1,737 | 1,591 | 733 | 1118 | 1552 | 3384 | 0 |
| 75 | 65 | V | 499 | 761 | 897 | 2157 | 1,492 | 1,563 | 1,781 | 1,633 | 745 | 1190 | 1597 | 3523 | 8 |
| 75 | 65 | VI | 501 | 806 | 867 | 2173 | 1,522 | 1,468 | 1,826 | 1,621 | 762 | 1183 | 1583 | 3522 | 8 |
| 75 | 65 | VII | 531 | 737 | 897 | 2165 | 1,360 | 1,589 | 1,618 | 1,539 | 723 | 1170 | 1452 | 3333 | 0 |
| 75 | 65 | VIII | 499 | 727 | 871 | 2097 | 1,407 | 1,522 | 1,734 | 1,583 | 703 | 1106 | 1510 | 3318 | 0 |
| 75 | 65 | IX | 485 | 758 | 928 | 2171 | 1,474 | 1,447 | 1,759 | 1,587 | 715 | 1098 | 1632 | 3444 | 4 |
| 80 | 65 | I | 501 | 724 | 798 | 2023 | 1,451 | 1,497 | 1,754 | 1,574 | 727 | 1084 | 1400 | 3185 | 0 |
| 80 | 65 | II | 505 | 792 | 828 | 2125 | 1,491 | 1,458 | 1,870 | 1,626 | 753 | 1154 | 1548 | 3455 | 0 |
| 80 | 65 | III | 488 | 743 | 924 | 2155 | 1,470 | 1,492 | 1,721 | 1,578 | 717 | 1109 | 1591 | 3401 | 0 |
| 80 | 65 | IV | 505 | 772 | 898 | 2174 | 1,466 | 1,460 | 1,764 | 1,587 | 740 | 1127 | 1583 | 3450 | 0 |
| 80 | 65 | V | 514 | 745 | 861 | 2120 | 1,481 | 1,502 | 1,834 | 1,631 | 762 | 1118 | 1578 | 3458 | 0 |
| 80 | 65 | VI | 483 | 731 | 911 | 2126 | 1,424 | 1,488 | 1,664 | 1,549 | 688 | 1088 | 1516 | 3292 | 0 |
| 80 | 65 | VII | 522 | 775 | 873 | 2170 | 1,465 | 1,517 | 1,778 | 1,609 | 764 | 1176 | 1553 | 3493 | 0 |
| 80 | 65 | VIII | 503 | 768 | 917 | 2189 | 1,467 | 1,529 | 1,681 | 1,577 | 738 | 1175 | 1542 | 3452 | 4 |
| 80 | 65 | IX | 502 | 750 | 866 | 2118 | 1,482 | 1,537 | 1,780 | 1,623 | 743 | 1154 | 1542 | 3439 | 0 |
| 70 | 68 | I | 477 | 778 | 902 | 2156 | 1,459 | 1,501 | 1,736 | 1,589 | 696 | 1167 | 1565 | 3426 | 4 |
| 70 | 68 | II | 478 | 714 | 878 | 2069 | 1,471 | 1,552 | 1,719 | 1,604 | 702 | 1107 | 1509 | 3318 | 0 |
| 70 | 68 | III | 505 | 742 | 934 | 2180 | 1,482 | 1,536 | 1,663 | 1,578 | 748 | 1139 | 1553 | 3440 | 0 |
| 70 | 68 | IV | 505 | 756 | 864 | 2125 | 1,487 | 1,561 | 1,650 | 1,578 | 750 | 1181 | 1426 | 3353 | 8 |
| 70 | 68 | V | 523 | 726 | 874 | 2123 | 1,445 | 1,566 | 1,723 | 1,601 | 756 | 1136 | 1506 | 3398 | 0 |
| 70 | 68 | VI | 490 | 766 | 871 | 2127 | 1,508 | 1,432 | 1,750 | 1,580 | 738 | 1098 | 1525 | 3361 | 0 |
| 70 | 68 | VII | 505 | 772 | 912 | 2188 | 1,426 | 1,529 | 1,747 | 1,596 | 720 | 1180 | 1593 | 3493 | 0 |
| 70 | 68 | VIII | 523 | 784 | 883 | 2189 | 1,419 | 1,472 | 1,814 | 1,597 | 742 | 1154 | 1601 | 3497 | 0 |
| 70 | 68 | IX | 513 | 749 | 872 | 2134 | 1,507 | 1,503 | 1,823 | 1,630 | 773 | 1125 | 1590 | 3478 | 9 |
| 70 | 71 | I | 492 | 741 | 918 | 2151 | 1,517 | 1,429 | 1,701 | 1,565 | 746 | 1058 | 1562 | 3367 | 0 |
| 70 | 71 | II | 539 | 721 | 898 | 2158 | 1,500 | 1,576 | 1,703 | 1,604 | 809 | 1136 | 1530 | 3463 | 0 |
| 70 | 71 | III | 485 | 746 | 918 | 2149 | 1,512 | 1,550 | 1,637 | 1,578 | 733 | 1156 | 1503 | 3391 | 4 |
| 70 | 71 | IV | 479 | 752 | 846 | 2077 | 1,474 | 1,415 | 1,798 | 1,585 | 706 | 1064 | 1521 | 3291 | 0 |
| 70 | 71 | V | 497 | 763 | 886 | 2146 | 1,506 | 1,423 | 1,737 | 1,569 | 748 | 1086 | 1539 | 3367 | 0 |
| 70 | 71 | VI | 498 | 775 | 874 | 2147 | 1,486 | 1,419 | 1,799 | 1,589 | 741 | 1100 | 1571 | 3412 | 0 |
| 70 | 71 | VII | 498 | 763 | 871 | 2133 | 1,475 | 1,491 | 1,772 | 1,602 | 735 | 1138 | 1543 | 3417 | 0 |
| 70 | 71 | VIII | 483 | 754 | 849 | 2085 | 1,549 | 1,532 | 1,833 | 1,658 | 748 | 1154 | 1556 | 3456 | 4 |
| 70 | 71 | IX | 482 | 757 | 945 | 2184 | 1,510 | 1,539 | 1,654 | 1,582 | 728 | 1164 | 1563 | 3455 | 4 |
| 75 | 68 | I | 522 | 771 | 900 | 2194 | 1,470 | 1,510 | 1,766 | 1,606 | 768 | 1165 | 1590 | 3522 | 0 |
| 75 | 68 | II | 522 | 689 | 857 | 2067 | 1,387 | 1,531 | 1,687 | 1,559 | 723 | 1054 | 1446 | 3223 | 0 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 75 | 68 | III | 521 | 733 | 882 | 2135 | 1,384 | 1,573 | 1,801 | 1,615 | 721 | 1153 | 1588 | 3447 | 8 |
| 75 | 68 | IV | 513 | 744 | 878 | 2135 | 1,476 | 1,544 | 1,765 | 1,615 | 757 | 1149 | 1550 | 3449 | 8 |
| 75 | 68 | V | 506 | 730 | 846 | 2082 | 1,452 | 1,542 | 1,678 | 1,575 | 735 | 1125 | 1419 | 3279 | 0 |
| 75 | 68 | VI | 481 | 709 | 898 | 2088 | 1,458 | 1,540 | 1,656 | 1,569 | 701 | 1091 | 1488 | 3275 | 4 |
| 75 | 68 | VII | 513 | 759 | 901 | 2173 | 1,467 | 1,536 | 1,705 | 1,590 | 752 | 1166 | 1536 | 3453 | 0 |
| 75 | 68 | VIII | 501 | 750 | 864 | 2116 | 1,485 | 1,548 | 1,802 | 1,637 | 744 | 1162 | 1558 | 3462 | 8 |
| 75 | 68 | IX | 495 | 774 | 847 | 2116 | 1,462 | 1,526 | 1,841 | 1,637 | 724 | 1181 | 1560 | 3465 | 0 |
| 80 | 71 | I | 483 | 754 | 882 | 2118 | 1,478 | 1,477 | 1,709 | 1,566 | 713 | 1114 | 1507 | 3317 | 0 |
| 80 | 71 | II | 481 | 712 | 917 | 2110 | 1,516 | 1,546 | 1,623 | 1,573 | 729 | 1101 | 1488 | 3318 | 0 |
| 80 | 71 | III | 477 | 724 | 823 | 2024 | 1,467 | 1,440 | 1,751 | 1,557 | 699 | 1043 | 1442 | 3152 | 4 |
| 80 | 71 | IV | 488 | 785 | 882 | 2155 | 1,491 | 1,412 | 1,849 | 1,598 | 728 | 1108 | 1630 | 3444 | 0 |
| 80 | 71 | V | 510 | 727 | 904 | 2142 | 1,481 | 1,565 | 1,708 | 1,606 | 756 | 1138 | 1544 | 3438 | 0 |
| 80 | 71 | VI | 490 | 798 | 915 | 2204 | 1,460 | 1,435 | 1,690 | 1,546 | 716 | 1146 | 1546 | 3408 | 0 |
| 80 | 71 | VII | 493 | 713 | 905 | 2112 | 1,475 | 1,557 | 1,733 | 1,611 | 728 | 1111 | 1569 | 3403 | 4 |
| 80 | 71 | VIII | 477 | 734 | 879 | 2090 | 1,510 | 1,538 | 1,669 | 1,587 | 720 | 1130 | 1467 | 3317 | 0 |
| 80 | 71 | IX | 500 | 746 | 903 | 2149 | 1,453 | 1,482 | 1,715 | 1,573 | 726 | 1105 | 1549 | 3380 | 0 |

Apêndice 4. Dados referentes ao abate de frangos de corte (artigo do Capítulo II).

| VAL:lys | ILE:lys | Rendimentos, % | | | | | |
|---|---|---|---|---|---|---|---|
| | | Bloco | Carcaça | Gordura | Peito | Pernas | Asas |
| 70 | 65 | I | 74,43 | 1,70 | 29,47 | 32,34 | 11,34 |
| 70 | 65 | II | 74,48 | 2,10 | 29,26 | 32,23 | 11,07 |
| 70 | 65 | III | 74,60 | 2,01 | 29,67 | 33,00 | 11,08 |
| 70 | 65 | IV | 74,98 | 1,74 | 30,59 | 31,73 | 11,37 |
| 70 | 65 | V | 74,53 | 1,90 | 29,68 | 32,54 | 11,05 |
| 70 | 65 | VI | 74,97 | 1,83 | 29,95 | 32,07 | 11,18 |
| 70 | 65 | VII | 74,97 | 1,82 | 29,66 | 33,00 | 10,99 |
| 70 | 65 | VIII | 74,38 | 1,72 | 29,84 | 32,62 | 11,22 |
| 70 | 65 | IX | 75,26 | 2,07 | 29,94 | 31,50 | 10,97 |
| 75 | 65 | I | 73,86 | 2,35 | 28,58 | 31,87 | 11,18 |
| 75 | 65 | II | 73,32 | 1,59 | 29,12 | 32,68 | 11,18 |
| 75 | 65 | III | 75,03 | 1,79 | 30,59 | 32,19 | 10,84 |
| 75 | 65 | IV | 72,80 | 2,14 | 28,84 | 33,44 | 11,15 |
| 75 | 65 | V | 73,67 | 2,07 | 28,78 | 33,26 | 11,18 |
| 75 | 65 | VI | 74,28 | 1,88 | 28,47 | 33,07 | 11,06 |
| 75 | 65 | VII | 74,54 | 1,72 | 29,62 | 32,34 | 10,40 |
| 75 | 65 | VIII | 74,38 | 1,95 | 28,78 | 33,60 | 11,37 |
| 75 | 65 | IX | 75,08 | 1,53 | 29,55 | 32,47 | 10,97 |
| 80 | 65 | I | 73,86 | 2,07 | 29,27 | 31,73 | 11,47 |
| 80 | 65 | II | 73,98 | 2,03 | 30,18 | 32,21 | 11,23 |
| 80 | 65 | III | 74,31 | 1,79 | 28,98 | 32,85 | 11,06 |
| 80 | 65 | IV | 73,14 | 1,87 | 29,17 | 33,18 | 10,84 |
| 80 | 65 | V | 73,42 | 2,07 | 29,56 | 32,71 | 11,28 |
| 80 | 65 | VI | 75,30 | 1,68 | 29,13 | 32,48 | 11,23 |
| 80 | 65 | VII | 74,61 | 1,71 | 29,26 | 31,95 | 10,97 |
| 80 | 65 | VIII | 75,58 | 1,51 | 29,68 | 32,36 | 11,30 |
| 80 | 65 | IX | 75,15 | 1,62 | 29,66 | 32,69 | 10,90 |
| 70 | 68 | I | 74,36 | 1,87 | 28,21 | 32,85 | 10,80 |
| 70 | 68 | II | 74,05 | 1,99 | 29,07 | 32,65 | 10,97 |
| 70 | 68 | III | 74,77 | 1,75 | 29,47 | 32,85 | 10,85 |
| 70 | 68 | IV | 76,63 | 1,94 | 29,88 | 32,14 | 10,91 |
| 70 | 68 | V | 75,06 | 1,82 | 29,12 | 32,66 | 11,25 |
| 70 | 68 | VI | 74,29 | 1,59 | 28,16 | 33,28 | 11,01 |
| 70 | 68 | VII | 73,69 | 1,74 | 30,04 | 32,81 | 11,32 |
| 70 | 68 | VIII | 74,82 | 1,71 | 29,97 | 32,53 | 10,70 |
| 70 | 68 | IX | 75,32 | 1,81 | 29,37 | 32,65 | 11,38 |
| 70 | 71 | I | 73,84 | 1,79 | 28,78 | 31,83 | 10,90 |
| 70 | 71 | II | 74,65 | 2,08 | 29,55 | 31,64 | 10,85 |
| 70 | 71 | III | 73,91 | 1,74 | 29,23 | 32,40 | 10,70 |
| 70 | 71 | IV | 74,58 | 1,96 | 29,09 | 32,73 | 11,28 |
| 70 | 71 | V | 74,56 | 1,64 | 28,55 | 32,34 | 10,92 |
| 70 | 71 | VI | 74,68 | 1,91 | 28,92 | 33,37 | 11,31 |
| 70 | 71 | VII | 74,50 | 2,06 | 29,79 | 32,03 | 11,28 |
| 70 | 71 | VIII | 73,97 | 1,87 | 28,36 | 32,14 | 11,15 |
| 70 | 71 | IX | 74,30 | 1,88 | 29,42 | 32,60 | 10,99 |
| 75 | 68 | I | 73,99 | 2,05 | 29,84 | 31,52 | 11,15 |
| 75 | 68 | II | 73,40 | 1,48 | 29,61 | 31,77 | 11,44 |
| 75 | 68 | III | 74,30 | 1,93 | 29,67 | 32,19 | 11,08 |
| 75 | 68 | IV | 74,96 | 2,22 | 28,46 | 33,39 | 11,11 |
| 75 | 68 | V | 72,69 | 1,78 | 28,89 | 33,21 | 11,41 |
| 75 | 68 | VI | 74,10 | 1,71 | 29,07 | 32,90 | 11,04 |
| 75 | 68 | VII | 74,76 | 1,69 | 30,13 | 32,98 | 11,04 |
| 75 | 68 | VIII | 74,66 | 1,92 | 29,30 | 32,83 | 10,94 |
| 75 | 68 | IX | 74,48 | 2,04 | 29,35 | 32,11 | 11,09 |
| 80 | 71 | I | 73,61 | 2,11 | 29,36 | 32,16 | 11,23 |
| 80 | 71 | II | 74,55 | 1,73 | 29,85 | 32,90 | 11,06 |
| 80 | 71 | III | 74,73 | 1,74 | 29,64 | 31,95 | 11,06 |
| 80 | 71 | IV | 74,48 | 2,21 | 28,80 | 32,46 | 11,17 |
| 80 | 71 | V | 74,03 | 1,96 | 28,10 | 32,84 | 11,19 |
| 80 | 71 | VI | 72,69 | 2,06 | 29,00 | 32,97 | 11,24 |
| 80 | 71 | VII | 74,59 | 1,79 | 28,66 | 32,43 | 10,65 |
| 80 | 71 | VIII | 75,08 | 1,65 | 30,13 | 32,31 | 11,36 |
| 80 | 71 | IX | 72,78 | 1,92 | 29,25 | 32,35 | 11,27 |

Apêndice 5. Ganho de peso (GP, g), conversão alimentar (CA), consumo de ração (Cons, g) e mortalidade (Mort, %) de frangos de corte no período de 21 a 42 dias de idade e rendimentos de carcaça, gordura e cortes aos 42 dias de idade (referentes ao artigo do Capítulo III).

| VAL | GP | CA | Cons | Mort | Rendimentos, % | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Carcaça | Gordura | Asas | Peito | Pernas |
| 0,64 | 2118 | 1,725 | 3695 | 1 | 79,09 | 1,87 | 10,29 | 32,51 | 32,09 |
| 0,64 | 2094 | 1,745 | 3652 | 1 | 79,70 | 2,68 | 10,09 | 30,64 | 30,53 |
| 0,64 | 2044 | 1,744 | 3576 | 0 | 78,13 | 1,96 | 10,44 | 30,84 | 33,19 |
| 0,64 | 2144 | 1,750 | 3736 | 1 | 76,79 | 2,00 | 10,35 | 30,41 | 33,20 |
| 0,64 | 2059 | 1,743 | 3562 | 0 | 78,18 | 2,17 | 9,81 | 31,98 | 32,22 |
| 0,64 | 2051 | 1,730 | 3543 | 1 | 78,98 | 1,93 | 10,39 | 32,66 | 31,01 |
| 0,64 | 2052 | 1,728 | 3557 | 0 | 78,20 | 1,80 | 10,63 | 31,78 | 32,62 |
| 0,64 | 2081 | 1,733 | 3542 | 1 | 79,56 | 2,40 | 10,38 | 32,15 | 31,35 |
| 0,70 | 2107 | 1,702 | 3535 | 0 | 80,78 | 1,81 | 10,17 | 31,85 | 31,85 |
| 0,70 | 2170 | 1,678 | 3637 | 1 | 78,07 | 2,00 | 10,39 | 31,66 | 31,64 |
| 0,70 | 2145 | 1,676 | 3683 | 1 | 78,42 | 1,85 | 10,31 | 32,33 | 32,40 |
| 0,70 | 2069 | 1,717 | 3564 | 2 | 78,69 | 2,24 | 9,97 | 30,53 | 32,84 |
| 0,70 | 2104 | 1,722 | 3552 | 1 | 79,13 | 1,68 | 10,45 | 32,12 | 32,45 |
| 0,70 | 2203 | 1,689 | 3683 | 1 | 77,04 | 2,16 | 10,37 | 30,39 | 33,08 |
| 0,70 | 2130 | 1,672 | 3550 | 0 | 77,42 | 1,98 | 10,34 | 31,07 | 32,13 |
| 0,70 | 2219 | 1,667 | 3687 | 0 | 79,88 | 1,80 | 10,42 | 31,58 | 32,17 |
| 0,70 | 2126 | 1,662 | 3594 | 0 | 78,12 | 1,92 | 10,13 | 31,65 | 32,60 |
| 0,75 | 2116 | 1,690 | 3608 | 1 | 78,99 | 1,76 | 10,44 | 30,58 | 32,64 |
| 0,75 | 2130 | 1,705 | 3615 | 0 | 79,96 | 1,50 | 9,75 | 33,80 | 31,00 |
| 0,75 | 2064 | 1,697 | 3599 | 1 | 78,95 | 2,04 | 10,45 | 31,93 | 32,77 |
| 0,75 | 2074 | 1,743 | 3502 | 2 | 78,55 | 1,69 | 10,37 | 31,84 | 32,37 |
| 0,75 | 2102 | 1,689 | 3651 | 1 | 78,86 | 1,75 | 10,39 | 31,05 | 32,96 |
| 0,75 | 2152 | 1,737 | 3733 | 4 | 77,63 | 1,72 | 10,26 | 32,59 | 31,96 |
| 0,75 | 2120 | 1,735 | 3576 | 0 | 77,38 | 1,90 | 10,37 | 32,04 | 31,97 |
| 0,75 | 2182 | 1,687 | 3700 | 1 | 79,06 | 1,90 | 10,42 | 31,37 | 31,78 |
| 0,75 | 2069 | 1,696 | 3496 | 0 | 79,23 | 2,20 | 10,05 | 32,09 | 31,68 |
| 0,81 | 2090 | 1,690 | 3558 | 0 | 78,56 | 2,01 | 10,44 | 30,33 | 32,76 |
| 0,81 | 2181 | 1,703 | 3666 | 0 | 79,82 | 2,11 | 10,00 | 31,82 | 32,38 |
| 0,81 | 2082 | 1,681 | 3419 | 0 | 79,53 | 1,54 | 10,21 | 32,59 | 32,70 |
| 0,81 | 2156 | 1,643 | 3665 | 1 | 78,88 | 1,52 | 10,50 | 32,39 | 32,19 |
| 0,81 | 2181 | 1,700 | 3801 | 2 | 78,65 | 2,00 | 10,03 | 31,63 | 32,65 |
| 0,81 | 2288 | 1,743 | 3776 | 2 | 78,31 | 1,90 | 10,41 | 31,68 | 32,02 |
| 0,81 | 2113 | 1,651 | 3618 | 2 | 79,66 | 1,90 | 10,22 | 31,53 | 31,76 |
| 0,81 | 2212 | 1,712 | 3738 | 1 | 78,65 | 1,70 | 10,31 | 31,91 | 31,98 |
| 0,81 | 2105 | 1,690 | 3571 | 3 | 80,24 | 2,07 | 10,10 | 31,11 | 31,92 |
| 0,86 | 2188 | 1,696 | 3723 | 2 | 79,59 | 1,96 | 10,61 | 30,60 | 32,13 |
| 0,86 | 2221 | 1,701 | 3765 | 1 | 80,04 | 1,86 | 10,06 | 31,38 | 32,04 |
| 0,86 | 2237 | 1,695 | 3776 | 1 | 77,65 | 1,96 | 10,19 | 30,71 | 32,85 |
| 0,86 | 2123 | 1,688 | 3616 | 0 | 77,61 | 2,04 | 10,14 | 31,09 | 32,46 |
| 0,86 | 2134 | 1,703 | 3609 | 0 | 77,54 | 1,66 | 10,04 | 31,78 | 32,76 |
| 0,86 | 2109 | 1,691 | 3557 | 0 | 78,09 | 1,91 | 10,57 | 32,25 | 32,99 |
| 0,86 | 2047 | 1,686 | 3506 | 1 | 79,28 | 2,23 | 10,42 | 30,39 | 31,58 |
| 0,86 | 2139 | 1,713 | 3623 | 0 | 80,52 | 1,63 | 10,47 | 31,52 | 31,17 |
| 0,86 | 2229 | 1,694 | 3678 | 0 | 78,74 | 1,71 | 10,23 | 31,95 | 32,49 |
| 0,92 | 2152 | 1,650 | 3616 | 0 | 77,99 | 2,30 | 10,22 | 30,84 | 31,83 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0,92 | 2105 | 1,680 | 3609 | 1 | 79,22 | 1,90 | 10,38 | 31,72 | 31,52 |
| 0,92 | 2097 | 1,714 | 3655 | 3 | 79,36 | 2,12 | 10,15 | 31,18 | 31,80 |
| 0,92 | 2129 | 1,743 | 3578 | 0 | 77,49 | 1,87 | 10,41 | 31,07 | 34,13 |
| 0,92 | 2037 | 1,681 | 3474 | 0 | 77,56 | 1,76 | 9,97 | 30,60 | 33,86 |
| 0,92 | 2097 | 1,705 | 3546 | 0 | 78,54 | 1,51 | 10,16 | 31,98 | 32,47 |
| 0,92 | 2106 | 1,691 | 3548 | 1 | 79,39 | 1,59 | 10,87 | 31,71 | 31,48 |
| 0,92 | 2129 | 1,684 | 3619 | 1 | 79,35 | 1,86 | 10,39 | 32,49 | 32,19 |
| 0,92 | 2235 | 1,700 | 3775 | 3 | 79,19 | 1,73 | 10,18 | 30,31 | 31,86 |
| 0,97 | 2151 | 1,689 | 3672 | 0 | 79,11 | 1,92 | 10,33 | 31,30 | 32,06 |
| 0,97 | 2110 | 1,707 | 3605 | 2 | 78,36 | 2,39 | 10,24 | 29,90 | 31,94 |
| 0,97 | 2208 | 1,708 | 3720 | 0 | 78,82 | 1,94 | 10,26 | 31,95 | 31,62 |
| 0,97 | 2141 | 1,685 | 3696 | 2 | 78,72 | 1,81 | 10,46 | 30,67 | 32,93 |
| 0,97 | 2094 | 1,727 | 3507 | 0 | 78,44 | 1,59 | 10,54 | 31,97 | 32,31 |
| 0,97 | 2170 | 1,674 | 3652 | 1 | 80,18 | 1,50 | 9,93 | 32,42 | 32,22 |
| 0,97 | 2084 | 1,683 | 3557 | 0 | 79,33 | 1,66 | 10,42 | 31,81 | 32,60 |
| 0,97 | 2155 | 1,707 | 3745 | 1 | 79,19 | 1,83 | 10,95 | 31,60 | 31,74 |
| 0,97 | 2229 | 1,738 | 3625 | 0 | 78,99 | 1,56 | 10,12 | 32,26 | 31,76 |

Apêndice 6. Ganho de peso (GP, g), conversão alimentar (CA), consumo de ração (Cons, g) e causas de mortalidade de frangos de corte (referentes ao artigo do Capítulo IV).

| U.E. | BLOCO | GP | | | | CA | | | | Cons | | | | Causas mortalidade (1 – 42 d), % | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1-7 d | 1-21 d | 1-35 d | 1-42 d | 1-7 d | 1-21 d | 1-35 d | 1-42 d | 1-7 d | 1-21 d | 1-35 d | 1-42 d | Ascite | Morte Súbita | Pernas | Outros | Total |
| T1 | I | 141 | 982 | 2548 | 3162 | 1,076 | 1,308 | 1,409 | 1,491 | 152 | 1284 | 3591 | 4714 | 0 | 0 | 0 | 0 | 0 |
| T1 | II | 127 | 976 | 2509 | 3096 | 1,101 | 1,283 | 1,409 | 1,496 | 140 | 1251 | 3534 | 4633 | 0 | 0 | 0 | 0 | 0 |
| T1 | III | 144 | 988 | 2504 | 3031 | 1,035 | 1,294 | 1,412 | 1,519 | 149 | 1278 | 3536 | 4605 | 0 | 0 | 0 | 0 | 0 |
| T1 | IV | 143 | 1008 | 2551 | 3153 | 1,065 | 1,267 | 1,394 | 1,495 | 152 | 1277 | 3555 | 4714 | 0 | 0 | 0 | 0 | 0 |
| T1 | V | 131 | 964 | 2428 | 2998 | 1,033 | 1,252 | 1,403 | 1,489 | 135 | 1206 | 3406 | 4464 | 0 | 0 | 0 | 0 | 0 |
| T1 | VI | 133 | 961 | 2451 | 3042 | 1,091 | 1,314 | 1,425 | 1,510 | 145 | 1262 | 3493 | 4593 | 0 | 4 | 0 | 0 | 4 |
| T1 | VII | 135 | 955 | 2494 | 3137 | 1,016 | 1,280 | 1,398 | 1,473 | 137 | 1223 | 3488 | 4621 | 0 | 4 | 0 | 4 | 7 |
| T1 | VIII | 137 | 1013 | 2611 | 3235 | 1,063 | 1,262 | 1,402 | 1,486 | 146 | 1278 | 3661 | 4808 | 0 | 4 | 0 | 0 | 4 |
| T1 | IX | 136 | 1011 | 2586 | 3226 | 1,058 | 1,305 | 1,452 | 1,525 | 144 | 1319 | 3753 | 4920 | 0 | 4 | 0 | 0 | 4 |
| T2 | I | 139 | 971 | 2496 | 3089 | 1,005 | 1,291 | 1,411 | 1,502 | 140 | 1253 | 3521 | 4639 | 0 | 0 | 0 | 0 | 0 |
| T2 | II | 117 | 934 | 2461 | 3101 | 1,122 | 1,295 | 1,411 | 1,493 | 131 | 1210 | 3474 | 4629 | 0 | 0 | 0 | 0 | 0 |
| T2 | III | 131 | 976 | 2473 | 3082 | 1,083 | 1,308 | 1,444 | 1,515 | 142 | 1276 | 3570 | 4669 | 0 | 0 | 0 | 4 | 4 |
| T2 | IV | 147 | 989 | 2517 | 3096 | 1,034 | 1,309 | 1,426 | 1,533 | 152 | 1295 | 3589 | 4746 | 0 | 0 | 0 | 0 | 0 |
| T2 | V | 137 | 978 | 2514 | 3120 | 1,036 | 1,316 | 1,435 | 1,522 | 142 | 1287 | 3607 | 4748 | 0 | 0 | 0 | 0 | 0 |
| T2 | VI | 148 | 987 | 2525 | 3116 | 1,043 | 1,299 | 1,417 | 1,519 | 154 | 1282 | 3578 | 4733 | 0 | 0 | 0 | 0 | 0 |
| T2 | VII | 136 | 984 | 2490 | 3074 | 1,037 | 1,298 | 1,432 | 1,515 | 141 | 1277 | 3565 | 4658 | 0 | 4 | 0 | 0 | 4 |
| T2 | VIII | 129 | 961 | 2471 | 3179 | 1,028 | 1,284 | 1,442 | 1,510 | 132 | 1234 | 3563 | 4801 | 0 | 0 | 0 | 0 | 0 |
| T2 | IX | 134 | 976 | 2453 | 3043 | 1,048 | 1,290 | 1,423 | 1,496 | 141 | 1259 | 3491 | 4553 | 0 | 4 | 0 | 7 | 11 |
| T3 | I | 136 | 977 | 2521 | 3137 | 1,032 | 1,317 | 1,449 | 1,529 | 140 | 1287 | 3653 | 4798 | 0 | 0 | 0 | 4 | 4 |
| T3 | II | 140 | 998 | 2534 | 3133 | 1,036 | 1,274 | 1,427 | 1,506 | 145 | 1272 | 3615 | 4717 | 0 | 4 | 0 | 4 | 7 |
| T3 | III | 145 | 980 | 2479 | 3070 | 1,020 | 1,305 | 1,421 | 1,507 | 148 | 1279 | 3523 | 4626 | 0 | 4 | 0 | 0 | 4 |
| T3 | IV | 141 | 1000 | 2477 | 3053 | 1,040 | 1,293 | 1,436 | 1,509 | 147 | 1293 | 3557 | 4607 | 0 | 0 | 7 | 0 | 7 |
| T3 | V | 144 | 1015 | 2503 | 3133 | 1,045 | 1,286 | 1,444 | 1,521 | 151 | 1306 | 3615 | 4766 | 0 | 0 | 0 | 0 | 0 |
| T3 | VI | 144 | 998 | 2506 | 3116 | 1,045 | 1,278 | 1,413 | 1,493 | 150 | 1276 | 3541 | 4653 | 0 | 0 | 0 | 0 | 0 |
| T3 | VII | 145 | 1021 | 2506 | 3144 | 1,049 | 1,298 | 1,457 | 1,543 | 152 | 1325 | 3651 | 4850 | 0 | 0 | 0 | 0 | 0 |
| T3 | VIII | 134 | 977 | 2541 | 3161 | 1,031 | 1,273 | 1,398 | 1,476 | 139 | 1243 | 3554 | 4665 | 0 | 4 | 0 | 4 | 7 |
| T3 | IX | 132 | 969 | 2509 | 3152 | 1,043 | 1,279 | 1,425 | 1,515 | 138 | 1240 | 3576 | 4774 | 0 | 0 | 0 | 4 | 4 |
| T4 | I | 144 | 1008 | 2567 | 3162 | 0,965 | 1,266 | 1,403 | 1,490 | 139 | 1277 | 3602 | 4713 | 0 | 0 | 0 | 4 | 4 |
| T4 | II | 81 | 850 | 2389 | 2961 | 1,168 | 1,264 | 1,375 | 1,485 | 94 | 1074 | 3284 | 4398 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T4 | III | 134 | 976 | 2512 | 3146 | 1,048 | 1,285 | 1,389 | 1,465 | 140 | 1254 | 3489 | 4610 | 0 | 0 | 0 | 14 | 14 |
| T4 | IV | 141 | 976 | 2434 | 2994 | 1,000 | 1,275 | 1,402 | 1,487 | 141 | 1244 | 3414 | 4451 | 0 | 0 | 0 | 0 | 0 |
| T4 | V | 143 | 1013 | 2523 | 3161 | 1,005 | 1,274 | 1,409 | 1,474 | 144 | 1291 | 3555 | 4658 | 0 | 0 | 4 | 4 | 7 |
| T4 | VI | 139 | 976 | 2491 | 3085 | 1,036 | 1,295 | 1,416 | 1,502 | 144 | 1264 | 3529 | 4632 | 0 | 0 | 0 | 0 | 0 |
| T4 | VII | 135 | 1002 | 2486 | 3111 | 1,063 | 1,300 | 1,434 | 1,512 | 144 | 1303 | 3565 | 4704 | 0 | 0 | 0 | 4 | 4 |
| T4 | VIII | 145 | 1008 | 2556 | 3137 | 0,988 | 1,263 | 1,407 | 1,495 | 144 | 1274 | 3595 | 4691 | 0 | 7 | 0 | 0 | 7 |
| T4 | IX | 145 | 995 | 2548 | 3192 | 1,020 | 1,301 | 1,441 | 1,514 | 148 | 1294 | 3673 | 4834 | 0 | 4 | 0 | 0 | 4 |
| T5 | I | 139 | 998 | 2473 | 3060 | 1,010 | 1,268 | 1,413 | 1,491 | 140 | 1265 | 3494 | 4563 | 0 | 0 | 0 | 4 | 4 |
| T5 | II | 139 | 964 | 2491 | 3111 | 1,046 | 1,290 | 1,406 | 1,485 | 145 | 1244 | 3503 | 4619 | 0 | 0 | 0 | 4 | 4 |
| T5 | III | 124 | 922 | 2362 | 2963 | 1,098 | 1,323 | 1,437 | 1,508 | 136 | 1220 | 3395 | 4468 | 0 | 0 | 0 | 0 | 0 |
| T5 | IV | 140 | 999 | 2483 | 3085 | 1,051 | 1,300 | 1,453 | 1,533 | 147 | 1299 | 3607 | 4730 | 0 | 0 | 0 | 0 | 0 |
| T5 | V | 136 | 976 | 2526 | 3130 | 1,042 | 1,280 | 1,405 | 1,487 | 141 | 1249 | 3550 | 4656 | 0 | 0 | 0 | 0 | 0 |
| T5 | VI | 144 | 1002 | 2523 | 3135 | 1,010 | 1,255 | 1,391 | 1,473 | 145 | 1257 | 3510 | 4618 | 0 | 7 | 0 | 0 | 7 |
| T5 | VII | 146 | 1009 | 2585 | 3238 | 1,059 | 1,277 | 1,417 | 1,499 | 154 | 1288 | 3665 | 4853 | 4 | 0 | 0 | 0 | 4 |
| T5 | VIII | 122 | 964 | 2505 | 3115 | 1,076 | 1,279 | 1,408 | 1,555 | 131 | 1234 | 3528 | 4843 | 0 | 0 | 0 | 0 | 0 |
| T5 | IX | 137 | 998 | 2508 | 3130 | 0,964 | 1,258 | 1,424 | 1,511 | 132 | 1256 | 3570 | 4730 | 0 | 0 | 4 | 0 | 4 |
| T6 | I | 126 | 946 | 2469 | 3156 | 1,073 | 1,326 | 1,452 | 1,511 | 136 | 1254 | 3586 | 4768 | 0 | 0 | 0 | 0 | 0 |
| T6 | II | 134 | 970 | 2468 | 3100 | 1,096 | 1,328 | 1,431 | 1,496 | 146 | 1288 | 3531 | 4638 | 0 | 0 | 0 | 0 | 0 |
| T6 | III | 131 | 960 | 2488 | 3082 | 1,098 | 1,368 | 1,464 | 1,549 | 144 | 1313 | 3644 | 4774 | 0 | 4 | 0 | 0 | 4 |
| T6 | IV | 134 | 940 | 2421 | 3043 | 1,048 | 1,332 | 1,441 | 1,507 | 141 | 1252 | 3488 | 4586 | 0 | 0 | 0 | 0 | 0 |
| T6 | V | 127 | 979 | 2442 | 3003 | 1,118 | 1,338 | 1,463 | 1,595 | 142 | 1309 | 3574 | 4790 | 0 | 0 | 0 | 0 | 0 |
| T6 | VI | 135 | 967 | 2505 | 3124 | 1,063 | 1,320 | 1,434 | 1,512 | 144 | 1277 | 3592 | 4725 | 0 | 7 | 0 | 0 | 7 |
| T6 | VII | 131 | 934 | 2471 | 3118 | 1,049 | 1,319 | 1,453 | 1,520 | 137 | 1231 | 3590 | 4737 | 0 | 0 | 4 | 0 | 4 |
| T6 | VIII | 127 | 935 | 2436 | 3110 | 1,096 | 1,360 | 1,482 | 1,551 | 139 | 1271 | 3611 | 4825 | 0 | 0 | 0 | 0 | 0 |
| T6 | IX | 142 | 1026 | 2531 | 3098 | 1,040 | 1,318 | 1,449 | 1,546 | 148 | 1352 | 3668 | 4791 | 0 | 4 | 0 | 4 | 7 |
| T7 | I | 135 | 968 | 2464 | 3070 | 1,035 | 1,293 | 1,416 | 1,487 | 140 | 1251 | 3488 | 4566 | 0 | 7 | 0 | 0 | 7 |
| T7 | II | 144 | 986 | 2461 | 3025 | 0,975 | 1,294 | 1,431 | 1,511 | 141 | 1276 | 3523 | 4570 | 0 | 4 | 0 | 0 | 4 |
| T7 | III | 140 | 981 | 2519 | 3121 | 1,077 | 1,312 | 1,434 | 1,507 | 151 | 1286 | 3611 | 4703 | 0 | 0 | 0 | 4 | 4 |
| T7 | IV | 145 | 993 | 2514 | 3117 | 1,044 | 1,314 | 1,439 | 1,514 | 151 | 1305 | 3617 | 4718 | 0 | 0 | 0 | 0 | 0 |
| T7 | V | 131 | 955 | 2401 | 3012 | 1,027 | 1,278 | 1,424 | 1,489 | 135 | 1221 | 3420 | 4484 | 0 | 0 | 0 | 4 | 4 |
| T7 | VI | 152 | 993 | 2487 | 3080 | 1,014 | 1,286 | 1,439 | 1,520 | 154 | 1276 | 3579 | 4681 | 0 | 0 | 7 | 0 | 7 |
| T7 | VII | 144 | 978 | 2468 | 3031 | 1,040 | 1,307 | 1,434 | 1,525 | 149 | 1278 | 3539 | 4624 | 0 | 0 | 0 | 0 | 0 |
| T7 | VIII | 151 | 1009 | 2521 | 3121 | 0,986 | 1,310 | 1,470 | 1,562 | 149 | 1322 | 3704 | 4875 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T7 | IX | 138 | 961 | 2463 | 3077 | 1,016 | 1,309 | 1,452 | 1,534 | 140 | 1257 | 3576 | 4719 | 0 | 0 | 0 | 0 | 0 |
| T8 | I | 141 | 988 | 2563 | 3153 | 0,975 | 1,268 | 1,395 | 1,482 | 137 | 1253 | 3576 | 4674 | 0 | 4 | 0 | 0 | 4 |
| T8 | II | 125 | 966 | 2491 | 3155 | 1,078 | 1,287 | 1,408 | 1,476 | 134 | 1243 | 3506 | 4656 | 0 | 4 | 0 | 4 | 7 |
| T8 | III | 134 | 974 | 2530 | 3135 | 1,059 | 1,281 | 1,400 | 1,493 | 141 | 1247 | 3541 | 4681 | 0 | 0 | 0 | 0 | 0 |
| T8 | IV | 147 | 989 | 2478 | 3002 | 0,995 | 1,272 | 1,401 | 1,501 | 146 | 1258 | 3472 | 4507 | 0 | 4 | 0 | 4 | 7 |
| T8 | V | 133 | 1003 | 2487 | 3070 | 0,986 | 1,248 | 1,391 | 1,468 | 131 | 1252 | 3458 | 4507 | 0 | 4 | 0 | 0 | 4 |
| T8 | VI | 149 | 1026 | 2501 | 3100 | 1,048 | 1,290 | 1,427 | 1,510 | 156 | 1323 | 3570 | 4682 | 0 | 0 | 0 | 0 | 0 |
| T8 | VII | 151 | 1022 | 2517 | 3101 | 1,019 | 1,284 | 1,419 | 1,497 | 154 | 1312 | 3571 | 4643 | 0 | 0 | 0 | 0 | 0 |
| T8 | VIII | 144 | 998 | 2486 | 3088 | 1,005 | 1,288 | 1,422 | 1,498 | 144 | 1286 | 3534 | 4626 | 0 | 4 | 0 | 0 | 4 |
| T8 | IX | 140 | 999 | 2562 | 3190 | 1,005 | 1,273 | 1,418 | 1,493 | 141 | 1271 | 3631 | 4763 | 0 | 4 | 4 | 4 | 11 |

Apêndice 7. Rendimentos de carcaça, gordura e cortes comerciais de frangos de corte aos 42 dias de idade (referentes ao artigo do Capítulo IV), %.

| U.E. | Bloco | Carcaça | Gordura | Peito | Pernas | Asas | Dorso |
|---|---|---|---|---|---|---|---|
| T1 | I | 77,05 | 2,16 | 28,92 | 33,33 | 10,29 | 25,16 |
| T1 | II | 80,71 | 1,76 | 28,81 | 33,83 | 10,35 | 24,51 |
| T1 | III | 77,89 | 1,81 | 29,20 | 33,43 | 10,35 | 24,63 |
| T1 | IV | 78,37 | 1,96 | 29,18 | 33,51 | 10,87 | 24,37 |
| T1 | V | 78,25 | 1,97 | 28,41 | 33,82 | 10,84 | 24,40 |
| T1 | VI | 80,23 | 1,70 | 29,58 | 33,35 | 10,46 | 24,16 |
| T1 | VII | 78,43 | 2,05 | 28,71 | 33,42 | 10,38 | 24,74 |
| T1 | VIII | 78,79 | 1,58 | 29,10 | 33,17 | 10,59 | 24,81 |
| T1 | IX | 77,87 | 1,90 | 29,48 | 33,73 | 10,44 | 24,89 |
| T2 | I | 77,54 | 1,91 | 28,59 | 33,70 | 10,59 | 25,21 |
| T2 | II | 79,71 | 2,14 | 28,93 | 33,03 | 10,47 | 24,46 |
| T2 | III | 78,60 | 2,36 | 28,69 | 32,73 | 10,48 | 25,29 |
| T2 | IV | 79,40 | 1,95 | 29,88 | 33,06 | 10,48 | 23,88 |
| T2 | V | 79,54 | 2,12 | 28,25 | 33,25 | 10,85 | 24,46 |
| T2 | VI | 78,69 | 2,17 | 28,63 | 33,62 | 10,73 | 24,73 |
| T2 | VII | 79,81 | 2,13 | 29,18 | 33,23 | 10,30 | 24,59 |
| T2 | VIII | 77,64 | 1,85 | 29,22 | 32,92 | 10,68 | 24,44 |
| T2 | IX | 77,65 | 1,77 | 29,53 | 34,07 | 10,53 | 23,78 |
| T3 | I | 77,79 | 2,02 | 29,36 | 32,80 | 10,34 | 25,04 |
| T3 | II | 79,70 | 1,90 | 28,45 | 33,00 | 10,37 | 25,57 |
| T3 | III | 79,13 | 2,01 | 28,81 | 33,69 | 10,79 | 24,32 |
| T3 | IV | 79,55 | 1,69 | 29,96 | 33,02 | 10,38 | 24,60 |
| T3 | V | 77,61 | 2,07 | 29,19 | 33,03 | 10,77 | 24,64 |
| T3 | VI | 79,63 | 1,96 | 29,26 | 33,27 | 10,39 | 24,39 |
| T3 | VII | 79,50 | 2,05 | 28,68 | 32,86 | 10,79 | 24,85 |
| T3 | VIII | 77,86 | 1,74 | 30,10 | 32,98 | 10,67 | 24,16 |
| T3 | IX | 77,47 | 2,02 | 29,19 | 33,33 | 10,46 | 24,63 |
| T4 | I | 78,47 | 1,75 | 28,35 | 32,82 | 10,57 | 25,46 |
| T4 | II | 79,65 | 1,67 | 30,01 | 33,18 | 10,77 | 23,66 |
| T4 | III | 78,58 | 1,89 | 30,11 | 32,68 | 10,32 | 24,38 |
| T4 | IV | 78,81 | 1,82 | 29,67 | 32,52 | 10,76 | 24,05 |
| T4 | V | 78,57 | 1,89 | 29,40 | 32,78 | 10,87 | 24,69 |
| T4 | VI | 78,48 | 2,00 | 28,15 | 33,22 | 10,73 | 25,36 |
| T4 | VII | 78,17 | 1,96 | 29,13 | 32,40 | 10,63 | 25,17 |
| T4 | VIII | 78,61 | 1,84 | 29,47 | 33,31 | 10,47 | 24,33 |
| T4 | IX | 77,45 | 1,64 | 29,69 | 33,29 | 10,83 | 24,48 |
| T5 | I | 76,98 | 1,70 | 29,04 | 32,84 | 10,57 | 25,64 |
| T5 | II | 80,44 | 2,21 | 28,29 | 33,05 | 9,99 | 25,28 |
| T5 | III | 78,02 | 2,12 | 29,48 | 32,79 | 10,39 | 24,43 |
| T5 | IV | 78,37 | 1,90 | 29,90 | 33,09 | 10,51 | 24,33 |
| T5 | V | 79,06 | 1,74 | 29,26 | 32,87 | 10,57 | 24,59 |
| T5 | VI | 77,71 | 1,87 | 29,40 | 32,83 | 10,75 | 24,73 |
| T5 | VII | 78,48 | 2,10 | 28,49 | 33,80 | 10,68 | 24,68 |
| T5 | VIII | 78,40 | 1,99 | 30,35 | 32,68 | 10,45 | 24,38 |
| T5 | IX | 78,62 | 1,79 | 29,70 | 32,72 | 10,49 | 24,48 |
| T6 | I | 77,37 | 1,90 | 29,14 | 32,69 | 10,39 | 25,61 |
| T6 | II | 79,76 | 1,99 | 28,57 | 33,08 | 10,56 | 25,13 |
| T6 | III | 78,51 | 2,18 | 30,06 | 33,37 | 10,43 | 23,50 |
| T6 | IV | 77,64 | 2,02 | 29,03 | 33,35 | 10,71 | 24,43 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| T6 | V | 79,41 | 1,82 | 28,52 | 33,04 | 10,62 | 24,66 |
| T6 | VI | 79,18 | 2,03 | 28,86 | 33,11 | 10,49 | 24,52 |
| T6 | VII | 77,68 | 2,18 | 29,30 | 33,19 | 10,60 | 24,27 |
| T6 | VIII | 78,91 | 2,30 | 29,47 | 32,18 | 10,40 | 23,69 |
| T6 | IX | 78,93 | 2,11 | 30,48 | 32,34 | 10,04 | 24,08 |
| T7 | I | 78,53 | 1,83 | 29,83 | 32,20 | 10,41 | 24,90 |
| T7 | II | 78,99 | 1,89 | 30,07 | 32,20 | 10,46 | 25,05 |
| T7 | III | 80,90 | 1,81 | 29,35 | 33,46 | 10,29 | 24,06 |
| T7 | IV | 78,66 | 2,12 | 28,86 | 33,41 | 10,58 | 24,51 |
| T7 | V | 78,39 | 2,01 | 29,25 | 32,70 | 10,74 | 24,74 |
| T7 | VI | 79,08 | 1,91 | 29,23 | 33,22 | 10,34 | 24,39 |
| T7 | VII | 78,68 | 2,10 | 28,90 | 33,15 | 10,62 | 24,90 |
| T7 | VIII | 80,06 | 2,38 | 29,59 | 32,88 | 10,15 | 24,03 |
| T7 | IX | 78,55 | 2,27 | 30,56 | 32,71 | 10,21 | 24,07 |
| T8 | I | 78,26 | 1,62 | 30,54 | 32,75 | 10,30 | 24,24 |
| T8 | II | 79,00 | 1,97 | 29,81 | 33,02 | 10,55 | 24,12 |
| T8 | III | 79,39 | 1,69 | 29,80 | 32,31 | 10,37 | 24,46 |
| T8 | IV | 77,69 | 1,81 | 29,70 | 32,96 | 10,90 | 24,57 |
| T8 | V | 78,13 | 1,92 | 29,01 | 33,07 | 10,61 | 24,74 |
| T8 | VI | 78,87 | 1,85 | 28,91 | 32,82 | 10,72 | 24,99 |
| T8 | VII | 78,87 | 2,01 | 29,41 | 32,95 | 10,74 | 24,42 |
| T8 | VIII | 78,28 | 1,92 | 30,08 | 32,27 | 10,79 | 24,24 |
| T8 | IX | 78,02 | 1,50 | 30,31 | 32,66 | 10,61 | 24,26 |

Apêndice 8. Modelo geral do programa utilizado no pacote estatístico SAS (2001) para análise de linha quebrada (referente ao artigo do Capítulo III).

```
data one;
input x y;
cards;
0.64 1.733
0.70 1.704
0.75 1.709
0.81 1.691
0.86 1.691
0.91 1.695
;
data fill;
 do x=0.64 to 0.91 by 0.001; y=.; output; end;
run;
data one; set one fill; run;
proc sort data=one; by x;

proc nlin;
parameters l=1.6921 u=0.2321 r=0.7972;
z1=(x<r)*(r-x);
model y=l+u*(z1);
output out=ppp p=predy;
run;

proc gplot;
 title 'VAL Requirements';
 goptions hpos=45 vpos=45 ftext=swiss;
 symbol1 v=dot c=black;
 symbol2 i=join v=none c=black;
 plot y*x predy*x/overlay;
run;
quit;
```

# VITA

Josemar Berres, primogênito de Pedro Celso Berres e Arsicia Maria Berres, nasceu em Cândido Godói, RS, aos 12 de junho de 1981. Cursou o ensino fundamental nos colégios Medianeira (La Salle) em Cerro Largo, RS e Pio X em Palmeira das Missões, RS. Concluiu o ensino médio na Escola de 1° e 2° Graus da Universidade Regional Integrada de Frederico Westphalen, RS. Em 1999 ingressou no Curso de Zootecnia da Universidade Federal de Santa Maria, RS, obtendo o Grau de Zootecnista em janeiro de 2004. Iniciou, em março de 2004, o curso de mestrado na área de Produção Animal, subárea Nutrição de Não-ruminantes, no Programa de Pós-graduação em Zootecnia da Universidade Federal do Rio Grande do Sul, Porto Alegre, RS. No ano de 2006 prosseguiu em suas pesquisas na área de nutrição de frangos de corte quando iniciou seu doutorado nesta mesma instituição, permanecendo nesta até o presente momento.