MARIO LUIZ CHIZZOTTI

EXIGÊNCIAS NUTRICIONAIS DE BOVINOS NELORE, PUROS E CRUZADOS, DE DIFERENTES CLASSES SEXUAIS

Tese apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Zootecnia, para obtenção do título de *Doctor Scientiae.*

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À minha esposa Fernanda.

Ao meu filho Luigi.

Dedico

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BIOGRAFIA

MARIO LUIZ CHIZZOTTI, filho de Mario Chizzotti Filho e Terezinha Albina Destro Chizzotti, nasceu em Bocaina, SP, em 10 de maio de 1980.

Em setembro de 2002, graduou-se em Zootecnia pela Universidade Federal de Viçosa.

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RESUMO

CHIZZOTTI, Mario Luiz, D.Sc., Universidade Federal de Viçosa, setembro de 2007. **Exigências nutricionais de bovinos Nelore, puros e cruzados, de diferentes classes sexuais**. Orientador: Sebastião de Campos Valadares Filho. Co-Orientadores: Mario Fonseca Paulino e Rilene Ferreira Diniz Valadares

Foi conduzido um experimento de abate comparativo envolvendo 36 bovinos F1 Nelore x Red Angus (12 machos castrados, 12 machos inteiros e 12 fêmeas), com peso médio inicial de 274 kg, para determinar as exigências líquidas de proteína e energia para mantença e crescimento e as exigências líquidas para crescimento de macrominerais. Três animais de cada classe sexual (macho castrado, macho inteiro e fêmea) foram abatidos no início do experimento para determinação da composição corporal inicial. Os animais restantes foram aleatoriamente alocados em três tratamentos: alimentação ao nível de mantença (dieta fornecida ao nível de 1,2% do PV/dia, contendo 70% da matéria seca de silagem de milho) ou fornecimento de 0,75 ou 1,5 % do PV/dia de concentrado sendo a silagem de milho fornecida à vontade. As dietas foram isonitrogenadas (2% N, na base seca). O delineamento experimental proporcionou variação no consumo de energia metabolizável (CEM), peso vivo (PV) e ganho médio diário em peso (GMD) permitindo o desenvolvimento de equações de regressão para predizer as exigências líquidas energia e proteína para mantença (EL_m e PL_m, respectivamente) e para crescimento (energia retida, ER; e proteína retida, PR, respectivamente). Após 84 dias em confinamento, os animais foram abatidos. O trato gastrointenstinal vazio, órgãos, carcaças, cabeça, couro, cauda, patas, sangue e demais tecidos foram pesados para determinar o peso de corpo vazio (PCVZ). Cada parte foi pesada separadamente e amostrada para análise química. O consumo de matéria seca foi determinado individualmente e diariamente. Em cada período, foram coletadas amostras de fezes para determinação da digestibilidade da dieta. O antilog do intercepto da regressão linear do log da produção de calor (PC) no CEM foi utilizado para estimar a EL_m (na base kcal/$kg^{0,75}$ PCVZ/dia). A exigência de energia metabolizável para mantença foi calculada por iteração, assumido que o requerimento de mantença é o valor no qual a PC se iguala ao CEM na seguinte equação: $PC = \beta_0 \times e^{(\beta 1 \times CEM)}$. O coeficiente de inclinação da regressão da energia retida no CEM foi adotado como a eficiência de utilização da energia metabolizável para crescimento (K_g). Alternativamente, o intercepto dividido pelo K_g foi utilizado para calcular a exigência de energia metabolizável para mantença. A PR foi calculada por *c* + (*d* × PCVZ) + (*e* × ER) onde *c, d* e *e* são o intercepto e os coeficientes da regressão múltipla da PR no PCVZ e ER, respectivamente. O log do conteúdo corporal de cada mineral no PCVZ foi regredido no log do PCVZ para estimar as exigências líquidas de cada mineral por kg de ganho de PCVZ (GCPVZ). Uma meta-análise foi conduzida para determinar as exigências líquidas de energia e proteína de machos inteiro, machos castrados e fêmeas Nelore, puros e cruzados, em crescimento. Um banco de dados com 16 estudos de abate comparativo (n=389 animais) foi construído para fornecer informações necessárias para predizer os requerimentos líquidos de energia e proteína para mantença e crescimento. Os dados foram analisados utilizando-se um modelo de coeficientes aleatórios, considerando os estudos como efeito aleatório e a classe sexual (machos inteiros, machos castrados e fêmeas; n = 262, 103 e 24, respectivamente) e o grupo genético como efeitos fixos. Para o experimento descrito, não houve diferença na EL_m entre as classes sexuais de bovinos F1 Nelore x Red Angus. Os dados agrupados indicaram EL_m de 71,2 $kcal \cdot kg^{-0.75}$ $PCVZ \cdot dia^{-1}$, com eficiência parcial de utilização da energia metabolizável em energia líquida para mantença de 0,71. A eficiência parcial de utilização da energia metabolizável em energia líquida para crescimento foi de 0,54 para machos inteiros, 0,47 para machos castrados e 0,54 para fêmeas. A exigência de energia líquida para crescimento de machos castrados foi similar à de fêmeas, entretanto as exigências de ER de machos castrados e fêmeas foram 18,7% superiores à de machos inteiros. A PL_m não diferiu entre as classes sexuais apresentando média de 2,53 g $PB \cdot kg^{-0,75}$ $PCVZ \cdot dia^{-1}$. Similarmente, a PR não diferiu entre as classes sexuais. A porcentagem da energia retida depositada como proteína ($\%ER_p$) aumentou exponencialmente à medida que a concentração energética no ganho (ER_c, Mcal/kg GCPVZ) diminuiu. Não houve diferença nas exigências líquidas para crescimento de macrominerais entre classes sexuais. As equações dos dados em conjunto das exigências líquidas para crescimento (g/kg GCPVZ) foram: $0,3327 \times PCVZ^{0,6367}$ para Ca, $0,1121 \times PCVZ^{-0,5615}$ para P, $0,0108 \times PCVZ^{-0,3992}$ para Na, $0,004 \times PCVZ^{-0,153}$ para K e $0,0036 \times PCVZ^{-0,462}$ para Mg. Para a meta-análise, não houve diferença entre as classes sexuais e os grupos genéticos para a EL_m. Os dados agrupados indicaram EL_m de 75 $kcal/kg^{0,75}$ PCVZ, com uma eficiência parcial de utilização da energia metabolizável como EL_m de 0,67. A ER diferiu entre as classes sexuais e tendeu a diferença (P=0,06) entre os grupos genéticos. As equações de ER foram: 0,0514 × $PCVZ^{0,75}$ × $GPCPVZ^{1,070}$, para machos inteiros; 0,0700 × $PCVZ^{0,75}$ × $GPCPVZ^{1,070}$, para machos castrados; e 0,0771 × $PCVZ^{0,75}$ × $GPCPVZ^{1,070}$, para fêmeas. A eficiência parcial de utilização da EM para ER não foi diferente entre classes sexuais ou grupos genéticos, apresentando média de 0,44. Não houve diferença na exigência de PL_m entre classes sexuais ou grupos genéticos; a PL_m geral foi de 1,74 $g \cdot kg^{-0,75}$ $PCVZ \cdot dia^{-1}$. A PR, g/dia, não diferiu entre classes sexuais ou grupos genéticos; a equação geral foi GCPVZ × (217 – 12,8 × ER/GCPVZ). A $\%ER_p$ decresceu exponencialmente à medida que a ER_c aumentou. Como não houve efeito de estudo, os dados foram agrupados e a equação geral para predizer $\%ER_p$ foi $0,101 + 1,667 \times e^{(-0,660 \times ERc)}$. Nossos resultados não sustentam a hipótese de que machos inteiros têm exigências de EL_m superiores às de machos castrados e fêmeas. Similarmente, não houve diferença para as exigências de PL_m entre as classes sexuais e grupos genéticos. Entretanto, ER de machos castrados foi superior e inferior à de machos inteiros e fêmeas, respectivamente. Embora a porcentagem da energia retida como proteína tenha correlacionado negativamente com a ER_c, não houve diferenças para PR entre machos inteiros, machos castrados e fêmeas.

ABSTRACT

CHIZZOTTI, Mario Luiz, D.Sc., Universidade Federal de Viçosa, September of 2007. **Nutrient requirements of Nellore cattle, purebred and crossbred, of different sexual groups**. Adviser: Sebastião de Campos Valadares Filho. Co-Advisers: Mario Fonseca Paulino e Rilene Ferreira Diniz Valadares

A comparative slaughter trial was conducted with 36 F1 Nellore x Red Angus calves (12 steers, 12 bulls, and 12 heifers), averaging 274 kg BW, to assess the net requirements of protein and energy for growth and maintenance and the net requirements of macro-minerals for growth. Three animals from each group (i.e., steers, bulls, and heifers) were slaughtered at the beginning of the trial to determine the initial body composition. The remaining calves were randomly assigned to 3 treatments: maintenance level (diet containing 70% of DM as corn silage fed at 1.2% of BW daily) or fed concentrate at 0.75 or 1.5% of BW daily with corn silage available for ad libitum consumption. The diets were isonitrogenous (2% N, DM basis). The experimental design provided ranges in ME intake, BW, and ADG for the development of regression equations to predict the maintenance requirements for net energy and net protein (**NE_m** and **NP_m**, respectively) and the growth requirement for net energy and net protein (**NE_g** and **NP_g**, respectively). After 84 d of growth, cattle were slaughtered. The cleaned gastrointestinal tracts, organs, carcasses, heads, hides, tails, feet, blood, and tissues were weighed to measure empty BW (**EBW**). These parts were ground separately and sub-sampled for chemical analyses. For each animal within a period, DMI was measured daily and samples of feces were collected to determine diet digestibility. The antilog of the intercept of the linear regression between the log of heat production (**HP**) on metabolizable energy intake (**MEI**) was used to estimate the NE_m (on a $kcal/kg^{0.75}$ of EBW daily). The ME

required for maintenance (**ME_m**) was calculated by iteration, assuming that the maintenance requirement is the value at which HP is equal to MEI according to this equation: $HP = \beta_0 \times e^{(\beta 1 \times MEI)}$. The slope of the regression of retained energy (**RE**) on MEI was assumed to be the efficiency of energy utilization for growth (**K_g**). Alternatively, the intercept divided by the slope (K_g) was used to compute ME_m. The NP_m was assumed to be the intercept of the linear regression of the retained N on N intake. The NE_g was calculated as $a \times EBW^{0.75} \times EWG^b$, where **EBW** is empty BW; *a* and *b* are the antilog of the intercept and the slope of the linear regression of the log of the RE on the log of the empty body gain (**EWG**). The NP_g was calculated as $c + (d \times EBW) + (e \times RE)$ where *c*, *d*, and *e* are the intercept and slopes of the multiple regression of the retained protein on the EBW and RE, respectively. The log of the contents of each mineral in the EBW was regressed on the log of the EBW to estimate the net requirement for each mineral per kg of empty body gain (EBG). A meta-analysis was conducted to determine net energy and net protein requirements of growing bulls, steers, and heifers of Nellore purebred and Nellore × *Bos taurus* crossbreds. A database of 16 comparative slaughter studies (n = 389 animals) was gathered to provided enough information to develop equations to predict the NE_m, NE_g, NP_m and NP_g. The data were analyzed using a random coefficients model, considering studies as random effects, and genders (bulls, steers, and heifers; n = 262, 103 and 24, respectively) and breeds as fixed effects. For the experiment, there were no differences in NE_m ($P = 0.06$) among genders for F1 Nellore x Red Angus cattle. The combined data indicated a NE_m of 71.2 $kcal \cdot kg^{-0.75}$ of $EBW \cdot d^{-1}$, with a partial efficiency of use of ME to NE for maintenance of 0.71. The partial efficiency of use of ME to NE for growth was 0.54 for bulls, 0.47 for steers, and 0.54 for heifers. The NE_g for steers and heifers were similar but were 18.7% greater than for bulls.

The NP_m did not differ among genders and averaged 2.53 g $NP_m \cdot kg^{-0.75}$ of $EBW \cdot d^{-1}$. Likewise, NP_g was not different among genders. The percentage of retained energy deposited as protein (%RE_p) increased as the content of retained energy in the gain (RE_c, Mcal/kg of EWG) decreased. There were no differences in the net requirements for growth of macrominerals among genders. The equations of the pooled data of the net requirements for growth (g/kg EWG) were: $0.3326 \times EBW^{0.6367}$ for Ca, $0.1121 \times EBW^{-0.5615}$ for P, $0.0108 \times EBW^{-0.3992}$ for Na, $0.004 \times EBW^{-0.153}$ for K, and $0.0036 \times EBW^{-0.462}$ for Mg. For the meta-analisys study, there were no differences in NE_m among genders and breeds. The combined data indicated a NE_m requirement of 75 kcal/$kg^{0.75}$ of EBW with a partial efficiency of use of ME to NE_m of 0.67. The NE_g requirement was different ($P = 0.009$) among genders and tended ($P = 0.06$) to be different among breeds. The equation for NE_g for bulls was $0.0514 \times EBW^{0.75} \times EWG^{1.070}$, for steers it was $0.0700 \times EBW^{0.75} \times EWG^{1.070}$; and for heifers it was $0.0771 \times EBW^{0.75} \times EWG^{1.070}$. The partial efficiency of use of ME to NE_g was not different among genders and breeds, and averaged 0.44. There were no differences in NP_m requirement among genders and breeds; the overall NP_m requirement was 1.74 g of $NP \cdot kg^{-0.75}$ $EBW \cdot d^{-1}$. The overall MP requirement for maintenance was 2.59 g of $MP \cdot kg^{-0.75}$ $EBW \cdot d^{-1}$. The NP_g requirement, g/d, was not different among genders and breeds; the overall equation was $EWG \times (217 - 12.8 \times RE/EWG)$, where RE is Mcal/d. %$RE_p$ decreased exponentially as the RE_c incresead. Because no study effect was observed, we pooled the data across studies and the overall equation to predict %RE_p was $0.101 + 1.667 \times e^{(-0.660 \times REc)}$. Our results do not support the hypothesis that bulls have greater NE_m requirements than steers and heifers. Likewise, no significant differences in the NP_m requirements among bulls, steers, and heifers were detected. Nonetheless, the NE_g requirement of steers was greater than for bulls and lesser than for heifers. Even though the $\%RE_p$ was negatively correlated with RE_c, our findings indicated no differences in NP_g requirement for bulls, steers, and heifers.

INTRODUÇÃO

O êxito da exploração comercial bovina em regiões tropicais depende, em grande parte, do potencial de produção dos animais e da capacidade de adaptação destes ao ambiente. De acordo com Bezerra (1969), a vitória do Zebu na faixa tropical da pecuária nacional tem bases nas condições ecológicas da sua pátria de origem onde desenvolveu em milhares, talvez milhões, de anos, os admiráveis dispositivos de tolerância e resistência aos agentes agressivos dos trópicos. A predominância desses animais nos sistemas de produção de gado de corte no Brasil pode ser relacionada a um desempenho superior desses animais em relação aos taurinos quando ambos são alimentados com dietas de menor concentração energética, como as pastagens tropicais.

A exigência de energia líquida para mantença pode ser definida pela energia despendida no metabolismo basal, pelo calor produzido pelas atividades fisiológicas e físicas necessárias à sobrevivência do animal e pela energia de regulação térmica. Fatores como idade, peso, espécie, raça, classe sexual, atividade muscular, nível de ingestão alimentar e o clima ocasionam as principais diferenças nos requisitos nutricionais entre os animais (Garrett, 1980). A maior tolerância de bovinos Nelore ao estresse calórico em relação a bovinos *B. taurus* pode ser atribuída a fatores morfológicos como maior superfície corporal devido às dobras da pele, pêlo curto, que facilita a perda de calor corporal, e de coloração clara, que favorece a reflexão da radiação solar; pele escura que diminui danos causados pela radiação ultra-violeta e intensa sudação em decorrência do maior número, tamanho e atividade das glândulas sudoríparas em relação a bovinos *B. taurus*. Além disso, a adaptação de zebuínos ao ambiente tropical pode ser atribuída a adpatações fisiológicas, como uma menor geração de calor interno (metabólico) em relação aos taurinos, tornando os bovinos de origem Indiana mais eficientes no uso da energia despendida com a regulação térmica.

A atividade metabólica celular é distinta entre os diferentes tecidos que compõe o corpo do animal. Embora representem apenas 8 a 14 % do peso animal, o trato gastrointestinal (TGI) e o fígado consomem aproximadamente metade da energia para mantença (Seal & Reynolds, 1993), sendo considerados os tecidos de maior atividade metabólica, em função da alta taxa de *turnover* protéico e transporte iônico ativo. Segundo Caton & Dhuyvetter (1997) os tecidos viscerais e muscular consomem 50% e 23% da energia utilizada para mantença, e tal diferença pode ser atribuída à maior taxa de *turnover* protéico dos órgãos viscerais em relação ao tecido muscular. De acordo com Reynolds (2002), o conjunto fígado-TGI foi responsável pela utilização de 36 a 54% do total do oxigênio consumido por bovinos lactantes ou em crescimento e realizaram entre 25 a 45 % da síntese protéica total. Desta forma, diferenças no tamanho (ou atividade) do fígado e do TGI entre raças bovinas podem resultar em alterações nas exigências nutricionais. Ferrell & Jenkins (1998) encontraram diferenças nas exigências líquidas de energia para mantença entre novilhos cruzados filhos de touros *Bos taurus* ou *Bos indicus*. Neste mesmo estudo os autores identificaram efeito da raça do touro sobre o peso de órgãos e vísceras da sua progenie, onde os filhos de touros Tuli (*B. indicus*) apresentaram pesos do fígado e do TGI inferiores aos observados na progenie de touros Angus (*Bos taurus*). Menezes et al. (2007) reportaram que o peso do fígado e do TGI expressos em porcentagem do peso de corpo vazio foram maiores em novilhos Charolês em relação aos Nelore. Peron et al. (1993) também observaram menores pesos do TGI em animais Nelore em relação aos taurinos. O menor tamanho do TGI pode ser atribuído ao menor potencial de consumo das raças zebuínas em relação à taurinas, como observado por Menezes & Restle (2005) e Ferrell & Jenkins (1998). Portanto, em virtude da maior porcentagem de órgãos de alta atividade metabólica em relação ao peso de corpo vazio em taurinos, pode-se inferir que esses geram mais calor devido à atividade desses órgãos do que animais zebuínos.

A perda metabólica fecal é proveniente da incompleta reabsorção dos nutrientes perdidos pela descamação e pela secreção enzimática do TGI e pode ser alterada pelo tipo e quantidade de alimento ingerido, bem como pelo tamanho e atividade do TGI. Ezequiel (1987) estimou que as exigências de proteína metabolizável para mantença de 1,72 e 4,28 g/kg^{0,75} PV para novilhos Nelore e Holandês, respectivamente o que sugere que a a perda através da excreção de metabólitos endógenos em bovinos Nelore é inferior à de bovinos Holandeses. A maior excreção endógena leva a uma maior perda líquida de aminoácidos e, como esses são amplamente catabolizados ou excretados pelas células intestinais, a reciclagem (ou *turnover*) de aminoácidos deverá ser maior para que existam aminoácidos disponíveis para a síntese de proteínas do muco, do epitélio intestinal e do complexo enzimático envolvido na digestão, aumentando a produção de calor associada à taxa de *turnover* protéico.

O NRC (2000) sugere que zebuínos apresentam exigências de energia líquida para mantença 10 % inferiores à de taurinos. Baseando-se no valores de energia metabolizável para mantença do NRC (2000) de 118 para machos castrados e fêmeas e 136 kcal/PCVZ^{0,75}/dia para machos inteiros de origem taurina, Valadares Filho et al. (2006) reportaram que as exigências energéticas de zebuínos foram inferiores em 8% para machos castrados e fêmeas e em 20% para machos inteiros. Entretanto, Tedeschi et al. (2002) utilizando informações de três experimentos, reportaram exigências de energia líquida para mantença de bovinos Nelore semelhantes à adotada pelo NRC (2000) para bovinos *B. taurus*.

A exigência líquida de energia para o crescimento pode ser definida como a energia retida no corpo, a qual depende do ganho e da composição do ganho de corpo vazio. O principal determinante da composição do ganho de corpo vazio não é o peso corporal absoluto, mas sim o peso relativo ao peso à maturidade do animal. À medida que o animal aproxima-se de seu peso à maturidade, observa-se um aumento progressivo na proporção de gordura e concomitante decréscimo das de água, proteína e minerais no corpo animal (AFRC, 1993). Diferenças na composição do ganho entre raças de pequeno ou grande porte são esperadas para animais de mesmo peso corporal absoluto. Dessa forma, para animais de mesmo peso absoluto e à mesma taxa de ganho em peso, são esperadas maiores concentrações energéticas no ganho de animais com menor peso à maturidade em relação aos animais de maturidade mais tardia.

A eficiência de utilização da energia metabolizável para ganho de peso (K_g) tem sido estimada pelo coeficiente da regressão linear entre a energia retida (ER) e o consumo de energia metabolizável (Ferrell & Jenkins, 1998; NRC, 2000) e mais recentemente, a estimativa da K_g foi realizada baseada nas eficiências de deposição de gordura e proteína no corpo vazio (Tedeschi et al, 2004; Willians & Jenkins, 2003), devido às distintas eficiências de deposição de gordura e proteína. A eficiência energética de acréscimo protéico é altamente variável, pois é afetada pelo estágio fisiológico, estado de nutrição e pela taxa de reciclagem protéica do animal, ao contrário da eficiência de acréscimo de gordura, que é reconhecida como de menor amplitude de variação. Geay (1984) relataram que as eficiências energéticas de acréscimo de proteína e gordura foram de 0,20 e 0,75, respectivamente, utilizando dados obtidos em 52 experimentos utilizando predominantemente raça taurinas. A variação na eficiência de acréscimo protéico está relacionada às variações na taxa de *turnover*, pois maiores taxa de *turnover* protéico associados a maiores taxas de acréscimo muscular resultam em aumento na produção de calor e redução na eficiência de utilização da energia metabolizável (Owens et al., 1995). A redução do *turnover* protéico pode ocasionar um maior acúmulo de tecido muscular. Com a redução na taxa de degradação protéica com a mesma (ou até mesmo inferior) taxa de síntese protéica a eficiência de acréscimo muscular é melhorada, favorecendo a sua deposição. O acréscimo de tecido muscular através da redução da degradação protéica é mais eficiente do que por meio do aumento na síntese desta, pois um aumento significativo na taxa de oxidação de aminoácidos é esperado para promover uma maior taxa de síntese protéica (Lobley, 2003).

Além do grupo genético, a classe sexual (macho castrado, macho não-castrado ou fêmea) influencia a deposição de tecidos, a composição da carcaça, a eficiência alimentar (Berg & Butterfield, 1976) e as exigências de energia líquida para mantença (ARC, 1980; NRC, 2000). De acordo com o NRC (2000), machos inteiros têm exigências de energia líquida para mantença 15% superiores e de energia líquida para ganho em peso 18% inferiores às de machos castrados, enquanto fêmeas requerem 18% mais de energia líquida para ganho em peso em relação aos machos castrados. Valadares Filho et al. (2006) relataram que as exigências de energia líquida para ganho de peso de machos castrados foi 13% superior e 17% inferior às de machos inteiros e fêmeas, respectivamente. Observa-se que a maioria das pesquisas com animais zebuínos e seus cruzados foram efetuadas com machos inteiros, alguns trabalhos foram realizados com machos castrados, e poucos utilizaram fêmeas de corte em crescimento.

Na literatura nacional, são verificadas discrepâncias entre as exigências de zebuínos e seus cruzados propostas por autores brasileiros e as estabelecidas por conselhos de pesquisa internacionais (ARC, 1980; AFRC 1993; NRC, 2000). Quando o efeito do estudo sobre as observações bem como a heterogeneidade das variâncias não são considerados em regressões envolvendo dados de múltiplos experimentos, erros consideráveis podem estar contidos nas estimativas dos parâmetros da equação de regressão (St-Pierre, 2001), limitando a inferência quantitativa dos dados avaliados. Recentemente, com o avanço nos softwares estatísticos e no conhecimento do uso de modelos mistos (aqueles contendo efeitos fixos e aleatórios) a análise de dados provenientes de diferentes experimentos foi aprimorada, possibilitando uma avaliação quantitativa dos resultados disponíveis na literatura. Quando o efeito de estudo é quantificado e considerado pelo modelo estatístico na comparação de dados oriundos de diferentes experimentos, essa análise estatística é denominada meta-análise (Glass, 1976).

A otimização da utilização de dietas, assim como a estimação do desempenho animal, demanda o conhecimento das exigências nutricionais. Portanto, torna-se imprescindível determinar as exigências nutricionais de bovinos de diferentes classes sexuais e grupos genéticos, criados sob condições brasileiras pois essas são notadamente distintas daquelas presentes em países de clima temperado. A meta-análise dos dados disponíveis sobre as exigências nutricionais de bovinos Nelore e seus cruzados no Brasil é necessária para promover uma interpretação conjunta desses dados, bem como para detectar lacunas no conhecimento e indicar a necessidade de novas pesquisas na área.

Diante do exposto, o presente trabalho foi conduzido objetivando-se:

- Determinar as exigências nutricionais de proteína, energia e macrominerais de animais F1 Nelore x Red Angus de diferentes classes sexuais;
- Determinar as exigências nutricionais de energia e proteína de bovinos Nelore, puros ou cruzados com *Bos taurus*, de diferentes classes sexuais, criados sob condições brasileiras.

Essa tese foi redigida no formato de artigos científicos. Os artigos científicos 1 e 2 foram redigidos de acordo com as normas do Journal of Animal Science e o artigo científico 3 de acordo com as normas do periódico Animal Feed Science and Technology.

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Energy and protein requirements for growth and maintenance of F1 Nellore x Red Angus bulls, steers, and heifers[1]

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ABSTRACT: A comparative slaughter trial was conducted with 36 F1 Nellore x Red Angus calves (12 steers, 12 bulls, and 12 heifers), averaging 274 kg BW, to assess the net requirements of protein and energy for growth and maintenance. Three animals from each group (i.e., steers, bulls, and heifers) were slaughtered at the beginning of the trial to determine the initial body composition. The remaining calves were randomly assigned to 3 treatments: maintenance level (diet containing 70% of DM as corn silage fed at 1.2% of BW daily) or fed concentrate at 0.75 or 1.5% of BW daily with corn silage available for ad libitum consumption. The diets were isonitrogenous (2% N, DM basis). The experimental design provided ranges in ME intake, BW, and ADG for the development of regression equations to predict the maintenance requirements for NE and net protein (**MRNE** and **MRNP**, respectively) and the growth requirement for NE and net protein (**GRNE** and **GRNP**, respectively). After 84 d of growth, cattle were slaughtered. The cleaned gastrointestinal tracts, organs, carcasses, heads, hides, tails, feet, blood, and tissues were weighed to measure empty BW (**EBW**). These parts were ground separately and sub-sampled for chemical analyses. For each animal within a period, DMI was measured daily and samples of feces were collected to determine diet digestibility. There were no differences in MRNE ($P = 0.06$) among genders. The combined data indicated a MRNE of 71.2 $\text{kcal}\cdot\text{kg}^{-0.75}$ of $\text{EBW}\cdot\text{d}^{-1}$, with a partial efficiency of use of ME to NE for maintenance of 0.71. The partial efficiency of use of ME to NE for growth was 0.54 for bulls, 0.47 for steers, and 0.54 for heifers. The GRNE for steers and heifers were similar ($P = 0.15$) but were 18.7% greater ($P = 0.03$) for steers and heifers than for bulls. The MRNP did not differ among genders and averaged 2.53 g $\text{CP}\cdot\text{kg}^{-0.75}$ of $\text{EBW}\cdot\text{d}^{-1}$. Likewise, GRNP was not different among genders. The percentage of retained energy deposited as protein (**$\mathbf{RE_p}$**) increased as the content of retained energy in the gain (**$\mathbf{RE_c}$**, Mcal/kg of empty body gain) decreased. The RE_p equation of the pooled data was $46.5 \times e^{-0.2463 \times RE_c}$. We conclude that the energy requirement of crossbred *Bos indicus* x *Bos taurus* for maintenance might be less than that of pure *Bos taurus* and that RE_p is nonlinearly, negatively correlated with RE_c. The GRNE was less for bulls than for steers and heifers. However, we found no differences in MRNE, MRNP, and GRNP for bulls, steers, and heifers of Nellore x Red Angus crossbreds.

Key Words: beef cattle, *Bos indicus*, comparative slaughter, digestible energy, net energy, net protein

INTRODUCTION

The nutrient requirements recommended by NRC (2000) are widely adopted to formulate diets around the world. Nevertheless, the nutrient requirement equations were based on *Bos taurus* cattle, with adjustments to maintenance requirements for NE (**MRNE**) for *Bos indicus* breeds. Crossbred cattle (*Bos indicus* × *Bos taurus*) are an important component of beef production systems in several parts of the world, including tropical and sub-tropical regions. The availability and quality of meat depends on accurate information about energy and nutrient requirements for these breeding systems. According to NRC (2000), *Bos indicus* breeds of cattle require about 10% less energy for maintenance than beef breeds of *Bos taurus* cattle, with crossbreds being intermediate. Nevertheless, Tedeschi et al. (2002), using data of 3 studies with Nellore (*Bos indicus*) steers and bulls, found maintenance requirements similar to that adopted by the NRC (2000) for *Bos taurus* breeds.

Additionally, it has been recognized that gender (castrate and intact male or female) influences growth of body tissues, carcass composition, feed conversion (Berg and Butterfield, 1976), and the energy and nutrient requirements for maintenance (ARC, 1980). The NRC (2000) also discussed the effect of gender on energy requirements for maintenance and growth, although few studies have compared genders under the same experimental conditions.

The objective of this study was to use body composition data from a comparative slaughter trial of bulls, steers, and heifers of Nellore (*Bos indicus*) and Red Angus (*Bos taurus*) crossbreds fed high levels of forage to determine energy and protein requirements for maintenance and growth.

MATERIALS AND METHODS

Animal and Management Description

The trial was conducted at the Federal University of Viçosa, in Brazil, with 36 F1 Nellore x Red Angus calves (12 bulls, 12 steers, and 12 heifers). Humane animal care and handling procedures were followed, according to the guidelines of the Federal University of Viçosa (Brazil). All calves were from the same sire (Red Angus). The average age and initial shrunk BW (**SBW**) were 14 to 16 mo and 275 ± 7 kg for bulls, 14 to 16 mo and 278 ± 8 kg for steers, and 12 to 14 mo and 228 ± 10 kg for heifers. The cattle were fed the same diet during 2 wk (75% corn silage and 25% concentrate C1, DM basis; Table 1) until the beginning of the experiment. The average initial DMI was 2.36 ± 0.35% of BW daily. The diet DM was formulated to be isonitrogenous (2% N; 12.5% CP) among treatments and consisted of corn silage and concentrate (Table 1). The baseline group was composed of 3 randomly selected calves of each gender. Three animals of each gender were randomly assigned to 3 treatments: fed at maintenance level (1.2% of BW daily of a diet containing 70% corn silage and 30% concentrate C1, DM basis) or fed concentrate at 0.75 or 1.5% of BW daily with corn silage offered for ad libitum consumption. Calves fed at maintenance level and at 0.75% BW of concentrate daily, received the concentrate C1, whereas calves fed at 1.5% BW daily received the concentrate C2 (Table 1); concentrate C1 had greater content of CP and minerals than concentrate C2 to ensure a similar intake of these nutrients between cattle fed at 0.75 or 1.5% BW of concentrate daily. The animals were fed twice daily (at 0700 and 1600) in individual sheltered pens. Feeds and orts were weighed daily, sampled, and frozen. There were 3 growing periods of 28 d, starting after the slaughter of the baseline group. The cattle were weighed at the beginning and at the end of each period, within which animal performance and diet composition and digestibility were measured. A 14-d adaptation period was used to adapt cattle to the diets.

Diet Digestibility Determination

Digestion trials were conducted with all cattle in each period to determine diet DE. Indigestible ADF was used as a marker to estimate fecal DM excretion. Feces were collected at 0800 on d 15, at 1200 on d 17, and at 1600 on d 19 of each experimental period. The samples of feces, feeds (silage and concentrate), and orts of the digestibility trial's week were dried at 60 to 65ºC, ground to pass a 1-mm screen, and proportionally sub-sampled to a composite sample. The composite sample for each material (silage, concentrate, orts, and feces) was used to determine the ether extract (**EE**, by loss in weight of the dry sample upon extraction with diethyl ether in Soxhlet extraction apparatuses for 6 h; AOAC, 1990), protein (N analysis via micro Kjeldahl using 0.3 g of sample; AOAC, 1990), NDF (Van Soest et al., 1991), and ash (complete combustion in a muffle furnace at 600°C for 6 h; AOAC, 1990). Non-fiber carbohydrates (**NFC**) were calculated as 100 – [(%CP - %CP from urea + % of urea) + %NDF + %EE + %ash] (Hall, 2000) and apparent TDN was calculated as (CP intake – fecal CP) + (NDF intake – fecal NDF) + (NFC intake – fecal NFC) + [2.25 × (EE intake – fecal EE)] (Sniffen et al., 1992).

Urinary N Excretion

Because total urinary output was not obtained in this study, urinary creatinine concentration was used as an indicator of urine output (Chizzotti et al., in press). Urine samples were collected from all cattle on d 14 of the second experimental period, 4 h after feeding. Urinary N contents were analyzed as described above, but using 2 mL of sample. Commercial kits were used to analyze these samples for creatinine (No. 555-A; Sigma Chem. Co., St. Louis, MO). Urine volume was estimated using creatinine concentration as a marker and assuming a daily creatinine excretion of 27.8 mg/kg of BW (Rennó, 2003). Urinary N excretion was calculated as N content multiplied by the estimated urine volume.

Slaughter and Body Composition Techniques

Before slaughter, SBW was measured as the BW after 18 h without feed and water. At slaughter, cattle were stunned using a cash knocker (GIL, Ribeirão Preto, Brazil) and killed by exsanguination using conventional humane procedures. Blood was weighed and sampled. The body was separated into individual components, which were separately weighed. Included were internal organs (liver, heart, lungs, trachea, kidneys, reproductive tract, and spleen), cleaned digestive tract (rumen, reticulum, omasum, abomasum, and small and large intestines), tongue, tail, hide, head, feet, and carcass. The digestive tract was cleaned by emptying and flushing with water, and physically stripped. The carcass was split into 2 identical longitudinal halves. After a 24-h chill, the whole right half of the carcass was manually separated into bone, muscle, and fat. Head and feet were separated into bone, hide, and soft tissue. Internal organs, cleaned digestive tract, tail, and tongue were ground together. Muscle, fat, and soft tissues of head and feet were ground separately. Hide was sampled and cut in small pieces. Carcass, head, and feet bones were sawn into small pieces, homogenized, and proportionally sampled. Except for blood samples, which were dried at 60°C for 72 h, all other samples were dried at 105°C for 80 h for DM determination and partially defatted by washing with diethyl ether; the fat was computed by weight difference. Then, these samples were ground again in a ball mill (TE350, Tecnal, Piracicaba, Brazil) and analyzed for EE and N as described above.

Empty BW (**EBW**) was computed as the sum of the right and left halves of the warm carcass, hide, head, feet, tail, blood, cleaned gastrointestinal tract, and internal organs.

Data Calculation and Analyses

Prediction of Diet ME. The dietary DE was estimated as 4.409 Mcal/kg of TDN, and DE was converted to ME using an efficiency of 82% to convert DE to ME (NRC, 2000). The 82% is consistent with the findings of Tedeschi et al. (2002) using Nellore cattle and a similar diet.

Calculation of Initial Body Composition. The procedures used to compute energy retained and maintenance energy requirement were similar to those of Lofgreen and Garrett (1968). The initial EBW was computed from SBW, and then initial empty body fat (**EBF**) and protein (**EBP**) were estimated from EBW for each animal, using the average EBW, SBW, EBF, and EBP data from the baseline group of the appropriate gender.

Net Requirement Calculations*.* Empty body gains of body components were calculated as the difference between initial and final weights of the respective body components, similar to Tedeschi et al. (2002). The caloric values of retained fat and protein were assumed to be 9.367 and 5.686 Mcal/kg (Blaxter and Rook, 1953), respectively. Heat production (**HP**, kcal·kg$^{-0.75}$ of EBW·d^{-1}) was calculated as the difference between ME intake (**MEI**, kcal·kg$^{-0.75}$ of EBW·d^{-1}) and retained energy

(**RE**, kcal·kg$^{-0.75}$ of EBW·d^{-1}). The average of the antilog of the intercept confidence interval (95%) of the linear regression between the log of HP on MEI was used to estimate the MRNE (kcal·kg$^{-0.75}$ of EBW·d^{-1}) (Lofgreen and Garrett, 1968). The maintenance requirement for ME (**MRME**) was calculated by iteration, assuming that the maintenance requirement is the value at which HP is equal to MEI (kcal·kg$^{-0.75}$ of EBW·d^{-1}). The efficiency of energy utilization for maintenance (**K*m***) was calculated as MRNE/MRME. The slope of the regression of RE on MEI was assumed to be the efficiency of energy utilization for growth (**K*g***). Alternatively, we used the intercept divided by the K_g to compute MRME, which was then multiplied by the K_m to estimate the MRNE. This second approach of calculating MRNE was compared to the MRNE estimated using the regression of the log of HP on MEI.

The maintenance requirement for net protein (**MRNP**, g·kg$^{-0.75}$ of EBW·d^{-1}) was calculated as 6.25 × the negative intercept of the linear regression of the N balance calculated by difference (N intake minus N excreted in feces and urine, g·kg$^{-0.75}$ of EBW·d^{-1}) on N intake (g·kg$^{-0.75}$ of EBW·d^{-1}) (INRA, 1988). Alternatively, the MRNP was calculated as 6.25 × the negative intercept of the linear regression of the retained N calculated from tissue deposition (g·kg$^{-0.75}$ of EBW·d^{-1}) on N intake (g·kg$^{-0.75}$ EBW·d^{-1}).

The growth requirement for NE (**GRNE**, Mcal·kg$^{-0.75}$ EBW·d^{-1}) was calculated as shown in Eq. [1] and the growth requirement for net protein (**GRNP**, g·kg$^{-0.75}$ EBW·d^{-1}) was calculated as shown in Eq. [2].

$$\text{GRNE (Mcal·kg}^{-0.75}\text{ of EBW·d}^{-1}) = a \times \text{EBW}^{0.75} \times \text{EBG}^{b} \quad [1]$$

$$\text{GRNP (g·kg}^{-0.75}\text{ of EBW·d}^{-1}) = w \times z \times \text{EBW}^{z-1} \quad [2]$$

where *a* is the antilog of the intercept and *b* is the slope of the linear regression of the logarithm of RE (Mcal·kg$^{-0.75}$ of EBW·d^{-1}) on the logarithm of empty body gain (EBG, kg/d), and *w* is the antilog of the intercept and *z* is the slope of the linear regression of the logarithm of body protein (kg/kg EBW) on the logarithm of EBW.

Statistical Analyses. Statistical analyses were performed using SAS (SAS Inst. Inc., Cary, NC). The analyses of intake, diet energetic concentration, performance, and body composition were performed by PROC GLM assuming a 3 × 3 factorial design of diet (maintenance level or 0.75 or 1.5 % of BW as concentrate daily) and gender (bulls, steers, and heifers), as per the following statistical model:

$$Y = \mu + \alpha + \beta + \alpha\beta + \varepsilon$$

where μ is the mean, α is the effect of diet, β is the effect of gender, $\alpha\beta$ is the interaction effect of diet and gender, and ε is the random error.

Outliers and systematic bias were identified using the plot of studentized residuals against the predicted values (X-variable) and by the leverage and Cook's D coefficients (Neter et al., 1996). At the end of the experiment during the cleaning of a pen, 1 heifer was injured and, therefore, it was removed from the data set.

The comparison of intercept and slope among diets and gender was performed by using the PROC GLM procedure using the SOLUTION statement and the sum of squares type 3. The interaction or the main effects were removed from the statistical model if, and only if, $P > 0.05$. The comparisons of means were performed using least square means at $P = 0.05$.

RESULTS AND DISCUSSION

Intake and Digestibility

Table 2 shows the mean intake and digestibility of the nutrients. There were effects of gender and diet on intake of all nutrients (kg/d). As expected, cattle fed at maintenance level had the lowest intake of all nutrients and the greatest diet DE concentration. Digestibility in the rumen is the result of the competition between digestion and passage rates, and passage rate is positively correlated with DMI (Van Soest, 1994). Therefore, the lesser DMI of cattle on restricted intake likely resulted in a slower passage rate and a greater digestibility of the diet. Animals fed at 0.75% BW of concentrate daily had less (P = 0.01) DMI than animals fed at 1.5% of BW as concentrate daily because their diets had a greater forage to concentrate ratio, which might have decreased the ruminal escape of DM and limited the intake by rumen filling effect (Allen, 1996). Bulls had the greatest DMI (kg/d), but there were no differences (P = 0.85) among genders on DMI as a percentage of BW. Bulls had greater intakes (P = 0.04) of NFC than steers, but they had similar (P = 0.95) energy intake. Heifers had less intake than bulls and steers, probably due to their lighter mean BW.

Performance and Body and Gain Compositions

Table 3 shows the mean body composition for the baseline animals of each gender. The initial SBW and mean body composition was similar between bulls and steers, but heifers had lighter SBW and greater fat (% of EBW) than males, likely because the heifers were closer to their mature weight.

The growth performance, body composition, and energy balance data are shown in Table 4. There was no interaction between gender and diet for ADG. As expected, cattle of treatment 1.5% of BW as concentrate daily had greater performance than those fed 0.75% of BW as concentrate daily, which had greater ADG than cattle fed for maintenance. Bulls had greater ADG ($P < 0.01$) than steers and heifers. An interaction occurred between gender and diet for EBG in that bulls receiving 1.5% of BW daily of concentrate had the greatest EBG. Bulls accumulate more protein and water and less fat in the gain than steers and heifers receiving the same diet (Berg and Butterfly, 1976), justifying their greater EBG. Although the ADG of cattle on the maintenance diet indicated loss of weight, bulls, steers, and heifers had similar positive EBG, which was likely due to the differences in the gastrointestinal content between animals of maintenance treatment and the baseline groups. Fat content (% of EBW) demonstrated effects of gender and diet; heifers had greater ($P < 0.01$) fat content than bulls and steers, and within diets fat content was greatest ($P < 0.01$) for cattle fed concentrate at 1.5% of BW daily and least for those fed to maintenance. For protein content (% of EBW), there was no effect ($P = 0.28$) of gender, but protein content was different ($P = 0.01$) for diets within gender in that those cattle on the ad libitum treatments (0.75 and 1.5% of BW daily of concentrate) had greater fat content and less protein in the empty body. These findings are in agreement with Ferrell and Jenkins (1998), who also found less protein and greater fat content in steers fed ad libitum than in limit-fed steers.

Energy Requirement for Maintenance and Efficiency of Energy Utilization

Gender had no effect on RE and HP (kcal·kg$^{-0.75}$ of EBW·d^{-1}), but RE and HP increased as cattle consumed more energy, indicating that HP increased as MEI increased. Turner and Taylor (1983) suggested that HP is greater in cattle with increased plane of nutrition mainly due to elevation of metabolism involved in the synthesis of RE. Similarly, Williams and Jenkins (2003) proposed that ME consumed above the maintenance requirement is associated with an elevation of vital functions (support metabolism) and that this HP is driven by amount of MEI.

The intercept and the slope of the regression of log of the HP on MEI as well as MRNE are shown in Table 5. The exponential relationship between HP and MEI are shown in Figure 1. There were no differences (P = 0.06) in MRNE among genders; steers had a 9 and 13% lower MRNE than bulls and heifers, respectively. The analysis of the pooled data resulted in a common MRNE of 71.2 kcal·kg$^{-0.75}$ of EBW·d^{-1}, which is 7% less than the MRNE of 77 kcal·kg$^{-0.75}$ of EBW·d^{-1} reported by Lofgreen and Garrett (1968), and corroborates the assumption of the NRC (2000) that *Bos indicus* crossbreds have lower MRNE requirements. Our value is nearly identical to the value of 70.8 kcal·kg$^{-0.75}$ of EBW·d^{-1}reported by Silva et al. (2002) in a data compilation of F1 *Bos indicus* × *Bos taurus* bulls. The average value of MRNE reported by Ferrell and Jenkins (1998) for steers of *Bos indicus* crossbreds was 74.5 kcal·kg$^{-0.75}$ of EBW·d^{-1}. Henrique et al. (2005) using data of 320 Nellore purebred and crossbred cattle obtained from 8 comparative slaughter studies reported a MRNE of 73 kcal·kg$^{-0.75}$ of EBW·d^{-1}. Paulino et al. (2006) using individual observations collected from 7 different trials comprising 135 intact Nellore males that averaged 303 kg also found a MRNE of 73 kcal·kg$^{-0.75}$ of EBW·d^{-1}. The lower MRNE for Nellore crossbreds could be attributed to the lower ratio of kidney-pelvic-renal fat to carcass fat, lower internal organs mass, and lower protein turnover of *B. indicus* compared to *B. taurus* cattle (Valadares Filho et al., 2005). In contrast, the MRNE reported by Ferrell and Jenkins (1998) for Brahman crossbreds was 82.8, which is 16% greater than our finding, but this divergence could be attributed to differences in environmental conditions. Tedeschi et al. (2002) also reported a greater MRNE of 77.2 kcal·kg$^{-0.75}$ of EBW·d^{-1} for Nellore purebred cattle (348 kg BW), but they also did not find differences between bulls (69.8) and steers (81.2) in MRNE.

The MRME estimated using the relationship between RE and MEI (Table 6) also indicated no difference ($P = 0.39$) in the MRME among genders. Nonetheless, the overall estimate of MRME was smaller than that determined based on the relationship between HP and MEI (91.8 vs 100 kcal·kg$^{-0.75}$ of EBW·d^{-1}). Although not statistically different, steers tended ($P = 0.06$) to have MRME 17% less than bulls and 23% less than heifers. The NRC (2000) assumes that steers have MRNE 15% less than bulls, but does not account for differences between steers and heifers. The K_m (Table 5) and K_g values (Table 6) were not different ($P = 0.24$ and 0.26, respectively) among genders and were on average 71.3 and 51.9%, respectively. Similar values of K_m and K_g (69.9 and 52.7%, respectively) for steers were reported by Tedeschi et al. (2002), but lower K_m and K_g (63.7 and 38.5%, respectively) were observed for bulls. Ferrell and Jenkins (1998) reported similar values of K_m (ranging from 65 to 69%) and greater K_g in crossbred *Bos indicus* × *Bos taurus* than in *Bos taurus* crossbred steers.

Protein Requirement for Maintenance

The mean values of intake, excretion, balance, and retention of N are presented in Table 7. The intake, excretion, and balance of N (g·kg$^{-0.75}$ of EBW·d^{-1}) were not different among genders ($P = 0.06$, 0.15 and 0.56, respectively); however, as expected, they were affected by diet in that cattle in the maintenance treatment had lesser values than cattle fed concentrate at 0.75 or 1.5% of BW daily. There was an interaction between gender and diet for retained N; cattle in the maintenance treatment had the smallest value, and bulls and heifers of treatments 0.75 and 1.5% of BW as concentrate daily retained more N ($g\cdot kg^{-0.75}$ of $EBW\cdot d^{-1}$) than steers (0.41 and 0.53, 0.41 and 0.43, and 0.24 and 0.40, respectively). Daily N balance and retained N ($g\ N\cdot kg^{-0.75}$ of $EBW\cdot d^{-1}$) were regressed against daily N intake ($g\ N\cdot kg^{-0.75}$ of $EBW\cdot d^{-1}$) to determine MRNP (Figure 2). The MRNP is assumed to be the sum of endogenous urinary N, metabolic fecal N, and dermal (scurf and hair) N losses, multiplied by the factor 6.25 (NRC, 1985). When N balance is regressed against N intake, the negative intercept (at zero N intake) provides an estimate of minimum N losses which should be similar to the sum of endogenous urinary N and metabolic fecal N (Susmel et al., 1993). There were no differences ($P = 0.45$) in MRNP among genders. The pooled data indicated a MRNP of 0.40 $g\ N\cdot kg^{-0.75}$ of $EBW\cdot d^{-1}$, which is equivalent to 2.53 $g\ CP\cdot kg^{-0.75}$ of $EBW\cdot d^{-1}$. The efficiency of conversion of maintenance requirement for MP (**MRMP**) to MRNP of feeding systems ranges from 0.67 for NRC (1985) to 1.0 for ARC (1980). Assuming an efficiency of 0.67, the calculated MRMP was 3.78 $g\ CP\cdot kg^{-0.75}$ of $EBW\cdot d^{-1}$, which is equivalent to 3.4 $g\ CP\cdot kg^{-0.75}$ of $SBW\cdot d^{-1}$. This value was 10% lower than the recommendation of NRC (2000) of 3.8 $g\ CP\cdot kg^{-0.75}$ of $EBW\cdot d^{-1}$. The Institute National de la Recherche Agronomique (INRA, 1988) used N balance studies to determine the maintenance requirement of 3.25 $g\ MP\cdot kg^{-0.75}$ of $SBW\cdot d^{-1}$. Similarly, Smuts (1935) determined a value of 3.52 $g\ MP\cdot kg^{-0.75}$ of $SBW\cdot d^{-1}$, which was close to our findings. Even though our MRMP value was similar to those values reported in the literature, the diets in our experiments were designed to be first limiting in energy, whereas protein is first limiting in experiments designed to determine protein requirements using the regression of N balance on N intake.

Alternatively, the MRNP was estimated as the intercept of the regression of retained N on N intake, which should be similar to the N losses at zero N intake. The estimated MRNP value was 0.50 g $N\cdot kg^{-0.75}$ of $EBW\cdot d^{-1}$ or 3.09 g $CP\cdot kg^{-0.75}$ of $EBW\cdot d^{-1}$. Using this method, the MRNP was 22% greater than that calculated using the N balance data. The difference may be attributed to losses of N that are not accounted for by the N balance (e.g. scurf, hair, saliva N losses) and issues related to accurate measurements of urinary N based on creatinine as a marker. The scurf protein represents about 20% of the maintenance requirement of the ARC system (ARC, 1980).

Energy Requirement for Growth

Table 8 depicts the intercept and slope of the regression equations of logarithm of body fat, energy, and protein content on the logarithm of the EBW. As cattle grow the content of energy and fat increases whereas the content of protein decreases in the EBG (Berg and Butterfly, 1976). There were differences (Table 8) on the rate of fat deposition in which the percentage of fat in the EBG was greater ($P = 0.03$), on a decreasing order, in steers, heifers, and then bulls, for cattle weighing more than 360 kg.

The coefficients to predict the GRNE from the RE are listed in Table 9. The coefficient “a” of the nonlinear regression to predict the RE was less ($P < 0.01$) for bulls than for steers and heifers (0.0482 vs. 0.0575 and 0.0603); therefore the GRNE ($Mcal\cdot kg^{-0.75}$ of $EBW\cdot d^{-1}$) for steers and heifers were greater than for bulls. Figure 3 illustrates the difference between bulls and the pooled data of heifers and steers for the relationship between RE and EBG. According to NRC (2000), heifers and bulls with similar parents as the steers have 18% greater and lesser, respectively, GRNE at the same weight and rate of gain. We concluded that steers and heifers had similar GRNE and that bulls had 18.7% lesser GRNE than steers and heifers. Nonetheless, the GRNE of bulls, steers, and heifers were 24, 27, and 44% less than proposed by the NRC (2000), probably due to differences in RE in gain between pure *Bos taurus* and *Bos taurus* × *Bos indicus* crossbreds. This is likely due to changes in the fat depots among breeds (more internal vs. carcass fat for *Bos indicus*). The *b* coefficient was not different ($P = 0.90$) among genders; it was 1.081, which is close to the 1.097 reported by Lofgreen and Garret (1968) and adopted by the NRC (2000). This suggests the greater the EBG the greater is the RE in the EBG.

Protein Requirement for Growth

The protein deposition in the empty body has been estimated using the rate of ADG and the composition of the gain (NRC, 2000). The composition of the gain depends on physiological maturity of the cattle, which is affected by gender and breed (NRC, 1984). Although not significantly different among genders (Table 8), steers had GRNP that were 14% and 17% less than those of bulls and heifers, respectively. This tendency is in contrast with the findings reported by Robelin and Daenicke (1980), who evaluated the effect of sex on body composition and found the percentage of protein in the EBG of steers and heifers was 10% less than in bulls. Our finding was because animals had similar BW, but different body chemical composition, likely due to different degrees of maturity, which would affect the composition of the gain and the requirements for protein (Owens et al., 1995).

The percentage of RE deposited as protein (**RE_p**) increased as content of RE in the gain (**RE_c**, Mcal/kg EBG) decreased (Figure 4), suggesting that RE_p can be used to compute the partial efficiency of ME to NE for growth (Williams and Jenkins, 2003; Tedeschi et al., 2004). No differences (P = 0.81) among genders occurred; the RE_p equation of the pooled data was $46.5 \times e^{-0.2463 \times REc}$ (R^2 = 0.67). Geay (1984) found that RE_p was greater for bulls than for heifers and decreased as the RE increased; however, Tedeschi et al. (2002) did not detect differences between bulls and steers. The equation developed by Tedeschi et al. (2004) for Nellore bulls and steers over-predicts the RE_p, likely due to the greater fat content, and consequent lesser protein content of the EBG of Nellore × Red Angus crossbreds. This finding is in agreement with the discussion above, regarding the possible differences in maturity degree of our cattle compared to other studies.

IMPLICATIONS

The requirement of net energy for maintenance was similar for bulls, steers, and heifers. Our findings supported the hypothesis that *Bos indicus* × *Bos taurus* crossbreds might have a lesser maintenance requirement for net energy than *Bos taurus* purebreds. The growth requirement for NE was less for bulls than for steers and heifers. Although the energy retained as protein was negatively correlated with the concentration of energy in the empty weight gain, our data indicated no differences in growth requirement for net protein for bulls, steers, and heifers of Nellore x Red Angus crossbreds.

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Table 1. Ingredient and chemical composition of feeds (%, DM basis)

Ingredient	Concentrate C1	Concentrate C2	Corn silage
Cracked corn grain	59.7	82.0	-
Soybean meal	34.1	14.9	-
Urea	1.80	0.90	-
Ammonium sulfate	0.20	0.10	-
Limestone	2.05	1.02	-
Salt	0.89	0.44	-
Commercial premix [a]	1.25	0.62	-
Chemical component			
DM	89.5	88.7	24.5
CP	28.1	17.9	6.7
Ether Extract	2.61	2.35	2.25
Ash	7.26	4.10	8.60
NDF	12.1	12.1	55.9
Non-fiber carbohydrates	53.3	65.2	26.5
Indigestible ADF	0.83	0.90	15.1

[a] Contained 24% Ca, 17.4% P, 100 mg/kg Co, 1,250 mg/kg Cu, 1,795 mg/kg Fe, 2,000 mg/kg Mn, 15 mg/kg Se, 5,270 mg/kg Zn, and 90 mg/kg I.

Table 2. Intake of nutrients and energy concentration of diets for each treatment

	Bulls			Steers			Heifers				*P*-value[1]		
Item	Maint[2]	0.75[2]	1.5[2]	Maint	0.75	1.5	Maint	0.75	1.5	SEM	G	T	G × T
n	3	3	3	3	3	3	3	3	3	-	-	-	-
					Intake								
DM, kg/d	2.85^{aC}	8.69^{bC}	10.2^{cC}	3.00^{aB}	8.32^{bB}	9.23^{cB}	2.61^{aA}	7.00^{bA}	8.84^{cA}	0.16	<0.001	<0.001	0.06
DM, % of BW/d	1.04^{a}	2.46^{b}	2.63^{b}	1.10^{a}	2.42^{b}	2.59^{b}	1.12^{a}	2.45^{b}	2.65^{b}	0.04	0.86	<0.001	0.94
CP, kg/d	0.35^{aB}	1.05^{bB}	1.27^{cB}	0.37^{aB}	1.01^{bB}	1.12^{cB}	0.32^{aA}	0.86^{bA}	0.99^{cA}	0.02	0.001	<0.001	0.06
NDF, kg/d	1.18^{aB}	3.83^{bB}	3.72^{bB}	1.25^{aA}	3.66^{cA}	3.31^{bA}	1.08^{aA}	3.10^{bA}	3.32^{bA}	0.08	0.006	<0.001	0.11
NFC[3], kg/d	1.00^{aC}	2.97^{bC}	4.47^{cC}	1.06^{aB}	2.84^{bB}	4.11^{cB}	0.92^{aA}	2.40^{bA}	3.81^{cA}	0.05	<0.001	<0.001	0.06
TDN, kg/d	1.95^{aB}	4.67^{bB}	6.23^{cB}	2.09^{aB}	4.75^{bB}	5.98^{cB}	1.80^{aA}	4.05^{bA}	5.45^{cA}	0.10	0.002	<0.001	0.37
DE, Mcal/d	8.61^{aB}	20.6^{bB}	27.5^{cB}	9.22^{aB}	20.9^{bB}	26.4^{cB}	7.92^{aA}	17.8^{bA}	24.0^{cA}	0.45	0.002	<0.001	0.37
ME, Mcal/d	7.06^{aB}	16.9^{bB}	22.5^{cB}	7.56^{aB}	17.2^{bB}	21.6^{cB}	6.50^{aA}	14.6^{bA}	19.7^{cA}	0.37	0.002	<0.001	0.37
					Energy concentration								
TDN, % of DM	68.6^{cA}	53.7^{aA}	61.3^{bA}	69.6^{cB}	57.0^{aB}	64.9^{bB}	68.7^{bAB}	57.7^{aAB}	61.6^{aAB}	0.70	0.04	<0.001	0.30
DE, Mcal/kg	3.02^{cA}	2.37^{aA}	2.70^{bA}	3.07^{cB}	2.51^{aB}	2.86^{bB}	3.03^{bAB}	2.54^{aAB}	2.71^{aAB}	0.03	0.04	<0.001	0.30
ME, Mcal/kg	2.48^{cA}	1.94^{aA}	2.22^{bA}	2.51^{cB}	2.06^{aB}	2.34^{bB}	2.48^{bAB}	2.08^{aAB}	2.23^{aAB}	0.02	0.04	<0.001	0.30

[1] G = gender, T = treatment.

[2] Maint = fed at maintenance level; 0.75 and 1.5 = cattle fed concentrate at 0.75 or 1.5% of BW daily, with ad libitum access to corn silage.

[3] NFC = non-fiber carbohydrates.

[a,b,c] Distinct lowercase letters in the same row, within gender, differ at $P < 0.05$ by least square means for diet effect.

[A, B, C] Distinct capital letters in the same row, differ at $P < 0.05$ by least square means for gender effect.

Table 3. Body composition of baseline bulls, steers, and heifers

Item	Bulls	Steers	Heifers
n	3	3	3
SBW[1], kg	291 ± 30.8	294 ± 29.0	251 ± 15.7
EBW[1], kg	235 ± 16.5	232 ± 26.8	194 ± 19.4
HCW, kg	147 ± 11.9	140 ± 17.2	116 ± 16.9
Fat, % of EBW	6.42 ± 1.32	5.63 ± 0.31	10.17 ± 3.70
Protein, % of EBW	22.2 ± 0.38	21.6 ± 0.24	20.3 ± 0.58
Water, % of EBW	64.2 ± 1.26	65.7 ± 0.07	63.9 ± 3.16
Ash, % of EBW	7.22 ± 0.85	7.05 ± 0.40	5.67 ± 0.11
Energy, Mcal/kg EBW	1.85 ± 0.11	1.74 ± 0.02	2.10 ± 0.32

[1] SBW = shrunk BW, EBW = empty BW.

Table 4. Effect of diet and gender on performance, body composition, and energy balance

	Bulls			Steers			Heifers				*P*-value[1]		
Item	Maint[2]	0.75[2]	1.5[2]	Maint	0.75	1.5	Maint	0.75	1.5	SEM	G	T	G×T
Initial SBW[3], kg	277^{B}	290^{B}	291^{B}	288^{B}	295^{B}	292^{B}	248^{A}	240^{A}	263^{A}	19.3	0.02	0.72	0.93
Final SBW, kg	274^{aB}	411^{bB}	485^{cB}	270^{aB}	406^{bB}	447^{cB}	231^{aA}	347^{bA}	424^{cA}	22.7	0.007	<0.001	0.81
EBW[3], kg	247^{aC}	383^{bC}	446^{cC}	243^{aB}	369^{bB}	395^{cB}	211^{aA}	307^{bA}	373^{cA}	17.8	<0.001	<0.001	0.34
EBW:SBW, %	89.7	93.2	92.1	89.9	90.9	88.8	91.6	88.5	88.2	2.15	0.29	0.74	0.41
HCW, kg	154^{aC}	240^{bC}	281^{cC}	151^{aB}	228^{bB}	246^{cB}	132^{aA}	187^{bA}	232^{cA}	12.0	<0.001	<0.001	0.32
VOM[3], kg	33.3^{a}	58.7^{b}	70.4^{c}	33.9^{a}	59.5^{b}	64.1^{c}	30.0^{a}	50.1^{b}	59.7^{c}	4.20	0.06	<0.001	0.35
ADG, kg/d	-0.03^{aB}	1.19^{bB}	1.84^{cB}	-0.19^{aA}	1.04^{bA}	1.26^{cA}	-0.18^{aA}	0.95^{bA}	1.40^{cA}	0.12	0.002	<0.001	0.19
EBG[3], kg/d	0.24^{d}	1.41^{fg}	1.99^{h}	0.18^{d}	1.28^{ef}	1.54^{g}	0.21^{d}	1.14^{e}	1.59^{g}	0.08	<0.001	<0.001	0.04
ADG:EBG, %	-16.7^{a}	84.7^{b}	92.6^{b}	-128^{a}	80.7^{b}	82.0^{b}	-114^{a}	82.6^{b}	87.1^{b}	3.74	0.23	<0.001	0.36
Fat, % of EBW	11.6^{aA}	15.2^{bA}	19.8^{cA}	11.2^{aA}	18.3^{bA}	20.2^{Ac}	12.6^{aB}	18.4^{bB}	24.2^{cB}	1.01	0.003	<0.001	0.11
Protein, % of EBW	18.3^{b}	18.8^{c}	18.0^{a}	19.0^{c}	16.7^{a}	17.6^{b}	19.0^{c}	17.9^{b}	17.0^{a}	0.54	0.28	0.01	0.05
Water, % of EBW	64.0^{aB}	60.9^{bB}	57.6^{cB}	63.3^{aB}	59.9^{bB}	56.9^{cB}	61.6^{aA}	58.6^{bA}	54.0^{cA}	1.15	0.008	<0.001	0.92
Ash, % of EBW	6.11^{a}	5.10^{b}	4.55^{b}	6.52^{a}	5.14^{b}	5.32^{b}	6.82^{a}	5.12^{b}	4.77^{b}	0.43	0.36	<0.001	0.69
RE[3], $\text{kcal}\cdot\text{kg}^{-0.75}$ $\text{EBW}\cdot\text{d}^{-1}$	19.2^{a}	66.6^{b}	100^{c}	21.8^{a}	74.9^{b}	93.1^{c}	14.5^{a}	67.6^{b}	104^{c}	5.80	0.94	<0.001	0.30
HP[3], $\text{kcal}\cdot\text{kg}^{-0.75}$ $\text{EBW}\cdot\text{d}^{-1}$	93.0^{a}	157^{b}	173^{c}	106^{a}	155^{b}	190^{c}	112^{a}	161^{b}	187^{c}	7.05	0.06	<0.001	0.45

[1] G = gender, T = treatment.

[2] Maint = fed at maintenance level; 0.75 and 1.5 = cattle fed concentrate at 0.75 or 1.5% of BW daily, with ad liaitum access to corn silage.

[3] SBW = shrunk BW, EBW = empty BW, VOM = visceral organs mass, EBG = empty body gain, RE = retained energy, HP = heat production.

[a, b, c] Distinct lowercase letters in the same row, within gender, differ at $P < 0.05$ by least square means for diet effect.

[A, B, C] Distinct capital letters in the same row, differ at $P < 0.05$ by least square means for gender effect.

[d, e, f, g, h] Distinct lowercase letters in the same row, differ at $P < 0.05$ by least square means.

Table 5. Regression of logarithm of heat production (kcal·kg$^{-0.75}$ of EBW·d^{-1}) on ME intake (kcal·kg$^{-0.75}$ of EBW·d^{-1}) to describe energy utilization by bulls, steers, and heifers [1]

Gender	Intercept	Slope (×1000)	n	r^2	RMSE	MRNE	MRME	K_m, %
Bulls	1.86 ± 0.04	1.41 ± 0.14	7[2]	0.93	0.025	72.4	100.4	72.1
Steers	1.82 ± 0.03	1.62 ± 0.07	9	0.98	0.014	65.8	93.2	70.6
Heifers	1.88 ± 0.03	1.38 ± 0.12	8	0.95	0.023	75.8	106.3	71.3
All	1.85 ± 0.01	1.47 ± 0.07	24	0.95	0.021	71.2	100.0	71.3

[1] Values are mean ± SE. RMSE = root of the mean square error, MRNE = maintenance requirements for NE (kcal·kg$^{-0.75}$ of EBW·d^{-1}) calculated as the antilog of the intercept, MRME = maintenance requirement for ME (kcal·kg$^{-0.75}$ of EBW·d^{-1}) calculated by iteration assuming heat produced is equal to ME intake at maintenance, K_m = efficiency of use of ME for MRNE (calculated as MRNE/MRME).

[2] Two outliers were identified and removed from the calculations

Table 6. Regression of retained energy (kcal·kg$^{-0.75}$ of EBW·d^{-1}) on ME intake (kcal·kg$^{-0.75}$ of EBW·d^{-1}) to describe energy utilization [1]

Gender	Intercept	Slope	n	r^2	RMSE	MRME	K_g, %
Bulls	-50.9 ± 11.6	0.54 ± 0.05	7[2]	0.93	9.29	93.4	54.5
Steers	-37.0 ± 14.3	0.47 ± 0.06	9	0.98	7.15	78.9	47.0
Heifers	-55.0 ± 14.3	0.54 ± 0.06	8	0.97	7.21	101.4	54.3
All	-47.6 ± 5.28	0.52 ± 0.02	24	0.96	7.27	91.8	51.9

[1] Values are mean ± SE. RMSE = root of the mean square error, maintenance requirement for ME (MRME) was calculated as the ME intake when retained energy (RE) is equal to zero and K_g (efficiency of use of ME for RE) was calculated as the slope of the regression of RE (kcal·kg$^{-0.75}$ of EBW·d^{-1}) on ME intake (kcal·kg$^{-0.75}$ of EBW·d^{-1}).

[2] Two outliers from the maintenance treatment were identified and removed from the calculations.

Table 7. Nitrogen intake, excretion, and balance and retained N by diet and gender

	Bulls			Steers			Heifers			SEM	*P*-value[1]		
Item	Maint[2]	0.75[2]	1.5[2]	Maint	0.75	1.5	Maint	0.75	1.5		G	T	G × T
N intake [3]	1.04^{a}	2.30^{b}	2.34^{b}	1.10^{a}	2.26^{b}	2.30^{b}	1.07^{a}	2.15^{b}	2.19^{b}	0.05	0.050	<0.001	0.283
N excretion [3]	1.07^{a}	1.97^{b}	1.91^{b}	1.15^{a}	1.81^{b}	1.93^{b}	1.08^{a}	1.79^{b}	1.80^{b}	0.06	0.141	<0.001	0.858
N balance [3]	-0.09^{a}	0.48^{b}	0.56^{b}	-0.05^{a}	0.44^{b}	0.40^{b}	-0.01^{a}	0.46^{b}	0.42^{b}	0.04	0.386	<0.001	0.209
N retained [3]	-0.14^{c}	0.41^{fg}	0.53^{g}	-0.08^{cd}	0.24^{e}	0.40^{f}	0.03^{d}	0.41^{fg}	0.43^{fg}	0.05	0.019	<0.001	0.033

[1] G = gender, T = treatment.

[2] Maint = fed at maintenance level; 0.75 and 1.5 = cattle fed concentrate at 0.75 or 1.5% of BW daily, with ad libitum access to corn silage.

[3] g·kg$^{-0.75}$ of EBW·d^{-1}.

[a,b] Distinct letters in the same row, within gender, differ at $P < 0.05$.

[c,d,e,f,g] Distinct letters in the same row differ at $P < 0.05$.

Table 8. Regression of logarithm of the body protein (kg), fat (kg), or energy (Mcal) content on the logarithm of empty BW (EBW) to describe the net retention by bulls, steers and heifers[1]

Gender	Intercept	Slope	n	r^2	RMSE	Coefficients[2]	
						a	*b*
				Fat			
Bulls	-5.37 ± 0.47^{d}	2.77 ± 0.19^{d}	8[3]	0.97	0.07	1.21×10^{-5}	1.77
Steers	-6.57 ± 0.72^{c}	3.26 ± 0.31^{e}	8[3]	0.95	0.09	8.77×10^{-7}	2.26
Heifers	-3.91 ± 0.72^{e}	2.28 ± 0.29^{c}	8	0.91	0.10	2.81×10^{-4}	1.28
All	-4.47 ± 0.59	2.44 ± 0.24	24	0.82	0.15	-	-
				Energy			
Bulls	-1.30 ± 0.21	1.66 ± 0.08	8[3]	0.98	0.03	0.0832	0.66
Steers	-1.85 ± 0.26	1.88 ± 0.10	8[3]	0.98	0.03	0.0266	0.88
Heifers	-1.04 ± 0.31	1.60 ± 0.13	8	0.96	0.04	0.1459	0.60
All	-1.07 ± 0.23	1.59 ± 0.09	24	0.93	0.06	-	-
				Protein			
Bulls	0.13 ± 0.06	0.67 ± 0.02	8[3]	0.99	0.01	0.9048	-0.33
Steers	0.19 ± 0.16	0.63 ± 0.06	8[3]	0.94	0.02	0.9758	-0.37
Heifers	-0.19 ± 0.17	0.78 ± 0.07	8	0.95	0.02	0.5036	-0.22
All	-0.10 ± 0.12	0.75 ± 0.05	24	0.92	0.03	-	-

[1] Values are mean ± SE. RMSE = root of the mean square error.

[2] Nonlinear equation $Y = a \times EBW^{b}$ (kg), where Y = fat (kg/kg empty body gain, EBG), energy (Mcal/kg EBG) or protein (kg/kg EBG) in gain.

[3] One outlier from the maintenance treatment was identified and removed from the dataset of bulls and steers.

[c,d,e] Within a column, means without a common superscript letter differ ($P < 0.05$).

Table 9. Coefficients for the standard nonlinear equation to predict retained energy from empty body gain and empty BW for F1 Nellore × Red Angus bulls, steers, and heifers

Gender	Coefficients[1]		R^2	RMSE	n
	a	*b*			
Bulls	0.0482^{c}	1.059	0.84	0.04	6
Steers	0.0575^{d}	1.103	0.93	0.02	6
Heifers	0.0603^{d}	1.093	0.87	0.05	5
Steers and heifers	0.0593	1.065	0.88	0.03	11
All animals	0.0476	1.081	0.87	0.04	17
NRC (2000)	0.0635	1.097	0.87	-	-

[1] Nonlinear equation: $RE = a \times EBG^{b} \times EBW^{0.75}$, where RE = retained energy (Mcal/d), EBG = empty body gain (kg/d), EBW = empty BW (kg), and RMSE = root of the mean square error.

$^{c, d}$ Different letters in the same column differ at $P < 0.05$.

Figure 1. Exponential relationship between heat production (HP) and ME intake (MEI) for all animals (HP = 71.3 × e $^{(0.0034 \times \mathrm{MEI})}$, $R^2 = 0.95$). Data are from bulls (■), steers (○), and heifers (×).

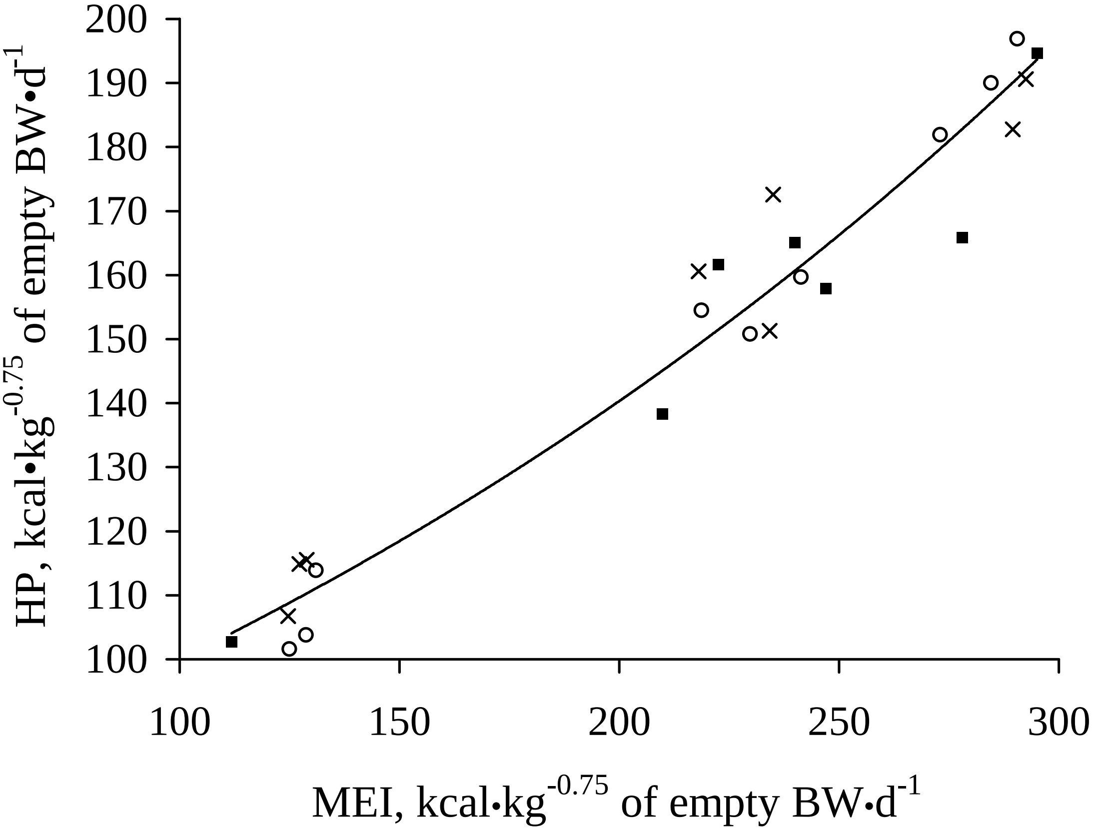


Figure 2. Relationships between N balance, retained N, and N intake (g·kg$^{-0.75}$ of empty BW·d^{-1}). Symbols are data from bulls (■ and □), steers (○ and●) and heifers (▲ and Δ). Open symbols and dashed line are from N balance calculated by difference of N ingested minus excreted N {N balance = - 0.405 (± 0.050) + [0.355 (± 0.026) × N intake], r^2 = 0.91} and filled symbols and solid line are from retained N calculated from tissue deposition {retained N = - 0.495 (± 0.058) + [0.406 (± 0.030) × N intake], r^2 = 0.85}.

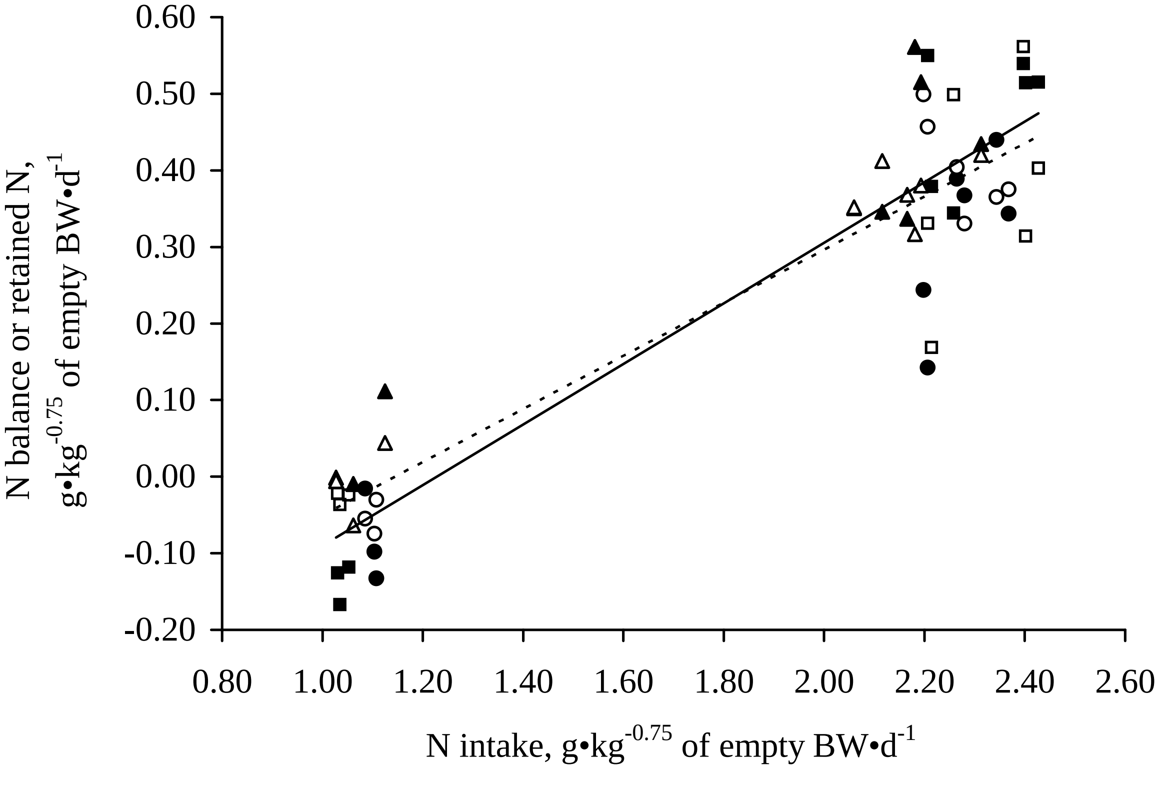


Figure 3. Relationship between logarithms of retained energy (RE) and empty body gain (EBG) for bulls [log RE = -1.317 + (1.059 × log EBG), solid line] and steers and heifers [log RE = -1.227 + (1.065 × log EBG), dashed line]. Data are from bulls (■), steers (○), and heifers (×).

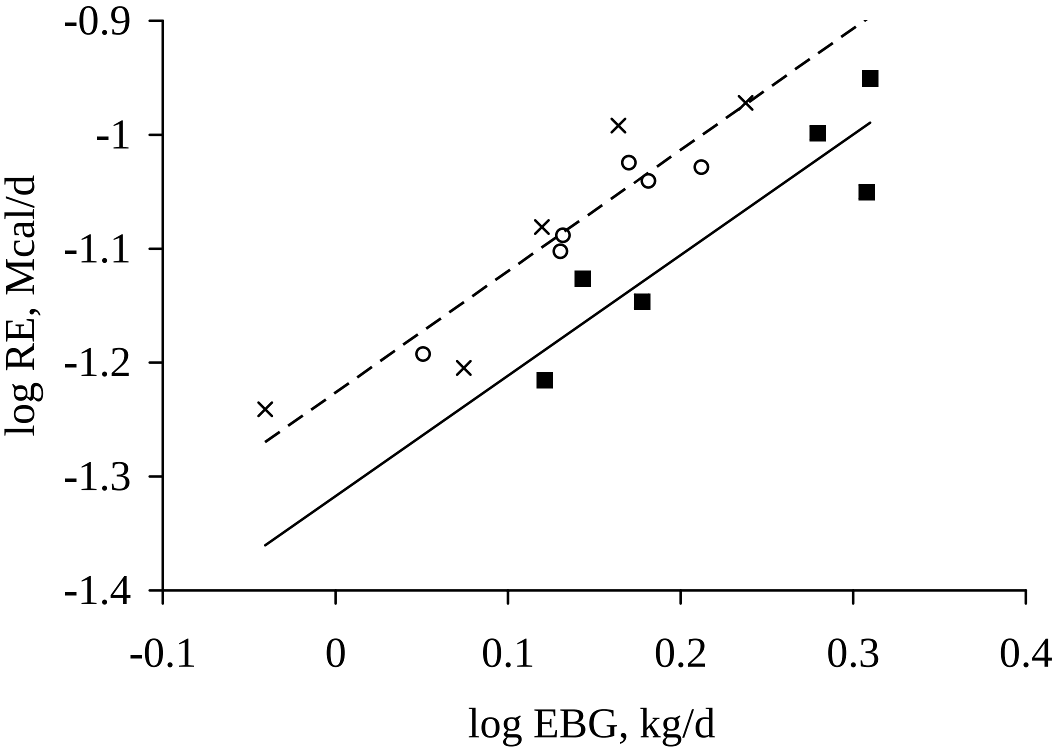
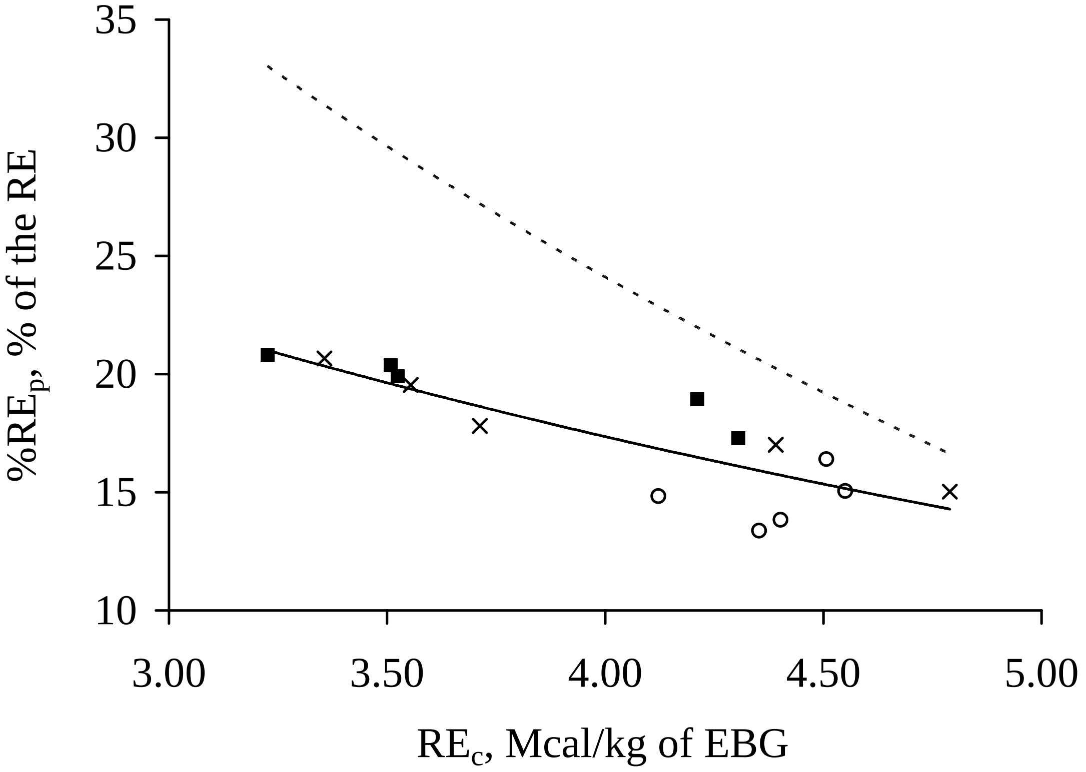


Figure 4. Relationship between the percentage of retained energy deposited as protein (%RE_p) and the content of retained energy in the empty body gain (RE_c; Mcal/kg of empty body gain, EBG): %$RE_p = 46.5 \times e^{-0.2463 \times REc}$, $R^2 = 0.67$). Data are from bulls (■), steers (○), and heifers (×). Solid line is from data of this trial, and dashed line is the equation proposed by Tedeschi et al. (2004) (%$RE_p = 5.54 + 169.39 \times e^{-0.5573 \times REc}$).



A meta-analysis of energy and protein requirements for maintenance and growth of Nellore cattle

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ABSTRACT: A meta-analysis was conducted to determine NE and net protein requirements of growing bulls, steers, and heifers of Nellore purebred and Nellore × *Bos taurus* crossbreds. A database of 16 comparative slaughter studies (n = 389 animals) was gathered to provided enough information to develop equations to predict the requirements of NE_m, NE_g, and net protein for maintenance (NP_m) and growth (NP_g). The data were analyzed using a random coefficients model, considering studies as random effects, and genders (bulls, steers, and heifers; n = 262, 103 and 24, respectively) and breeds as fixed effects. There were no differences in NE_m requirements among genders ($P = 0.73$) and breeds ($P = 0.82$). The combined data indicated a NE_m requirement of 75 kcal/kg$^{0.75}$ of empty BW (EBW) with a partial efficiency of use of ME to NE_m of 0.67. The NE_g requirement was different ($P = 0.009$) among genders and tended ($P = 0.06$) to be different among breeds. The equation for NE_g requirement for bulls was $0.0514 \times EBW^{0.75} \times EWG^{1.070}$, for steers it was $0.0700 \times EBW^{0.75} \times EWG^{1.070}$; and for heifers it was $0.0771 \times EBW^{0.75} \times EWG^{1.070}$, where EWG is empty weight gain, kg/d. The partial efficiency of use of ME to NE_g was not different among genders ($P = 0.33$) and breeds ($P = 0.20$), and averaged 0.44. There were no differences in NP_m requirement among genders (*P* = 0.59) and breeds (*P* = 0.92); the overall NP_m requirement was 1.74 g of $NP\cdot kg^{-0.75}$ $EBW\cdot d^{-1}$. The overall MP requirement for maintenance was 2.59 g of $MP\cdot kg^{-0.75}$ $EBW\cdot d^{-1}$. The NP_g requirement, g/d, was not different among genders (*P* > 0.59) and breeds (*P* > 0.14); the overall equation was EWG × (217 - 12.8 × RE/EWG), where RE is retained energy, Mcal/d. The percentage of RE deposited as protein ($\%RE_p$) decreased exponentially as the content of RE in the gain (REc, Mcal/kg of EWG) increased. Because no study effect was observed, we pooled the data across studies and the overall equation to predict $\%RE_p$ was $0.101 + 1.667 \times e^{(-0.660 \times REc)}$. Our results do not support the hypothesis that bulls have greater NE_m requirements than steers and heifers. Likewise, no significant differences in the NP_m requirements among bulls, steers, and heifers were detected. Nonetheless, the NE_g requirement of steers was greater than for bulls and lesser than for heifers. Even though the $\%RE_p$ was negatively correlated with the concentration of energy in the EWG, our findings indicated no differences in NP_g requirement for bulls, steers, and heifers.

KEYWORDS: *Bos indicus*, comparative slaughter, growth, Nellore, net energy, net protein.

INTRODUCTION

The *Bos indicus* cattle and their crossbreds are commonly used in beef production systems in tropical and sub-tropical regions. They possess abilities to withstand hot and humid weather, to tolerate intense sunshine, to resist to parasites, and are adapted to utilize poor quality forages (Turner, 1980).

The National Research Council guidelines for beef cattle production (NRC, 2000) are widely adopted to formulate diets around the world; however, energy and nutrient requirements are based on *B. taurus* data. The NRC (2000) indicates that *B. indicus* breeds require about 10% less NE_m than beef breeds of *B. taurus*. Tedeschi et al. (2002) indicated that steers and bulls of Nellore, a *B. indicus* breed, had NE_m requirements similar to that adopted by the NRC (2000). Additionally, it has been recognized that gender (castrate and intact male or female) influences growth of body tissues, affecting carcass composition and feed efficiency (Berg and Butterfield, 1976) and the NE_m requirement (ARC, 1980; NRC, 2000). An increase on ME intake results in a non-linear response of energy losses and retained energy (**RE**), suggesting the maximum efficiency in feedlot cattle may occur at less than maximum energy intake (Ferrell and Jenkins, 1998). Therefore, improvements in the beef cattle production in tropical and sub-tropical regions require an accurate assessment of energy and protein requirements of cattle.

Several studies have been independently conducted to determine energy and protein requirements of *B. indicus* purebred and their crossbreds with *B. indicus*. A meta-analysis of this data is necessary to provide an overall summary and directions for future experiments. Therefore, the objective of this study was to perform a meta-analysis to determine energy and protein requirements for maintenance and growth of bulls, steers, and heifers of Nellore and Nellore × *B. taurus* crossbreds from independent studies that used comparative slaughter technique to measure energy and protein balances.

MATERIALS AND METHODS

Data Collection

A database that included general information (e.g. title, author name, date of publication), qualitative (e.g. breed, gender, treatment), and necessary quantitative data was gathered for this study. Quantitative information included days on feed, mean intake of ME and N, initial and final shrunk BW (**SBW**), empty BW (**EBW**), content of ether extract and protein of the EBW for each animal. Studies that provided enough information to compute these variables were included. Data from individual animals were obtained from 16 studies (Paulino, et al., 1999; Ferreira et al., 1999; Véras et al., 2001; Martins, 2001; Silva et al., 2002; Veloso et al., 2002; Paulino et al., 2004; Putrino et al., 2006; Tedeschi et al., 2002; Backes et al., 2005; Freitas, 2004; Chizzotti et al. 2007; Paulino, 2006; and Marcondes, 2007), resulting in 389 animal records. Animals from all studies were individually fed and no implant was used. Breeds were coded as Nellore purebred and Nellore crossbred with Angus, Red Angus, Simmental, Limousin, or Brangus. Table 1 depicts the descriptive statistics of the database classified by breed and gender.

Data Calculation and Analyses

The procedures used to compute energy requirements for maintenance and growth were similar to those described by Lofgreen and Garrett (1968), except we used data from the baseline animals (within each study) to develop a linear regression equation to determine the initial composition of the EBW and SBW of growing animals rather than using the mean BW and body composition as described by Tedeschi et al. (2002). The initial EBW was computed from SBW using the appropriate equation for each trial, and then initial empty body fat (**EBF**) and protein (**EBP**) were estimated from EBW for each animal. Empty body gains of body components were calculated as the difference between final and initial EBW of the respective body components. The caloric values of retained fat and protein were assumed to be 9.367 (Blaxter and Rook, 1953) and 5.686 (Garrett, 1958) Mcal/kg, respectively.

Linear and non-linear regressions were used to estimate energy and protein utilization. The models that best described data with a minimal possible number of parameter estimates were determined based on Akaike's Information Criteria (**AIC**) and Schwartz's Bayesian Information criteria (**BIC**) (Mills and Prasad, 1992).

Heat production (**HP**, kcal/kg$^{0.75}$ EBW) was calculated as the difference between ME intake (**MEI**, kcal/kg$^{0.75}$ EBW) and retained energy (**RE**, kcal/kg$^{0.75}$ EBW). The average of the antilog of the intercept confidence interval (95%) of the linear regression between the log of HP on MEI was used to estimate the requirement for NE$_m$ (kcal/kg$^{0.75}$ EBW) (Lofgreen and Garrett, 1968). The ME required for maintenance (**ME$_m$**) was calculated by iteration, assuming that the maintenance requirement is the value at which HP is equal to MEI (kcal·kg$^{-0.75}$ EBW·d^{-1}) as shown in the Eq. [1].

$$HP = \beta_0 \times e^{(\beta 1 \times MEI)} \qquad [1]$$

Where HP is heat production, Mcal/d, β_0 and β_1 are coefficients, *e* is the Neperian constant, and MEI is ME intake, Mcal/d.

The efficiency of NE utilization for maintenance (**k$_m$**) was calculated as the NE$_m$ requirement divided by the ME$_m$ requirement. The slope of the regression of

RE on MEI was assumed to be the efficiency of energy utilization for growth (**K_g**). Alternatively, the intercept divided by the slope (i.e. K_g) was used to compute ME_m requirement, which was then multiplied by the k_m to estimate the NE_m requirement. This second approach of calculating NE_m requirement was compared to the NE_m requirement estimated using the regression of the log of HP on MEI.

The net requirements of protein for maintenance (**NP_m**, $g \cdot kg^{-0.75}$ $EBW \cdot d^{-1}$) was assumed to be the intercept of the linear regression of the retained N ($g \cdot kg^{-0.75}$ $EBW \cdot d^{-1}$) on N intake ($g \cdot kg^{-0.75}$ $EBW \cdot d^{-1}$), and then multiplied by 6.25 to convert to protein.

Animals fed at the maintenance level were not utilized in the calculations of growth requirement. The NE_g requirement ($Mcal \cdot kg^{-1}$ $EWG \cdot d^{-1}$) was calculated as shown in Eq. [2] and the net protein requirement for gain (**NP_g**, g of NP_g/d) was calculated as shown in Eq. [3].

$$NE_g = a \times EBW^{0.75} \times EWG^{b} \quad [2]$$

$$NP_g = c + d \times EBW + e \times RE \quad [3]$$

Where a and b are the antilog of the intercept and the slope of the linear regression of the logarithm of the RE, $Mcal \cdot kg^{-0.75}$ $EBW \cdot d^{-1}$, on the logarithm of the empty body gain (EWG, kg/d), respectively; c, d, and e are the intercept and slopes of the multiple regression of the retained protein, g/d, on the EBW, kg, and RE, Mcal/d, respectively.

The partitioning of MEI to RE as fat and protein was computed using a multiple regression as shown in Eq. [4].

$$MEI = \beta_0 + \beta_1 \times RE_f + \beta_2 \times RE_p \quad [4]$$

Where EBW is empty BW, kg; MEI is metabolizable energy intake, Mcal·kg$^{-0.75}$ EBW·d^{-1}, RE$_f$ and RE$_p$ are the RE, Mcal·kg$^{-0.75}$ EBW·d^{-1}, as fat and protein, respectively.

The intercept (β_0) of Eq. [4] was assumed to be the estimate of the ME$_m$ and the coefficients β_1 and β_2 represented the amounts of ME required to deposit 1 Mcal of ME as fat or protein, respectively. The efficiencies of RE as fat and protein (K$_f$ and K$_p$, respectively) were calculated as the inverse of the coefficients β_1 and β_2, respectively.

Statistical Analysis

A random coefficients model was used assuming a random variation for the effect of study (Littell et al., 2006). The general statistical model used is shown in Eq. [5].

$$Y_{ij} = \beta_0 + \beta_1 X_{ij} + \beta_2 S_i + \beta_3 S_i X_{ij} + \varepsilon_{ij} \qquad [5]$$

where Y_{ij} = the dependent variable Y at level *j* of the independent variable X in the study *i* , β_0 = overall intercept with fixed effect, β_1 = overall slope that result from regressing Y on X across all studies with fixed effect, X_{ij} = observed value *j* of the independent variable X in the study *i*, β_2 = effect of study *i* (S_i) on the intercept, β_3 effect of study *i* on the slope of the regression of Y on X in study *i*, and ε_{ij} = the random, unexplained error.

An initial analysis was conducted assuming random slope and intercept effects, including a possible covariance between the slope and intercept using an unstructured variance-(co)variance matrix. The covariance parameter was considered different from zero if the *P*-value was greater than 0.10. A higher *P*-value than the traditional *P* = 0.05 was used because accurate estimations of variances and (co)variances require a considerable number of observations. In instances in which the covariance parameters were not different from zero, a variance components structure of the variance-(co)variance matrix was used. Outliers were identified and removed if the studentized residue were greater than 2.5 or lesser than -2.5 (Neter et al., 1996).

RESULTS AND DISCUSSION

Body Weight Measurements

Regression equations have been developed to estimate EBW from BW (NRC, 1984; NRC. 2000). According to Owens et al. (1995), EBW is the most precise index of energy and nutrient content of the body because the digesta are totally washed out from the gastrointestinal tract after animals are slaughtered and all remaining tissues are weighed and chemically analyzed. Neither effects of breeds (*P* = 0.30) nor genders (*P* = 0.22) in the prediction of EBW from SBW values were found. The overall equation is shown in Eq. 6 (n = 385). This equation resulted in predictions of EBW within the range reported by Owens et al. (1995) in which the EBW was about 85 to 95% of the SBW.

$$EBW = -15.6\ (\pm\ 3.71) + 0.928\ (\pm\ 0.009) \times SBW \qquad [6]$$

Where EBW is empty BW, kg; and SBW is shrunk BW, kg.

Similarly, the intercept was not different from zero (*P* = 0.23) and there were no effects of gender (*P* = 0.24) or breed (*P* = 0.24) on the estimates of the EWG from the ADG. The overall equation is shown in Eq. [7] (n = 385). The NRC (2000) assumes that EWG is 0.951×ADG, which is very close to our findings.

$$EWG = 0.961\ (\pm\ 0.027) \times ADG \qquad [7]$$

Where EWG is empty weight gain, kg/d.

Energy Requirement for Maintenance

The nonlinear regression indicated that HP increased exponentially as MEI increased. Similarly, Ferrell (1988) reported that energy intake affect HP due to an increase on mass and metabolic activity of visceral organs. The intercept and the slope of the regression of the log of HP on the MEI and NE_m requirements are shown in Table 2. There were no differences in NE_m requirements between breeds (*P* = 0.82). The combined data indicated a NE_m requirement of 75 kcal/kg$^{0.75}$ EBW, which is slightly lower than the NE_m of 77 kcal/kg$^{0.75}$ EBW reported by Lofgreen and Garrett (1968) using data from 5 studies involving 208 *B. taurus* heifers and steers. Freitas et al. (2006) found no differences in NE_m requirement among Nellore purebred and Nellore × Angus, Nellore × Brown Swiss, and Nellore × Simmental growing bulls, which was on average 79 kcal/kg$^{0.75}$ EBW. Ferrell and Jenkins (1998) reported an average value of NE_m requirement of 74.5 kcal/kg$^{0.75}$ EBW for *B. indicus* crossbred steers. There were no differences in NE_m requirements among genders (*P* = 0.73). The NRC (2000) assumed that steers have NE_m requirements 15% lesser than bulls. Because animals from our database were individually fed in stalls, the absence of difference among genders may be attributed to physical activity and other interactions among bulls when fed in group.

Similarly, the estimate of ME_m requirement based on the relationship between RE and MEI indicated no differences in the ME_m requirement among breeds and genders (Table 3). Nonetheless, the overall estimate of ME_m requirement was smaller than the exponential relationship between HP and MEI

(107 vs 112 kcal/kg$^{0.75}$ EBW, respectively). Similarly, Ferrell and Jenkins (1998) reported that the estimates of NE_m requirement, calculated as the ME intake at which energy gain equals to zero, resulted in the same ranking among sire-breeds as those estimated from the regression of the log of HP on MEI, but estimates were 3 to 37% lower.

The estimates of ME_m requirement using the exponential relationship between HP and MEI was based on the calculation of the intercept by extrapolating MEI to zero, whereas the calculation using the linear regression of RE on MEI the intercept (when RE is zero) is in-between the dataset. Using the linear regression of RE on MEI, the NE_m was 71.7 kcal/kg$^{0.75}$ EBW and close to the proposed value for *B. indicus* breeds (70 kcal/kg$^{0.75}$ EBW) by the NRC (2000). This method tends to yield lower values for NE_m because of the positive linear relationship between RE and MEI whereas the log of HP on MEI has a non-linear, ever-decreasing HP value as MEI diminishes. Sainz et al. (2005) also reported a lesser NE_m requirement of Nellore bulls than that of *B. taurus* breeds and suggested that the lower maintenance expenditure might partially be explained by the lower protein turnover (one of the major contributor to endogenous energy expenditures) reported in Nellore cattle. Ferrell and Jenkins (1998) found that NE_m requirement differed ($P < 0.05$) among *B. taurus* and *B. indicus* sire breeds. The authors also found an effect of breed sire on weight of the liver and visceral organs in which the liver and the gastrointestinal compartments of ad libitum fed Tuli-sired steers represented 0.79 and 5.1% of the EBW vs. 1.27 and 6.10% of the EBW of Angus-sired steers, respectively. Although visceral tissues represent approximately 6% of EBW, their energy expenditure can account for more than 40% of total energy utilized for maintenance (Ferrell, 1988).

The partial efficiency of conversion of ME to NE_m was similar among genders and breeds with an average value of 67% (Table 2). Similar to these results, Freitas et al. (2006) reported a k_m of 67%, and found no differences between Nellore purebred and Nellore × *B. taurus* bulls. Ferrell and Jenkins (1998) reported similar values of k_m (ranging from 65 to 69%) in crossbreds of *B. indicus* × *B. taurus* and *B. taurus*× *B. taurus* steers.

We concluded the use of log of HP on MEI to determine NE_m is likely to be more accurate than using a simple linear relationship between RE and MEI because of the non-linear relationship between these variables. In addition, our results indicated no differences among gender and between Nellore purebred and Nellore × *B. taurus* on NE_m and energy efficiency for maintenance.

Protein Requirement for Maintenance

The NP_m requirement is usually assumed to be the sum of endogenous urinary N, metabolic fecal N, and dermal (scurf and hair) N losses, multiplied by the factor 6.25 (NRC, 1985). Alternatively, the NP_m requirement might be estimated as the intercept of the regression of retained N on N intake, which should be similar to the N losses at zero N intake. The main difference is that N balance is the difference between the ingested N and the fecal and urinary N excreted by the animal and does not account for losses of metabolizable protein, such as hair and scurf.

Our results indicated an overall NP_m requirement of 1.74 g of $NP \cdot kg^{-0.75}$ $EBW \cdot d^{-1}$ and no differences in NP_m requirement among genders (P = 0.59) and breeds (P = 0.92). Assuming an efficiency of use of MP to NP_m of 0.67 (NRC, 2000) and converting the EBW to SBW according to Eq. [6], the overall MP requirement for maintenance was 2.30 g of MP·kg$^{-0.75}$ SBW·d^{-1}. This value was lower than the recommendation of NRC (2000) of 3.8 g MP·kg$^{-0.75}$ SBW·d^{-1}. The Institute National de la Recherche Agronomique (INRA, 1988) used N balance studies to determine the maintenance requirement of 3.25 g MP·kg$^{-0.75}$ SBW·d^{-1}. Similarly, Smuts (1935) determined a value of 3.52 g MP·kg$^{-0.75}$ SBW·d^{-1}. The lesser NP_m requirement of Nellore cattle might be attributed to the lower rates of degradation and turnover of protein during growth of Nellore cattle in comparison with *B. taurus* species (Sainz et al., 2005). Nevertheless, the diets in most of the studies used in our database were designed to be first limiting in energy, whereas protein is first limiting in experiments designed to determine protein requirements using the regression of N balance on N intake.

Energy Requirement for Growth

The coefficients to predict the NE_g requirement from the RE are listed in Table 4. Rates of protein deposition increase at decreasing rates whereas rates of fat deposition increase at increasing rates with the rate of gain (Byers, 1982). Consequently, the NE_g requirement was exponentially related to the EWG. There were no differences in NE_g requirement among breeds. Nonetheless, the regression of the logarithm of RE on the logarithm of EWG indicated a similar slope (P = 0.92) but a different intercept (P = 0.01) among genders. The NE_g requirement calculated assuming a common slope among genders for bulls, steers, and heifers is shown in Eq. [8].

$$NE_g = a \times EBW^{0.75} \times EWG^{1.070} \quad [8]$$

Where NE_g is Mcal/d; EBW is empty BW, kg; EWG is empty weight gain, kg/d; and *a* is either 0.0514, 0.07, or 0.0771 for bulls, steers, or heifers, respectively.

According to the NRC (2000), heifers and bulls have 18% greater and lesser NE_g requirements than steers at the same BW, respectively. Our data indicated that NE_g requirement for bulls was 27% lesser than that for heifers and 10% greater than that for steers. These findings are in agreement with the differences on carcass composition and rates of fat accretion among genders reported by Berg and Butterfield (1976). These authors indicated that fat deposition was greater (in a decreasing order) for heifers, steers, and bulls.

Protein Requirement for Growth

The protein deposition in the empty body has been estimated using the rate of ADG and the composition of the gain (NRC, 2000). The composition of the gain depends on physiological maturity of the animal, which is affected by gender and breed of the animal (NRC, 1984). The NP_g requirement was not different among genders ($P > 0.59$) and breeds ($P > 0.14$) suggesting that composition of gain can account for a significant amount of the variation in the protein retention due to breeds and genders (Eq. [9]).

$$NP_g = EWG \times (217 - 12.8 \times RE/EWG) \qquad [9]$$

Where NP_g is net protein requirement for growth, g/d; and EWG is empty weight gain, kg/d.

The percentage of RE deposited as protein ($\%RE_p$) decreased exponentially as the content of RE in the gain (REc, Mcal/kg EWG) increased (Figure 1), suggesting that $\%RE_p$ can be used to compute the partial efficiency of ME to NE for growth (Williams and Jenkins, 2003; Tedeschi et al, 2004). Because no study effect was observed, we pooled the data across studies and Eq. [10] was obtained.

$$\%RE_p = 0.101 + 1.667 \times e^{(-0.660 \times REc)} \quad [10]$$

Where $\%RE_p$ is the percentage of RE as protein; REc is the concentration of RE in the empty weight gain, Mcal/kg; and *e* is the Neperian number.

Our findings are not in agreement with those reported by Geay (1984), who reported that $\%RE_p$ was greater for bulls than for heifers likely because of greater protein content of protein in the gain. This is possible when animals have similar maturity degree in which the composition of gain is identical and the RE concentration is comparable.

Efficiencies of Fat and Protein Accretion

The analysis of the partition of MEI above maintenance to protein and fat deposition based on Eq. [4] is shown in Table 6. Based on this multi-linear approach, the efficiencies of protein and fat deposition were not different among breeds and genders, and were on average 0.34 and 0.79, respectively. Owens et al. (1995) reported that protein accretion had an average efficiency of 0.47 and the efficiency of fat accretion was 0.79, which is identical to our finding. In contrast, Geay (1984) reported efficiencies of protein and fat accretion of 0.20 and 0.75, respectively, using data from 52 experiments. The efficiency of protein accretion is highly variable and depends on physiological stage, nutritional status, and protein turnover. Unlike protein, fat accretion efficiency is thought to be less variable (CSIRO, 1990). According to Tedeschi et al. (2004), the ME for fat deposition has a higher efficiency than for protein likely due to the cost of protein turnover and the fact that fat is deposited from excess of fat intake or synthesized from protein and carbohydrate whereas protein is deposited only from amino acids.

The variation in efficiency of protein accretion is related to the variations in turnover rate because faster protein turnover at greater accretion rates will increase HP and decrease GE efficiency (Owens et al. 1995). Our efficiency of protein accretion was greater than that observed by Geay (1984) (0.34 vs. 0.20, respectively); this was likely because of lower rates of protein turnover of Nellore cattle in comparison with *B. taurus* breeds (Sainz et al., 2005).

Efficiencies of Retained Energy

The partial efficiency of use of ME to NE_g estimated as the slope of the linear regression of RE on MEI was not different among genders ($P = 0.33$) and breeds ($P = 0.20$), and averaged 0.44 (Table 3). Ferrell and Jenkins (1998) reported a non-linear regression in which energy gain increased asymptotically as MEI increased. However, the linear regression of the RE on MEI fitted better in our dataset than the exponential regression, because it had smaller AIC and BIC values (Mills and Prasad, 1992).

Even though Ferrell (2003) reported that variations on body composition and composition of the gain can affect the partial efficiency of energy utilization, the ARC (1980), CSIRO (1990), AFRC (1993), and NRC (2000), computes K_g based on biological values of the diet. Because the energy content of the fat and lean tissue differs, Tedeschi et al. (2004) suggested that K_g depends on the composition EWG. Assuming the equation proposed by Tedeschi et al. (2004) to compute partial efficiency of NE for growth ($RE/K_g = RE_f/K_f + RE_p/K_p$) and the K_f and K_p values found in this study, the K_g can be estimated from Eq. [11].

$$K_g = 1343 / (1700 + 2250 \times \%RE_p) \qquad [11]$$

where K_g is partial efficiency of ME to NE_g and $\%RE_p$ is the proportion of protein energy in the retained energy (Mcal/Mcal). The use of K_g based on the EWG composition might be preferable over a single efficiency to compute ME to NE_g based on diet ME content.

As expected, Eq. [11] will yield greater K_g than that equation proposed by Tedeschi et al. (2004) at the same RE_p. In addition, as RE_p increases, the difference between K_g predicted by Eq. [11] and Tedeschi et al.'s (2004) equation increases.

Energy Partition of the MEI

The most efficient animal is the one that converts ME to RE more efficiently by expending less energy for maintenance (Herd et al., 2004). The percentage of the MEI utilized for maintenance and growth was plotted against MEI to evaluate differences in efficiency among breeds and genders (Figure 2). There were no effects of gender ($P > 0.36$) and breeds ($P > 0.91$) on the energy partitioning, and as expected, the relationships between HP or RE and MEI were quadratic ($P < 0.01$). Figure 2 suggests the maximum proportion of the MEI deposited in the body (high growth efficiency) do not occurs at the maximum energy intake level. Our data suggested that HP increases exponentially with MEI (Table 2) and, although RE increases with increased MEI, it happens in a lesser incremental rate than that with the HP. This occurs because as MEI increases the energy utilized for feed intake, digestion, absorption, and metabolism of nutrients also increases. In addition, the metabolic activity of the visceral organs increases with MEI, resulting on a greater HP. Ferrell and Jenkins (1998) reported that HP increased exponentially and energy gain increased asymptotically as DMI increased above maintenance, supporting the quadratic effect that we observed. Our results suggested that at the MEI of 0.316 Mcal·kg$^{-0.75}$ of EBW·d^{-1}, animals retained the greatest portion of the ME consumed.

Implications

Our results do not support the hypothesis that bulls have greater NE$_m$ requirements than steers and heifers. Similarly, no differences in the NP$_m$ among bulls, steers, and heifers were detected. Nonetheless, the NE$_g$ of steers might be greater than that for bulls and lesser than that for heifers. Even though the %RE$_p$ was negatively correlated with the concentration of energy in the EWG, our findings indicated no differences in NP$_g$ among bulls, steers, and heifers. The greatest energy efficiency did not occur at the maximum metabolizable energy intake.

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Table 1. Description of the database [a]

	iSBW	fSBW	iEBW	fEBW	ADG	EWG	RE	MEI
	Nellore (n = 268)							
Mean	296	392	255	351	0.82	0.84	3.72	16.5
Minimum	151	210	135	178	-0.12	-0.06	-1.30	6.93
Maximum	438	533	366	469	2.25	2.25	9.79	36.6
SD	55.0	63.4	44.4	57.5	0.42	0.43	2.19	4.88
	Nellore × *B. taurus* (n = 118)							
Mean	300	439	253	389	1.01	1.01	3.81	17.3
Minimum	194	187	129	175	-0.36	-0.05	-0.41	5.96
Maximum	393	531	337	466	1.93	2.05	8.76	29.3
SD	47.3	80.4	42.2	74.9	0.48	0.45	1.96	5.34
	Bulls (n = 262)							
Mean	298	420	255	373	0.98	0.97	3.69	17.4
Minimum	151	210	135	178	-0.08	-0.05	-1.30	6.26
Maximum	438	533	366	466	2.25	2.25	9.79	36.6
SD	58.1	72.5	45.9	67.0	0.41	0.43	2.14	5.27
	Steers (n = 103)							
Mean	300	386	258	347	0.70	0.73	3.95	15.6
Minimum	197	234	155	201	-0.36	-0.04	0.33	7.31
Maximum	399	520	352	469	1.72	1.62	7.47	23.2
SD	40.5	58.9	37.8	54.4	0.41	0.39	2.01	4.07
	Heifers (n = 24)							
Mean	277	338	237	309	0.55	0.66	3.56	14.2
Minimum	194	187	129	175	-0.31	-0.06	-0.02	5.96
Maximum	342	449	296	397	1.75	1.68	7.43	20.6
SD	31.8	63.1	40.8	56.6	0.52	0.48	2.32	4.54

[a] iSBW and fSBW = initial and final shrunk BW (kg), iEBW and fEBW = initial and final empty BW (kg), EWG = empty weight gain (kg/d), and MEI = ME intake (Mcal/d).

Table 2. Regression of logarithm of HP on ME intake to estimate the NE requirements for maintenance [a]

	Intercept	Slope × 1000	NE_m	ME_m	k_m	n	*P*-value [b]	
							Int.	Slope
Nellore	1.88 ± 0.03	1.56 ± 0.08	75.1	112	0.67	268	0.82	0.80
Nellore × *B. taurus*	1.88 ± 0.02	1.57 ± 0.07	76.3	116	0.66	118		
Bulls	1.86 ± 0.03	1.60 ± 0.09	73.0	109	0.67	258	0.73	0.13
Heifers	1.88 ± 0.04	1.44 ± 0.15	75.4	108	0.70	24		
Steers	1.88 ± 0.02	1.43 ± 0.08	76.7	110	0.69	103		
Overall	1.87 ± 0.01	1.55 ± 0.04	75.0	112	0.67	386		

[a] Using a variance components variance-(co)variance matrix and random interaction of study and intercept. Intercept and slope values are mean ± SE. NE_m requirement, kcal/kg$^{0.75}$ EBW, was calculated as the antilog of the intercept, ME_m = ME requirement for maintenance, kcal/kg$^{0.75}$ EBW, and was calculated by iteration assuming heat produced is equal to ME intake at maintenance, k_m (efficiency of use of ME for NE_m) was calculated as NE_m/ME_m, Int. = intercept.

[b] *P*-values for fixed effects of intercept and slope by breed or gender.

Table 3. Regression of RE on ME intake to describe energy utilization [a]

	Intercept × 100	Slope	K_g	ME_m	n	P value [b]	
						Int.	Slope
Nellore	-4.13 ± 2.07	0.42 ± 0.08	0.42	98.5	223	0.24	0.20
Nellore × *B. taurus*	-6.70 ± 1.81	0.52 ± 0.07	0.52	128.2	95		
Bulls	-4.07 ± 1.61	0.41 ± 0.06	0.41	99.3	201	0.68	0.33
Heifers	-5.31 ± 2.47	0.49 ± 0.10	0.49	107.6	20		
Steers	-5.41 ± 1.29	0.50 ± 0.05	0.50	108.9	97		
Overall	-4.75 ± 0.89	0.44 ± 0.03	0.44	106.8	318		

[a] Using a unstructured variance-(co)variance matrix and random interactions of study and intercept and study and slope. K_g = efficiency of use of ME for NE_g requirement was calculated as the slope of the regression of RE ($kcal/kg^{0.75}$ EBW) on ME intake ($kcal/kg^{0.75}$ EBW), and ME_m requirement was calculated as the ME intake when RE is equal zero, Int. = intercept.

[b] *P*-values for fixed effects of intercept and slope by breed or gender.

Table 4. Regression of logarithm of the RE on logarithm of the empty body gain and coefficients to predict RE from empty body gain and empty BW [a]

	Intercept	Slope	Coefficients		n	*P* value [b]	
			a	*b*		Int.	slope
Nellore	-1.19 ± 0.06	1.03 ± 0.08	0.0640	1.031	191	0.06	0.23
Nellore × *B. taurus*	-1.33 ± 0.05	1.13 ± 0.07	0.0469	1.128	104		
Bulls	-1.29 ± 0.05	1.07 ± 0.08	0.0514	1.071	214	0.009	0.92
Heifers	-1.12 ± 0.06	0.99 ± 0.21	0.0766	0.992	16		
Steers	-1.15 ± 0.04	1.08 ± 0.07	0.0701	1.076	65		
Overall	-1.22 ± 0.03	1.06 ± 0.03	0.0609	1.062	295		
		Using a common slope					
Bulls	-1.29 ± 0.05	1.07 ± 0.03	0.0514	1.070	214	0.009	-
Heifers	-1.11 ± 0.06	1.07 ± 0.03	0.0771	1.070	16		
Steers	-1.15 ± 0.04	1.07 ± 0.03	0.0700	1.070	65		

[a] Using a variance components variance-covariance matrix and random interaction of study and intercept. Coefficients *a* and *b* are from the regression: $NE_g = a \times EBW^{0.75} \times EWG^{b}$, where NE_g requirement is Mcal·kg^{-1} EWG·d^{-1}; EBW = empty BW (kg), EWG = empty weight gain (kg/d), Int. = intercept.

[b] *P*-values for fixed effects of intercept or slope by breed or gender.

Table 5. Regression of retained protein on RE and empty body gain to estimate the net protein requirements for gain [a]

	Intercept [b]	Coefficients		n	*P*-value [c]	
		d	*e*		*d*	*e*
Nellore	0.20 ± 11.2	-10.9 ± 5.0	214 ± 25	225	0.14	0.47
Nellore × *B. taurus*	-17.3 ± 10.0	-18.7 ± 4.6	233 ± 22	103		
Bulls	-1.74 ± 10.3	-12.1 ± 4.5	218 ± 26	229	0.99	0.59
Heifers	-22.6 ± 26.3	-13.0 ± 8.1	217 ± 53	19		
Steers	6.45 ± 8.73	-12.0 ± 3.9	191 ± 23	80		
Overall	-1.40 ± 4.48	-12.8 ± 2.0	217 ± 10	328		

[a] Using a variance components variance-covariance matrix and random interaction of study and slopes *d* and *e*. Intercepts and coefficients *d* and *e* are from the multiple regression of the retained protein (NP_g, g/d) on the EBW (kg) and RE (Mcal/d), respectively : NP_g = intercept + (*d* × EBW) + (*e* × RE).

[b] intercepts were not different from zero ($P > 0.75$).

[c] *P*-values for fixed effects of slopes *d* and *e* by breed or gender.

Table 6. Regression of RE as fat and RE as protein on ME intake to estimate the partial efficiency of energy retention as fat and protein [a]

	Intercept	Coefficients		K_f	K_p	n	*P*-value [b]		
		β_1	β_2				Intercept	β_1	β_2
Nellore	11.7 ± 2.98	1.15 ± 0.36	2.96 ± 1.94	0.87	0.34	225	0.71	0.69	0.53
Nellore × *B. taurus*	10.5 ± 2.60	1.30 ± 0.32	4.19 ± 1.70	0.77	0.24	103			
Bulls	12.1 ± 2.37	1.10 ± 0.31	3.30 ± 1.78	0.91	0.30	229	0.47	0.41	0.83
Heifers	10.4 ± 3.60	1.25 ± 0.49	1.89 ± 3.06	0.80	0.53	19			
Steers	9.20 ± 1.93	1.53 ± 0.25	2.48 ± 1.48	0.66	0.40	80			
Overall	11.5 ± 1.29	1.26 ± 0.16	2.97 ± 0.78	0.79	0.34	328			

[a] Using a variance components variance-(co)variance matrix and random interaction of study intercept, β_1, and β_2; The intercept and slopes β_1 and β_2 are from the regression: MEI ($\text{Mcal·kg}^{-0.75}$ EBW·d^{-1}) = $\beta_0 + \beta_1 \times RE_f + \beta_2 \times RE_p$, where RE_f and RE_p are the recovery energy as fat and protein, respectively ($\text{Mcal·kg}^{-0.75}$ EBW·d^{-1}). The efficiencies of retained energy as fat and protein (K_f and K_p, respectively) were calculated as $1/\beta_1$ and $1/\beta_2$, respectively.

[b] *P*-values for fixed effects of intercept and slopes β_1 and β_2 by breed or gender.

Figure 1. Relationship between the percentage of RE as protein and the retained energy concentration (REc) on the empty weight gain (EWG). Symbols are data from bulls (□ and ■), steers (○ and ●) and heifers (◊ and ♦). Opens symbols are data from Nellore purebreds and solid symbols are data from Nellore × *B. taurus* crossbreds. The solid line is the predicted values using the equation $\%RE_p = 0.101 (\pm 0.001) + 1.667 (\pm 0.158) \times e^{(-0.660 (\pm 0.045) \times REc)}$.

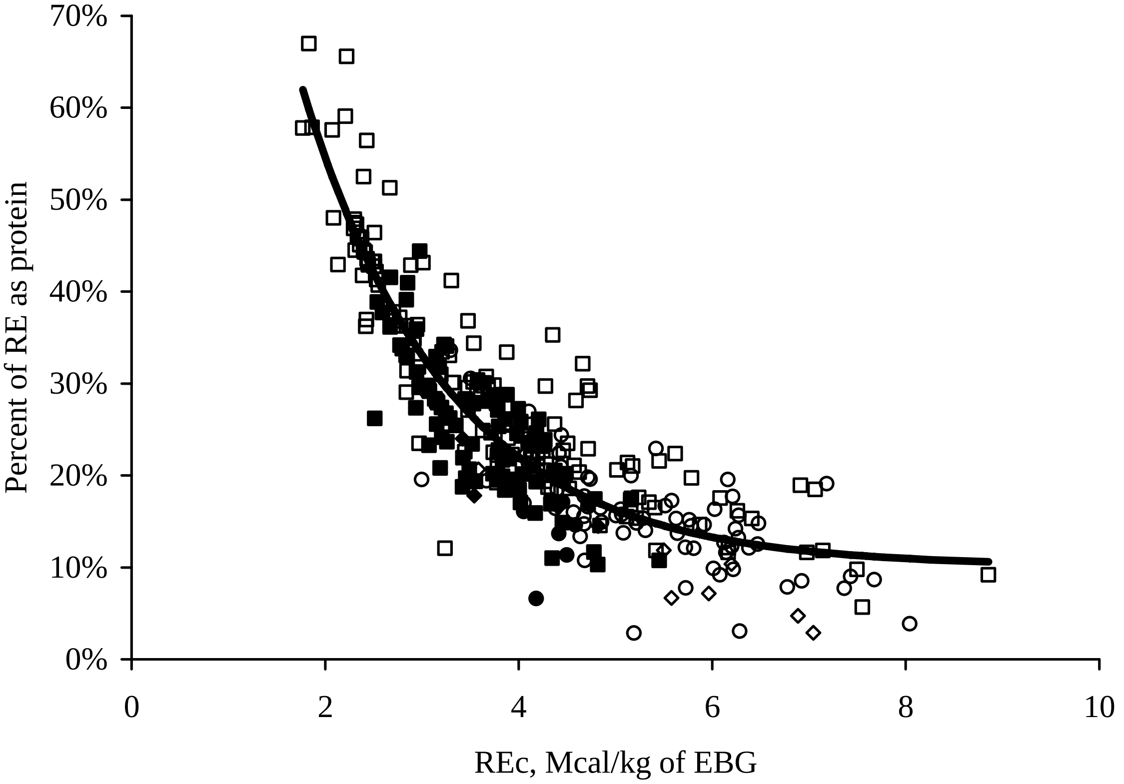
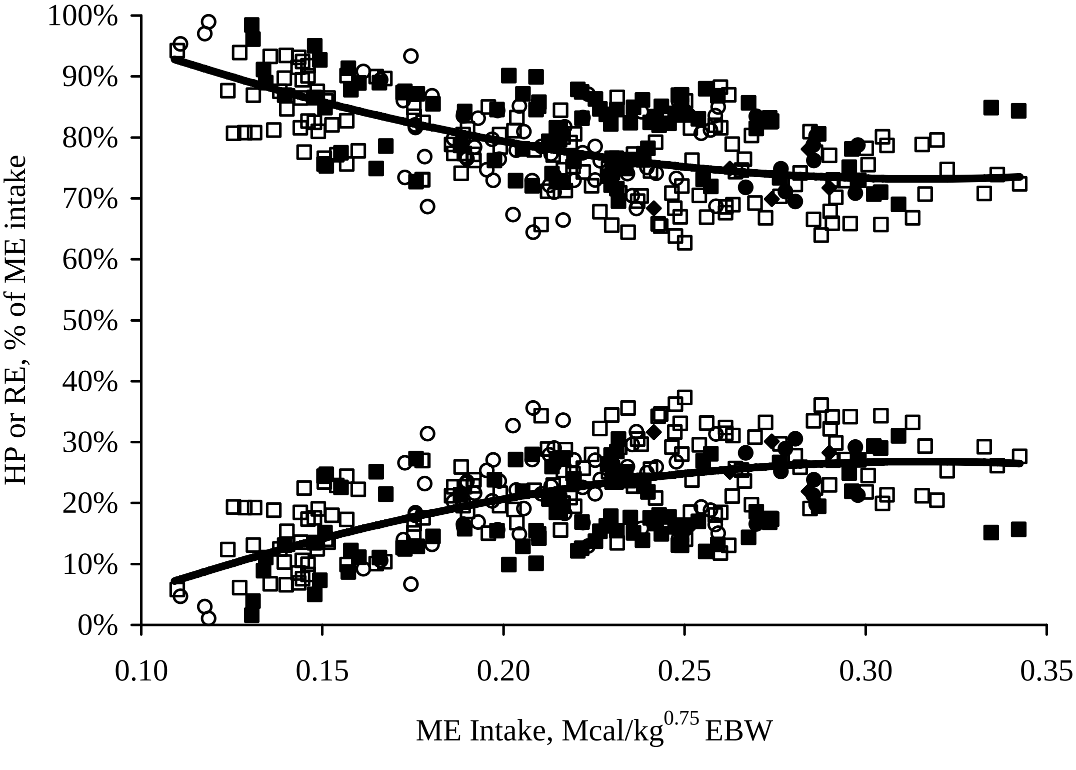


Figure 2. Relationship between the percentages of ME intake (MEI) as RE (bottom data points) and as HP (top data points) on MEI, Mcal/kg of empty BW$^{0.75}$. Symbols are data from bulls (□ and ■), steers (○ and ●) and heifers (◊ and ♦). Opens symbols are data from Nellore purebreds and solid symbols are data from Nellore × *B. taurus* crossbreds. Equations are HP = 1.19 (± 0.05) – 2.91 (± 0.51) × MEI + 4.60 (± 1.21) × MEI^2 (top data points) and RE = -0.19 (± 0.05) + 2.91 (± 0.51) × MEI – 4.60 (± 1.21) × MEI^2 (bottom data points).



Net requirements for growth of Calcium, Magnesium, Sodium, Phosphorus, Potassium of Nellore x Red Angus steers, bulls, and heifers

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Abstract

A comparative slaughter trial was conducted to access the net requirements of Ca, P, Na, K and Mg for gain of crossbreds Nellore x Red Angus bulls, steers and heifers. Twenty seven F1 Nellore x Red Angus calves (9 steers, 9 bulls, and 9 heifers), averaging 274 kg BW, were utilized. At the beginning of the trial, three animals from each gender were slaughtered to determine the initial body composition. The remaining 18 animals (3 animals of each gender) were randomly assigned to two treatments: fed 0.75 or 1.5% of BW of concentrate. The diets were based on corn silage and were isonitrogenous (2% N, DM). After three growing periods of 28 d, all animals were slaughtered. The cleaned gastrointestinal tract, organs, carcass, head, hide, tail, feet, and tissues were weighed to determine the empty BW (EBW). These parts were ground separately and subsampled for chemical analyses. The log of the contents of each mineral in the empty body was regressed on the log of the EBW to estimate the net requirement for each mineral per kg of empty body gain (EBG). There were no differences (P>0.05) in the net requirements for growth of all macrominerals among genders. The equations of the pooled data of the net requirements for growth (g/kg EBG) were: $332.6 \times EBW^{-0.6367}$ for Ca, $112.1 \times EBW^{-0.5615}$ for P, $0.01085 \times EBW^{-0.3992}$ for Na, $4.01 \times EBW^{-0.1530}$ for K, and $3.589 \times EBW^{-0.4620}$ for Mg. Our findings indicated that retained Ca and retained P are poorly related to the retained protein.

1. Introduction

Many of the essential minerals are usually found in insufficient concentrations in tropical grasses, and supplementation is necessary to optimize animal performance and health (McDowell, 1997). Nonetheless, accurate macromineral requirements have not being well established and few studies compared the net mineral requirements of bulls, steers and heifers under the same experimental conditions.

In recent years, mineral requirements have received a great deal of consideration because accurate prediction of mineral requirements may minimize mineral excretion and environmental pollution. The net mineral requirements recommendations of the ARC (1980), AFRC (1991), and NRC (2000) are similar. Nonetheless, Block et al. (2004) stated that the P requirements suggested by the NRC (2000) could be excessive for beef cattle and contribute to over-feeding of P, thereby elevating the risk of P pollution.

The objective of this study was to access the net requirements for growth of Ca, P, Na, K, and Mg of crossbreds Nellore × Red Angus bulls, steers and heifers.

2. Materials and methods

2.1. Animal and Management Description

The trial was conducted at the Federal University of Viçosa, in Brazil, with 27 F1 Nellore x Red Angus calves (9 bulls, 9 steers, and 9 heifers). Humane animal care and handling procedures were followed. All calves were from the same sire. The average age and initial shrunk BW (**SBW**) were 14-16 mo and 275 ± 19 kg for bulls, 14-16 mo and 278 ± 24 kg for steers, and 12-14 mo and 228 ± 19 kg for heifers. The animals were fed the same diet during two wk (75% corn silage, 25% concentrate C1, on DM basis; Table 1) until the beginning of the experiment. The baseline group was composed of three randomly selected calves of each gender (three bulls, three steers, and three heifers) and the remaining calves were randomly allocated to two diets (treatments) within gender group. The diet DM was formulated to be isonitrogenous (2% N) and consisted of corn silage and concentrate. Three animals of each gender were randomly assigned to two treatments: fed at 0.75 or 1.5% BW of concentrate and corn silage was offered ad libitum. Calves fed at 0.75% BW as concentrate, received the concentrate C1, whereas calves fed at 1.5% BW received the concentrate C2 (Table 1). A 14 d of adaptation period was used to adapt animals to the diets and pens. There were three growing periods of 28 d, starting after the slaughter of the baseline group. The animals were fed twice daily (at 0700 and 1600 h) in individual sheltered pens. Feeds and orts daily weighed, sampled and frozen. The animals were weighed at the beginning and at the end of each period.

2.2. Slaughter and Body Composition Techniques

Before slaughter, SBW was measured as the BW after 18 h without feed. At slaughter, steers were stunned and killed by exsanguination using conventional humane procedures, according to the Universidade Federal de Viçosa guidelines. Blood was weighed and sampled. The body was separated into individual components, which were then weighed separately. Included were internal organs (liver, heart, lungs, trachea, kidneys, reproductive tract, and spleen), cleaned digestive tract (rumen, reticulum, omasum, abomasum, and small and large intestines), tongue, tail, hide, head, feet, and carcass. The digestive tract was cleaned by emptying and flushing with water, and then physically stripped. The carcass was split into two identical longitudinal halves. After a 24-h chill, the whole right half of the carcass was manually separated into bone, muscle, and fat. Head and feet were separated in bone, hide, and soft tissue. Internal organs, cleaned digestive tract, tail, and tongue were ground together. Muscle, fat and soft tissues of head and feet were ground separately. Hide was sampled and cut in small pieces. Carcass, head and feet bones were saw in small pieces, homogenized, and proportionally sampled. Except blood samples, which were dried at 60°C for 72 h, all other samples were dried at 105°C for 80 h for DM determination and partially defatted by washing with diethyl ether, the fat was computed as the weight difference. Then, these samples were ground again in ball mill (TE350, Tecnal, Piracicaba, SP) and analyzed for ether extract and nitrogen as described above.

Empty BW (**EBW**) was computed as the sum of the right and left halves of the warm carcass, hide, head, feet, tail, blood, cleaned gastrointestinal, and internal organs.

2.3. Chemical Analysis

The determinations of DM, crude protein and ash were determined according to techniques described by AOAC (1990). The mineral solution for determination of the minerals was prepared by wet ashing, and, after the appropriated dilutions, the P content was determined by colorimetric procedure, the Ca and Mg content by atomic absorption spectrophotometer, and the Na and K content by flame spectrophotometer using the standard procedures described by AOAC (1990).

2.4. Data Calculation and Analyses

2.4.1.Calculation of Initial Body Composition

The procedures used to compute protein, Ca, P, Na, K and Mg retained were similar to those of ARC (1980). The initial EBW was computed from SBW, and then initial empty body content of protein, Ca, P, Na, K and Mg were estimated from EBW for each animal, using the average content of these minerals on the EBW of the baseline group of the appropriate gender.

2.4.2. Net requirements calculation

Empty body gains of body components were calculated as the difference between initial and final weights of the respective body component. The content of each macromineral retained on the empty body were estimated by regressing the logarithm of the content of Ca, P, Na, K, or Mg on the logarithm of the EBW as follows (ARC, 1980):

$$Y = a + b \times X + e_{ij} \qquad [1]$$

Where Y = the logarithm of the mineral content (Ca, P, Na, K, or Mg) on the EBW, a = the intercept, b = the slope, X = the logarithm of the EBW, and e_{ij} the random error.

The derivation of the above equations regarding the EBW was used to determine the daily net requirements of each mineral per kg of EBG (Eq. [2]).

$$NR_g = b \times 10^a \times EBW^{b-1} \quad [2]$$

Where NR_g = the net requirement for gain of each mineral (Ca, P, Na, K, or Mg), g/kg EBG/d, and a and b= the intercept and slope, respectively, of the Equation 1.

2.4.3. Statistical Analysis

Statistical analyses were performed using SAS (SAS Inst. Inc., Cary, NC). The analysis of body composition was performed by PROC GLM assuming a 2 × 3 factorial design of diet (0.75 or 1.5 % BW as concentrate) and gender (bulls, steers and heifers). The statistical model was $Y = \mu + \alpha + \beta + \alpha\beta + \varepsilon$, where μ is the mean, α is the effect of diet, β is the effect of sex, $\alpha\beta$ is the interaction effect between diet and sex, and ε is the random error.

The comparison of intercept and slope among diets and gender was done by the PROC GLM procedure using the SOLUTION statement and the sum of squares type 3 (SS3) was evaluated. The interaction or the main effect were removed from the statistical model if, and only if, $P > 0.05$. The comparisons of means were performed using the least square means method (LSMeans) at $P < 0.05$.

3. Results

3.1. Body and Gain Composition

Table 2 shows the mean body composition for the baseline animals for each gender category. The initial SBW and EBW were similar between bulls, steers and heifers, but heifers had lesser ash, P, Na and Mg content in the EBW than males.

The growth performance and mineral composition of the body are shown in Table 3. There was no interaction between gender and diet. As expected, animals of fed 1.5% of BW as concentrate had faster average daily gain (ADG) and EBG than those of fed 0.75% of BW. Bulls had faster ADG and EBG than steers and heifers. The average ratios EBW/SBW and EBG/shrunk body gain were 0.909 and 0.848, respectively.

The mineral content of the EBW of bulls, steers and heifers decreased in comparison with the baseline group, except for the K content. There were no differences between treatments or among genders for the ash content of the body weight. Nevertheless, the contents of Ca and Na were greater in animals fed 0.75% BW than in animals fed 1.5% BW as concentrated. There was gender effect only for the content of Na on the EBW in which heifers had lesser Na content than steers and bulls.

Table 4 shows the main pool of each mineral in the body. The bone tissue has more than 99, 90, and 72% of the total Ca, P, and Mg, respectively, in the empty body. The main pool of K are the soft tissues (muscle and fat). The Na is well distributed among body tissues and blood contains more than 11% of the total Na in the body.

The regression of retained Ca and retained P on retained protein were plotted in Figure 1. There were no significant regression equations (P values of 0.72 and 0.50 for Ca and P equations, respectively), to predict net Ca and P requirements for growth, using the method adopted by the NRC (2000). Nonetheless, retained Ca is related to retained P according to the equation: retained Ca = - 0.436 (±0.168) + 2.571 (±0.196) × retained P (g/g, *P value* < 0.001; $r^2 = 0.93$; root mean square error = 6.86).

3.2. Net requirements for gain

The coefficients of the alometric equation to describe the net retention of each mineral are shown in Table 5. There were no differences among genders for the net requirement for gain for all minerals, therefore data was pooled.

The equations of the pooled data of the net requirements for growth (NRG, g/kg EBG) for Ca, P, Na, K, Mg, respectively, were:

$$NRG_{Ca} = 332.6 \times EBW^{-0.6367};$$

$$NRG_{P} = 112.1 \times EBW^{-0.5615};$$

$$NRG_{Na} = 10.85 \times EBW^{-0.3992};$$

$$NRG_{K} = 4.01 \times EBW^{-0.153};$$

$$NRG_{Mg} = 3.589 \times EBW^{-0.462}.$$

The net requirements for growth of all minerals decreased as BW increased and were not different among bulls, steers, and heifers.

Our findings indicated that an animal of 250 kg BW would require 10.5, 5.33, 1.24, 1.75, and 0.29 g/kg EBG of Ca, P, Na, K and Mg, respectively, whereas an animal of 450 kg BW would require 7.2, 3.83, 0.98, 1.60, and 0.22 g/kg EBG of Ca, P, Na, K and Mg, respectively.

4. Discussion

4.1. Body and Gain Composition

The superior performance of animals fed 1.5% BW as concentrate is explained by the greater energy intake than the animals fed 0.75% BW as concentrate. Bulls had faster ADG and EBG likely because they tended to accumulate more protein and less fat in the gain than the steers and heifers receiving the same diet (NRC, 2000). According to Owens et al. (1995), more water is stored with deposited protein than with deposited fat, therefore lean tissue gain is four times as efficient as accretion of fat tissue.

The higher Ca content on animals fed 0.75% BW as concentrate than on that fed 1.5% BW is likely due to a higher percentage of bone tissue on the empty body resultant from the slower EBG. The lesser Na content on empty body of heifers may be consequence of the lesser water and protein and higher fat content in the empty body than bulls and steers (Chizzotti et al., 2007).

Bone tissue contains more than 99% of body Ca, 75% of body P and 70% of Mg (Hays and Swenson, 1993). Therefore, any change in the relative growth of muscle and bone tissues could contradict the relationship between Ca and P retention and protein in the gain adopted by the NRC (2000).

4.2. Net requirements for gain

The prediction of mineral requirements of ARC (1980), AFRC (1991), and NRC (2000) had similar net requirements, but different absorption coefficients. The NRC (2000) suggests that Ca and P requirement for growth of beef cattle is 7.2 and 3.9 g per 100 g of retained protein, respectively, and are based on body composition data of dairy cattle published by Ellenberger et al. (1950). According to Erickson et al. (2002), the cattle used for whole-body analysis by Ellenberger et al. (1950) were quite different in breed, body weight, age, and genetic potential than beef feedlot cattle fed today.

As shown in Figure 1 retained protein was not a good predictor of the retained Ca and P likely because the soft tissues (the main pool of body protein) contains only 0.4 and 7% of the total body Ca and P, respectively, and the muscle, fat, and bone show differential growth during development, in which bone, muscle and fat tissues has low, intermediate and high growth impetus, respectively (Berg and Butterfield, 1968). Therefore, if the rate of protein deposition does not follow the rate of bone mineralization, Ca and P should not be estimated from retained protein.

On average, the NRC (2000) model under-predicted by 13 and 7% the net requirements for growth of Ca and P, respectively. Nonetheless, Block et al. (2004) reported that recommended P requirements of NRC (2000) are excessive and suggested that basing P and Ca requirements for growth on skeletal tissue growth and mineralization should improve estimation of gain requirements.

Conclusions

The net requirements of Ca, P, Na, K, and Mg for growth decreased as BW increased and were not different among bulls, steers, and heifers. The retained protein was not related to the retained Ca and P.

Aknowledgement

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Table 1.Ingredients (DM basis) and chemical composition (% of DM) of feeds

Item	Concentrate C1	Concentrate C2	Corn silage
Cracked corn grain	59.7	82.0	-
Soybean meal	34.1	14.9	-
Urea	1.80	0.90	-
Ammonium sulphate	0.20	0.10	-
Limestone	2.05	1.02	-
Salt	0.89	0.44	-
Commercial premix[1]	1.25	0.62	-
DM, %	89.5	88.7	24.5
CP	28.1	17.9	6.74
EE	2.61	2.35	2.25
Ash	7.26	4.10	8.60
NDF	12.1	12.1	55.9
NFC	53.3	65.2	26.5
iADF	0.83	0.90	15.1

[1]- containing 24 and 17.4% of Ca and P and 100, 1250, 1795, 2000, 15, 5270 and 90 ppm of Co, Cu, Fe, Mn, Se, Zn and I, respectively.

Table 2. Body composition of baseline bulls, steers and heifers [a]

Item	Bulls	Steers	Heifers
SBW (kg)	291 ± 30.8	294 ± 29.0	251 ± 15.7
EBW (kg)	235 ± 16.5	232 ± 26.8	194 ± 19.4
Ash (g/100 g of the EBW)	7.22 ± 0.85[c]	7.05 ± 0.40[c]	5.67 ± 0.11[b]
Ca (g/100 g of the EBW)	3.02 ± 0.47	3.00 ± 0.28	2.36 ± 0.09
P (g/100 g of the EBW)	1.27 ± 0.18[c]	1.24 ± 0.07[c]	1.00 ± 0.04[b]
Na (g/100 g of the EBW)	0.20 ± 0.02[c]	0.22 ± 0.01[c]	0.17 ± 0.02[b]
K (g/100 g of the EBW)	0.21 ± 0.01	0.21 ± 0.00	0.19 ± 0.02
Mg (g/1000 g of the EBW)	0.53 ± 0.02[c]	0.57 ± 0.02[c]	0.48 ± 0.02[b]

[a] Values are mean and SE by gender. SBW = shrunk BW, and EBW = empty BW.

[b,c] Distinct lowercase letters differ at $P < 0.05$ by least square mean.

Table 3. Effect of diet and gender on performance, body composition and energy balance [a]

	Bulls		Steers		Heifers		SEM			*P*-value		
	0.75	1.5	0.75	1.5	0.75	1.5	G	T	G×T	G	T	G×T
SBW, kg	411^{bB}	485^{cB}	406^{bB}	447^{cB}	347^{bA}	424^{cA}	17.4	14.1	24.5	0.01	0.03	0.72
EBW, kg	383^{bC}	446^{cC}	369^{bB}	395^{cB}	307^{bA}	373^{cA}	13.6	11.1	19.2	<0.01	0.02	0.62
ADG, $kg.d^{-1}$	1.19^{bB}	1.84^{cB}	1.04^{bA}	1.26^{cA}	0.95^{bA}	1.40^{cA}	0.09	0.07	0.13	0.01	<0.01	0.21
EBG, $kg.d^{-1}$	1.41^{bB}	1.99^{cB}	1.28^{bA}	1.54^{cA}	1.14^{bA}	1.59^{cA}	0.07	0.06	0.10	<0.01	<0.01	0.25
Ash, g/100 g of the EBW	5.10	4.55	5.14	5.32	5.12	4.77	0.13	0.11	0.19	0.11	0.10	0.15
Ca, g/100 g of the EBW	2.10^{c}	1.88^{b}	2.14^{c}	2.11^{b}	2.09^{c}	1.93^{b}	0.06	0.04	0.08	0.21	<0.05	0.49
P, g/100 g of the EBW	0.92	0.84	0.92	0.95	0.91	0.83	0.02	0.02	0.03	0.19	0.15	0.21
Na, g/100 g of the EBW	0.18^{cB}	0.17^{bB}	0.17^{cB}	0.17^{bB}	0.15^{cA}	0.14^{bA}	0.003	0.003	0.005	>0.01	0.03	0.25
K, g/100 g of the EBW	0.21	0.19	0.22	0.19	0.18	0.18	0.009	0.007	0.012	0.19	0.12	0.76
Mg, g/1000 g of the EBW	0.43	0.39	0.41	0.44	0.45	0.43	0.001	0.001	0.001	0.10	0.37	0.10

[a] SBW = shrunk BW, EBW = empty BW, ADG = average daily gain, EBG = average empty body daily gain.

[b,c] Distinct lowercase letters in the same row, within gender, differ at *P* < 0.05 by least square means for diet effect.

[A, B] Distinct capital letters in the same row, differ at *P*< 0.05 by least square means for gender effect.

Table 4. Percentage of total mineral element on body tissues of bulls, steers and heifers[a]

	Bones	Soft tissue	Organs	Hide	Blood	Others
	Calcium					
Bulls	99.2	0.38	0.19	0.16	0.022	0.016
Steers	99.3	0.33	0.22	0.14	0.022	0.016
Heifers	99.1	0.38	0.28	0.16	0.021	0.013
SEM	0.05	0.02	0.03	0.01	0.001	0.001
	Phosphorus					
Bulls	89.8	7.6	1.89^{b}	0.35	0.080	0.025
Steers	90.5	6.7	2.07^{c}	0.36	0.079	0.027
Heifers	89.6	7.6	2.19^{c}	0.33	0.085	0.023
SEM	0.36	0.29	0.09	0.03	0.003	0.006
	Sodium					
Bulls	41.7	25.1	7.75	12.5	11.3	0.513
Steers	43.9	23.2	7.82	11.7	11.5	0.568
Heifers	41.5	22.5	8.43	13.1	12.7	0.600
SEM	1.00	0.94	0.42	0.46	0.49	0.037
	Potassium					
Bulls	10.2^{c}	72.1^{bc}	11.1	3.68	1.54	0.127
Steers	10.9^{c}	70.4^{c}	11.3	4.12	1.61	0.149
Heifers	8.3^{b}	73.3^{b}	11.3	3.78	1.74	0.156
SEM	0.53	0.52	0.50	0.32	0.12	0.040
	Magnesium					
Bulls	70.8^{b}	20.7^{b}	3.56	3.84	0.532	0.058
Steers	73.5^{c}	18.5^{c}	3.51	3.45	0.508	0.065
Heifers	72.9^{bc}	19.1^{bc}	3.66	3.04	0.756	0.053

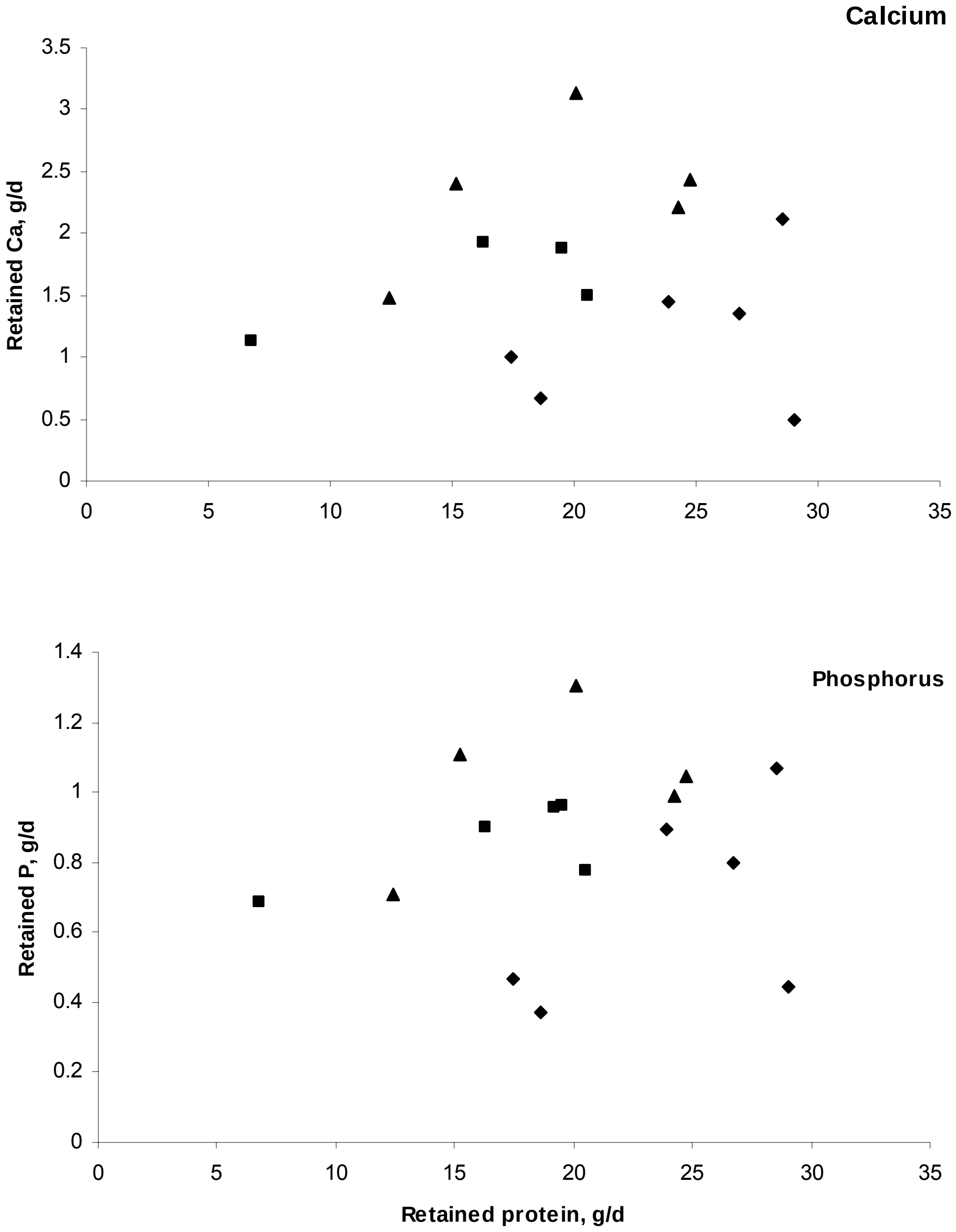
[a] Soft tissue = muscle plus fat

[b,c] Distinct lowercase letters in the same collumn, differ at *P* < 0.05 by least square means for sex effect.

Table 5. Regression of logarithm of empty body calcium, phosphorus, sodium, potassium or magnesium on logarithm of empty body weight to describe the net retention of each mineral by bulls, steers and heifers

	Intercept	Slope	r^2	RMSE
	Calcium			
Bulls	0.23 ± 0.35	0.26 ± 0.14	0.54	0.03
Steers	-0.06 ± 0.26	0.38 ± 0.10	0.66	0.03
Heifers	-0.41 ± 0.45	0.50 ± 0.18	0.77	0.03
All	-0.04 ± 0.17	0.36 ± 0.07	0.57	0.04
	Phosphorus			
Bulls	-0.33 ± 0.32	0.34 ± 0.13	0.74	0.03
Steers	-0.67 ± 0.24	0.47 ± 0.09	0.77	0.03
Heifers	-0.78 ± 0.41	0.50 ± 0.17	0.78	0.03
All	-0.59 ± 0.16	0.44 ± 0.07	0.68	0.03
	Sodium			
Bulls	-1.67 ± 0.20	0.59 ± 0.08	0.96	0.02
Steers	-1.55 ± 0.15	0.53 ± 0.06	0.91	0.02
Heifers	-1.54 ± 0.26	0.49 ± 0.10	0.87	0.02
All	-1.74 ± 0.20	0.60 ± 0.08	0.72	0.04
	Potassium			
Bulls	-2.45 ± 0.22	0.90 ± 0.09	0.96	0.03
Steers	-2.17 ± 0.16	0.79 ± 0.07	0.97	0.02
Heifers	-1.98 ± 0.28	0.70 ± 0.11	0.97	0.01
All	-2.32 ± 0.12	0.85 ± 0.05	0.93	0.03
	Magnesium			
Bulls	-2.10 ± 0.29	0.50 ± 0.12	0.88	0.02
Steers	-2.03± 0.22	0.48 ± 0.09	0.75	0.04
Heifers	-2.75 ± 0.38	0.77 ± 0.15	0.97	0.01
All	-2.18 ± 0.13	0.54 ± 0.05	0.83	0.03

Figure 1. Regression of retained Ca and retained P on retained protein of Nelore x Red Angus bulls steers and heifers. Symbols ♦, ■ and ▲ are from bulls, steers and heifers.



CONCLUSÕES GERAIS

Um experimento foi realizado no Departamento de Zootecnia da Universidade Federal de Viçosa, com o objetivo de avaliar os efeitos de classe sexual e do nível de oferta de concentrado sobre o consumo, desempenho e exigências de proteína, energia e macrominerais de bovinos F1 Red Angus x Nelore. Adicionalmente, foi realizada uma meta-análise nos dados de exigências nutricionais de bovinos em condições brasileiras com o objetivo de avaliar o efeito do grupamento genético (Nelore puro ou cruzado com bovinos *Bos taurus*) e da classe sexual sobre as exigências nutricionais.

Conclui-se que:

Não há diferenças para os consumos de matéria seca, expressos em relação ao peso do animal, entre machos inteiros, machos castrados e fêmeas, entretanto, a oferta de concentrado ao nível de 1,5% do PV resultam em maiores consumos de matéria seca e de energia metabolizável do que ao nível de 0,75% do PV.

Machos inteiros Red Angus x Nelore apresentam maior taxa de ganho em peso do que machos castrados e fêmeas. Ofertas de concentrado ao nível de 1,5% do PV resultam em maior ganho de peso diário do que ao nível de 0,75% do PV.

Ofertas de concentrado ao nível de 1,5% do PV aumentam a porcentagem de gordura no corpo vazio em relação ao nível de 0,75 % do PV. Fêmeas Red Angus x Nelore apresentam maior teor de gordura e menor teor de água no corpo vazio do que machos inteiros ou castrados.

As exigências líquidas de energia para mantença é similar entre as classes sexuais de bovinos Red Angus x Nelore.

Machos inteiros Red Angus x Nelore são menos exigentes em energia líquida para ganho em peso do que machos castrados e fêmeas.

A energia depositada como proteína é negativamente correlacionada com a concentração da energia no corpo vazio, entretanto não há diferença nas exigências de proteína líquida para crescimento entre as classes sexuais avaliadas de bovinos Red Angus x Nelore.

O resultado da meta-análise sugere que a exigência de energia líquida para mantença é de 75 kcal/kg$^{0.75}$ PCVZ e que não há diferença entre machos inteiros, machos castrado e fêmeas e também entre bovinos Nelore puros ou cruzados com *Bos taurus.*

A eficiência de utilização da energia metabolizável para mantença é de 67% para bovinos Nelore puros ou cruzados.

Embora similar entre bovinos Nelore puros ou cruzados, a exigência líquida de energia para crescimento de machos castrados é superior e inferior à de machos inteiros e fêmeas, respectivamente.

As eficiências de deposição da energia metabolizável com gordura e proteína são de 79 e 34%, respectivamente, e similar entre os grupos genéticos e classes sexuais avaliados.

A porcentagem de energia depositada como proteína decresce exponencialmente com o aumento na concentração da energia retida no ganho, entretanto não há diferença nas exigências de proteína líquida para ganho entre os grupos genéticos e entre as classes sexuais.

A eficiência de utilização da energia metabolizável para ganho em peso (K_g) pode ser calculada em função da concentração energética do ganho de corpo vazio(RE_c) pela equação: $K_g = 1343 / \{1700 + 2250 \times [0{,}101 + 1{,}667 \times e^{(-0{,}660 \times REc)}]\}$.

A máxima porcentagem de retenção da energia metabolizável ingerida ocorre ao nível de ingestão de 0,316 Mcal de ME·kg$^{-0.75}$ ·PCVZ·dia^{-1}, e apresenta comportamento quadrático em relação ao consumo de energia metabolizável.

As exigências líquidas dos minerais estudados não diferem entre as classes sexuais de bovinos Red Angus x Nelore e decrescem com o aumento do peso do animal.

O Ca e P retidos não são correlacionados com a proteína retida.

Apêndice

Tabela 1 – Número do animal, tratamento, classe sexual (CS; MI = macho inteiro, MC = macho castrado, F = fêmea),peso vivo inicial (PVi), peso vivo final (PVf), peso de corpo vazio inicial (PCVZi), peso de corpo vazio final (PCVZf) e dias em confinamento de bovinos F1 Red Angus X Nelore.

Animal	**Tratamento**	**CS**	**PVi, kg**	**PVf, kg**	**PCVZi, kg**	**PCVZf, kg**	**DC**
10	Mantença	MI	298,0	298,0	241,1	266,5	91
23	Mantença	MI	279,5	278,0	226,1	251,1	93
8	Mantença	MI	255,0	248,0	206,3	222,2	91
3	0,75% PV	MI	298,5	423,0	241,5	398,0	104
17	0,75% PV	MI	314,5	429,0	254,4	394,5	106
18	0,75% PV	MI	256,0	382,0	207,1	357,3	108
20	1,5% PV	MI	281,0	486,0	227,3	443,6	106
14	1,5% PV	MI	297,5	482,0	240,7	446,1	108
16	1,5% PV	MI	295,0	486,5	238,7	449,8	104
4	Mantença	MC	292,0	277,0	229,8	241,9	91
24	Mantença	MC	298,0	264,5	234,5	248,8	93
7	Mantença	MC	274,5	269,0	216,0	238,0	91
2	0,75% PV	MC	336,5	413,0	264,8	381,7	104
9	0,75% PV	MC	260,0	400,5	204,6	355,0	111
21	0,75% PV	MC	287,5	403,5	226,2	369,4	106
5	1,5% PV	MC	298,5	455,0	234,9	415,8	111
12	1,5% PV	MC	307,5	486,5	242,0	399,9	104
13	1,5% PV	MC	270,5	398,0	212,9	369,6	106
26	Mantença	F	260,0	231,5	200,4	218,4	91
30	Mantença	F	272,5	275,5	210,1	237,8	93
33	Mantença	F	211,0	186,5	162,7	175,5	93
28	0,75% PV	F	248,5	377,5	191,6	333,9	108
31	0,75% PV	F	277,0	376,5	213,5	337,0	104
36	0,75% PV	F	194,0	286,0	149,6	250,6	111
27	1,5% PV	F	262,0	398,0	202,0	359,5	108
29	1,5% PV	F	263,5	449,0	203,1	386,4	106

Continuação da Tabela 1...

1	Referência	MC	-	320,5	-	251,1	-
11	Referência	MC	-	293,0	-	235,0	-
19	Referência	MC	-	259,0	-	218,0	-
6	Referência	MI	-	311,5	-	246,5	-
15	Referência	MI	-	261,0	-	201,1	-
22	Referência	MI	-	311,0	-	248,6	-
25	Referência	F	-	268,5	-	215,6	-
32	Referência	F	-	245,5	-	178,9	-
34	Referência	F	-	238,5	-	186,3	-

Tabela 2 – Número do animal, tratamento, classe sexual (CS; MI = macho inteiro, MC = macho castrado, F = fêmea), conteúdos corporais inicial de extrato etéreo (EE), proteína bruta (PB) e energia de bovinos Nelore F1 Red Angus X Nelore.

Animal	Tratamento	CS	EE, kg	PB, kg	Energia, Mcal
10	Mantença	MI	32,01	49,17	578,0
23	Mantença	MI	32,87	45,69	566,4
8	Mantença	MI	21,38	40,41	428,7
3	0,75% PV	MI	64,16	72,16	1009,7
17	0,75% PV	MI	58,46	73,82	965,5
18	0,75% PV	MI	58,19	69,80	940,3
20	1,5% PV	MI	96,61	78,93	1352,6
14	1,5% PV	MI	90,12	82,38	1311,2
16	1,5% PV	MI	78,14	79,65	1183,3
4	Mantença	MC	25,60	45,05	494,5
24	Mantença	MC	30,41	47,12	551,5
7	Mantença	MC	25,69	46,11	501,4
2	0,75% PV	MC	72,51	69,23	1071,5
9	0,75% PV	MC	67,68	60,46	976,8
21	0,75% PV	MC	90,55	55,60	1164,2
5	1,5% PV	MC	86,24	70,23	1206,2
12	1,5% PV	MC	78,55	71,41	1140,6
13	1,5% PV	MC	74,84	66,48	1077,9
26	Mantença	F	30,21	40,52	512,3
30	Mantença	F	26,82	46,54	514,4
33	Mantença	F	22,34	33,09	396,5
28	0,75% PV	F	66,95	63,73	988,3
31	0,75% PV	F	59,37	58,69	888,7
36	0,75% PV	F	43,91	42,88	654,3
27	1,5% PV	F	88,88	61,23	1180,2
29	1,5% PV	F	91,81	65,64	1232,6

Continuação da Tabela 2...

1	Referência	MC	15,26	55,10	454,1
11	Referência	MC	18,51	51,63	465,1
19	Referência	MC	11,55	49,32	386,7
6	Referência	MI	14,36	53,40	436,1
15	Referência	MI	11,64	42,80	350,7
22	Referência	MI	13,09	54,03	427,7
25	Referência	F	21,50	44,51	453,0
32	Referência	F	11,75	37,08	319,5
34	Referência	F	26,02	36,68	451,3

Tabela 3 - Número do animal, tratamento, classe sexual (CS; MI = macho inteiro, MC = macho castrado, F = fêmea), oferta de matéria seca de silagem de milho e de concentrado (Silagem e Concent.), matéria seca de sobras (Sobras) e consumos de matéria seca (CMS) e matéria orgânica (CMO), expressos em kg/dia, em bovinos F1 Red Angus X Nelore.

Animal	**Tratamento**	**CS**	Silagem	Concent.	Sobras	CMS	CMO
10	Mantença	MI	2,053	0,999	-	3,052	2,802
23	Mantença	MI	1,919	0,934	-	2,853	2,619
8	Mantença	MI	1,766	0,868	-	2,634	2,418
3	0,75% PV	MI	7,040	2,347	0,850	8,537	7,832
17	0,75% PV	MI	7,435	2,399	0,908	8,927	8,191
18	0,75% PV	MI	7,373	2,273	1,034	8,611	7,919
20	1,5% PV	MI	6,565	4,765	1,007	10,322	9,649
14	1,5% PV	MI	7,020	4,665	0,920	10,766	10,050
16	1,5% PV	MI	5,733	4,837	1,123	9,447	8,845
4	Mantença	MC	2,038	0,997	-	3,035	2,786
24	Mantença	MC	2,075	1,010	-	3,085	2,833
7	Mantença	MC	1,947	0,948	-	2,894	2,657
2	0,75% PV	MC	6,886	2,409	0,874	8,421	7,733
9	0,75% PV	MC	6,984	2,216	0,889	8,311	7,639
21	0,75% PV	MC	6,963	2,176	0,897	8,242	7,564
5	1,5% PV	MC	6,124	4,355	0,928	9,551	8,933
12	1,5% PV	MC	5,612	4,646	1,077	9,180	8,598
13	1,5% PV	MC	5,640	4,286	0,976	8,949	8,373
26	Mantença	F	1,784	0,875	-	2,659	2,441
30	Mantença	F	1,992	0,974	-	2,966	2,724
33	Mantença	F	1,472	0,720	-	2,193	2,013
28	0,75% PV	F	6,404	1,963	0,928	7,440	6,832
31	0,75% PV	F	6,770	2,012	1,101	7,682	7,073
36	0,75% PV	F	5,107	1,633	0,855	5,884	5,410
27	1,5% PV	F	6,040	3,863	0,941	8,962	8,385
29	1,5% PV	F	5,890	3,751	0,926	8,716	8,140

Tabela 4 - Número do animal, tratamento, classe sexual (CS; MI = macho inteiro, MC = macho castrado, F = fêmea), consumos de proteína bruta (CPB), extrato etéreo (CEE), fibra em detergente neutro (CFDN), carboidratos não-fibrosos (CCNF) e nutrientes digestíveis totais (CNDT), expressos em kg/dia, em bovinos F1 Red Angus X Nelore.

Animal	**Tratamento**	**CS**	CPB	CEE	CFDN	CCNF	CNDT
10	Mantença	MI	0,418	0,072	1,268	1,077	2,100
23	Mantença	MI	0,391	0,067	1,185	1,007	1,968
8	Mantença	MI	0,362	0,062	1,092	0,931	1,791
3	0,75% PV	MI	1,052	0,205	3,719	2,934	4,628
17	0,75% PV	MI	1,079	0,214	3,935	3,043	4,792
18	0,75% PV	MI	1,034	0,205	3,825	2,932	4,578
20	1,5% PV	MI	1,175	0,242	3,790	4,523	6,122
14	1,5% PV	MI	1,210	0,250	4,026	4,643	6,415
16	1,5% PV	MI	1,102	0,219	3,360	4,245	6,149
4	Mantença	MC	0,417	0,072	1,259	1,072	2,151
24	Mantença	MC	0,423	0,073	1,282	1,090	2,185
7	Mantença	MC	0,397	0,068	1,202	1,022	1,939
2	0,75% PV	MC	1,047	0,202	3,676	2,888	4,811
9	0,75% PV	MC	1,012	0,203	3,662	2,836	4,582
21	0,75% PV	MC	0,989	0,200	3,641	2,807	4,844
5	1,5% PV	MC	1,092	0,224	3,468	4,224	6,155
12	1,5% PV	MC	1,073	0,217	3,252	4,134	5,902
13	1,5% PV	MC	1,033	0,211	3,214	3,987	5,898
26	Mantença	F	0,365	0,063	1,103	0,940	1,804
30	Mantença	F	0,407	0,070	1,231	1,048	2,130

Continuação da Tabela 4...

33	Mantença	F	0,301	0,052	0,910	0,775	1,457
28	0,75% PV	F	0,889	0,178	3,313	2,518	4,384
31	0,75% PV	F	0,894	0,181	3,473	2,593	4,423
36	0,75% PV	F	0,720	0,146	2,518	2,081	3,333
27	1,5% PV	F	0,992	0,213	3,430	3,816	5,688
29	1,5% PV	F	0,975	0,208	3,223	3,798	5,209

Tabela 5 - Número do animal, tratamento, classe sexual (CS; MI = macho inteiro, MC = macho castrado, F = fêmea), e coeficientes de digestibilidade aparente total de matéria seca (CD, MS), matéria orgânica (CD, MO), proteína bruta (CD, PB), extrato etéreo (CDEE), fibra em detergente neutro (CDFDN) e carboidratos não-fibrosos (CDCNF), expressos em % do ingerido, em bovinos F1 Red Angus X Nelore.

Animal	**Tratamento**	**CS**	CD, MS	CD, MO	CD, PB	CD, EE	CD, FDN	CD, CNF
10	Mantença	MI	67,1	71,2	73,6	87,3	55,3	88,5
23	Mantença	MI	68,0	71,5	73,1	82,4	56,9	88,1
8	Mantença	MI	66,6	70,5	70,1	80,6	55,9	88,0
3	0,75% PV	MI	52,4	56,0	57,6	72,9	40,2	75,6
17	0,75% PV	MI	52,0	55,3	55,2	77,1	39,8	74,6
18	0,75% PV	MI	51,3	54,6	55,7	80,1	40,5	72,6
20	1,5% PV	MI	57,5	60,7	54,1	68,8	41,1	79,1
14	1,5% PV	MI	58,3	61,1	56,2	71,6	42,3	78,6
16	1,5% PV	MI	63,6	66,4	62,6	80,8	44,0	83,5
4	Mantença	MC	69,9	73,4	73,8	88,1	57,6	91,6
24	Mantença	MC	69,3	73,5	73,6	83,3	61,5	87,9
7	Mantença	MC	66,2	69,4	70,0	81,0	59,8	80,6
2	0,75% PV	MC	54,4	58,9	58,0	79,5	44,1	77,9
9	0,75% PV	MC	53,9	56,9	58,1	80,7	42,4	75,1
21	0,75% PV	MC	55,9	60,8	60,6	81,7	43,1	83,7
5	1,5% PV	MC	63,1	65,9	61,3	81,0	42,9	85,1
12	1,5% PV	MC	62,5	65,5	57,5	80,6	43,4	83,8
13	1,5% PV	MC	64,5	67,4	62,3	81,6	46,6	85,4

Continuação da Tabela 4...

26	Mantença	F	65,2	70,1	71,3	89,7	53,9	88,1
30	Mantença	F	68,1	74,4	73,8	88,1	58,9	92,8
33	Mantença	F	64,6	68,7	68,9	86,4	49,7	90,8
28	0,75% PV	F	57,7	60,8	61,7	81,8	46,8	76,9
31	0,75% PV	F	55,8	59,4	59,2	79,4	45,1	77,8
36	0,75% PV	F	55,2	58,5	57,0	78,0	43,8	77,4
27	1,5% PV	F	61,1	64,8	57,8	78,7	49,7	80,7
29	1,5% PV	F	57,9	61,0	55,7	80,5	43,7	77,1