**UNIVERSIDADE ESTADUAL PAULISTA – UNESP**
**CÂMPUS DE JABOTICABAL**

# ENERGY AND PROTEIN REQUIREMENTS OF MALE AND FEMALE SAANEN GOATS

**Fernanda Oliveira de Miranda Figueiredo**
**Médica Veterinária**

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Tese apresentada à Faculdade de Ciências Agrárias e Veterinárias – Unesp, Câmpus de Jaboticabal, como parte das exigências para obtenção do título de Doutor em Zootecnia (Nutrição animal).

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## CERTIFICADO DE APROVAÇÃO

**TÍTULO:** ENERGY AND PROTEIN REQUIREMENTS OF MALE AND FEMALE SAANEN GOATS

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## DADOS CURRICULARES DO AUTOR

**FERNANDA OLIVEIRA DE MIRANDA FIGUEIREDO** – nasceu em Três Pontas, Minas Gerais no dia 14 de outubro de 1983. Em 2008, graduou-se em Medicina Veterinária pela Universidade Federal de Minas Gerais. Em 2009, ingressou no curso de Mestrado em Zootecnia pela Universidade Estadual Paulista, câmpus de Jaboticabal, defendendo a dissertação em fevereiro de 2011. Em 2011, ingressou no curso de doutorado também pela Universidade Estadual Paulista, câmpus de Jaboticabal. Durante o doutorado fez estágio sanduíche na The Ohio State University, Columbus, Ohio sob a orientação do Prof. Dr. Normand St-Pierre.

*“Talvez não tenha conseguido fazer o melhor, mas lutei para que o melhor fosse feito. Não sou o que deveria ser, mas graças a Deus, não sou o que era antes*”.

*Marthin Luther King*

***DEDICO***

*Aos meus pais por me ensinarem que as dificuldades sempre serão superadas.*

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*A minha querida e amada Vó Wanda... para sempre no meu coração.*

*Ao José Lima... Jamais me esquecerei de você.*

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Muito obrigada.

# SUMÁRIO

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# EXIGÊNCIAS DE ENERGIA E PROTEÍNA PARA CAPRINOS MACHOS E FÊMEAS DA RAÇA SAANEN

**RESUMO** – Os objetivos deste trabalho foram estimar, utilizando a técnica do abate comparativo, as exigências de energia e proteína para mantença e crescimento de caprinos Saanen, machos inteiros, machos castrados e fêmeas com peso corporal variando de 15 a 30 kg e, avaliar os modelos do AFRC (1998) e NRC (2007) para predizer o consumo de matéria seca (CMS) e ganho de peso (GP) de caprinos Saanen em crescimento. Para determinar as exigências líquidas de energia e proteína para mantença foram utilizados 25 machos castrados, 26 machos inteiros e 24 fêmeas. Destes, sete machos castrados, oito machos inteiros e seis fêmeas foram selecionados aleatoriamente e abatidos com 15 kg de peso corporal para a estimativa da composição corporal inicial. Os animais restantes, 18 machos castrados, 18 machos inteiros e 18 fêmeas foram distribuídos nos tratamentos, que consistiram de três níveis de ingestão: ad libitum, 75% e 50% do consumo ad libitum. Dentro de cada sexo, foram formados seis blocos de três animais e dentro de cada bloco, os animais foram distribuídos aleatoriamente em cada nível de ingestão. Assim, a alimentação foi estabelecida dentro de cada bloco com base no consumo dos animais alimentados ad libitum. Todos os animais dentro de um bloco foram abatidos quando o animal alimentado ad libitum atingiu 30 kg de peso corporal. A quantidade a ser fornecida aos animais submetidos aos tratamentos 75 e 50% do ad libitum foi determinada diariamente com base no CMS do animal alimentado ad libitum no dia anterior. As exigências de energia e proteína para crescimento foram obtidas usando 20 machos castrados, 20 machos inteiros e 18 fêmeas. Os animais foram alimentados ad libitum e abatidos aos 15, 23 e 30 kg de peso corporal. O sexo não afetou as necessidades de energia e proteína para mantença, bem como as exigências de proteína para o crescimento. No entanto, afetou as necessidades energéticas para o crescimento no qual machos castrados e fêmeas apresentaram exigência de energia para crescimento superior a dos machos inteiros. Para avaliar os modelos do AFRC (1998) e NRC (2007) para predizer o CMS e GP foram utilizadas observações individuais de 37 caprinos Saanen (12 machos inteiros, 13 machos castrados e 12 fêmeas) com peso corporal variando de 15,0 ± 0,4 to 31,2 ± 1,6 kg. Os sistemas de alimentação foram avaliados pela regressão do resíduo (observado – predito) com os valores preditos centralizados em suas médias. As avaliações mostraram que o AFRC (1998) foi o mais acurado em predizer o CMS (P = 0,96) e o GP (P = 0,68). O NRC (2007) não foi acurado em estimar o CMS (P < 0,0001) e o GP (P < 0,0001). Entretanto, quando o peso a maturidade foi utilizado como covariável tanto o AFRC (P = 0,81) quanto o NRC foram acurados em estimar o GP (P = 0,99).

**Palavras-chave:** abate comparativo, composição corporal, consumo, crescimento, ganho de peso, mantença

# ENERGY AND PROTEIN REQUIREMENTS OF MALE AND FEMALE SAANEN GOATS

**ABSTRACT –** The objective of this research was to estimate, using the comparative slaughter technique, energy and protein requirements for maintenance and growth of castrated males, intact males and females Saanen goat kids between 15 and 30 kg of body weight and to evaluate the models from AFRC (1998) and NRC (2007) for predicting dry matter intake (DMI) and average daily gain (ADG) of growing goats. To determine net energy and net protein requirements for maintenance 25 castrate males, 26 intact males and 24 females were used, where 7 castrated males, 8 intact males and 6 females were randomly selected to estimate the initial empty body composition. The remaining animals, 18 castrate males, 18 intact males, and 18 females were used with dietary treatments that consisted of 3 levels of intake: ad libitum, 75% and 50% of ad libitum intake. Within each sex, six blocks of 3 animals each were formed. Within each block, one animal was randomly assigned to each level of intake. Thus, pair feeding was established within each block based on the intake of the animal fed ad libitum. All animals within a block were slaughtered when the animal fed ad libitum reached 30 kg of BW. The 75 and 50% of ad libitum rationing were determined daily based on the DMI of the animal fed ad libitum on the previous day. The net energy and net protein requirements for gain ($NE_g$ and $NP_g$, respectively) were obtained using 20 castrated males, 20 intact males and 18 females. The animals were fed ad libitum and slaughtered at targeted BW of 15, 23, and 30 kg. We found that sex did not affect energy and protein requirements for maintenance as well as protein requirements for growth. However it affected energy requirements for growth where castrated males and females had the same $NE_g$ comparing with intact males. To evaluate the models from AFRC (1998) and NRC (2007) for predicting DMI and ADG of growing goats, individual data of 37 Saanen goat kids (12 intact males, 13 castrated males and 12 females) with body weight (BW) ranging from 15.0 ± 0.4 to 31.2 ± 1.6 kg were used. The feeding systems were evaluated by regressing the residual (observed minus predicted) on the predicted values centered on their means. The comparisons showed that AFRC feeding system was the most accurate for predicting DMI (P= 0.96) and ADG predictions (P = 0.68). The NRC feeding system is not accurate for predicting DMI (P < 0.0001) and ADG (P < 0.0001). However, when mature body weight was used as a covariate both AFRC and NRC was accurate in predicting the ADG (and P = 0.81 and P = 0.99 for NRC).

**Keywords:** comparative slaughter technique, body composition, growth, intake, maintenance, performance

# LISTA DE ABREVIATURAS

| | |
|---|---|
| ADF | Acid detergent fiber, % DM |
| ADG | Average daily gain, g/d |
| BL | Baseline group |
| BW | Body weight, kg |
| CP | Crude protein |
| CMS | Consumo de matéria seca, g/d |
| CPI | Crude protein intake, g/d |
| DCP | Digestibility of crude protein, % |
| DE | Digestible energy, Mcal/kg |
| DF | Degrees of freedom |
| DFG | Daily fat body gain, g/d |
| DGE | Digestibility of gross energy, % |
| DM | Dry matter |
| DMI | Dry matter intake, g/d |
| DPG | Daily protein body gain, g/d |
| EBW | Empty body weight, kg |
| EPG | Energy of gaseous products of digestion, kcal/d |
| EWG | Empty body weight gain, g/d |
| fBW | Final body weight, kg |
| FIG | Fat in gain, % EWG |
| GE | Gross energy |
| GEI | Gross energy intake, kcal/d; Mcal/d |
| HP | Heat production, kcal/kg$^{0.75}$ EBW.d |
| iBW | Initial body weight, kg |
| iEBW | Initial empty body weight, kg |
| iEnergy | Initial body energy, kcal |
| iFat | Initial body fat, g |
| iProtein | Initial body protein, g |
| $k_g$ | Efficiency of energy utilization for gain |
| $k_m$ | Efficiency of energy utilization for maintenance |

| | |
|---|---|
| ME | Metabolizable energy, Mcal/kg |
| MEI | Metabolizable energy intake, kcal/d; Mcal/d |
| $ME_g$ | Metabolizable energy requirements for gain, Mcal/kg EBW gain |
| $ME_m$ | Metabolizable energy requirements for maintenance, kcal/kg$^{0.75}$ EBW.d |
| $NE_g$ | Net energy requirements for gain, Mcal/kg EBW gain |
| $NE_m$ | Net energy requirements for maintenance, kcal/kg$^{0.75}$ EBW.d |
| NFD | Neutral detergent fiber, % DM |
| NI | Nitrogen intake, g of N/kg$^{0.75}$ EBW.d |
| $NP_g$ | Net protein requirements for gain, g/kg EBW gain |
| $NP_m$ | Net protein requirements for maintenance, g/kg$^{0.75}$ EBW.d |
| NRet | Nitrogen retained in the body, g of N/kg$^{0.75}$ EBW.d |
| PIG | Protein in gain, % EWG |
| $q_m$ | Metabolizability of energy |
| RE | Retained energy in the body, kcal/kg$^{0.75}$ EBW.d |
| $RE_c$ | Concentration of RE in the body, kcal/kg$^{0.75}$ EBW.d |

# CERTIFICADO DA COMISSÃO DE ÉTICA NO USO DE ANIMAIS

**UNIVERSIDADE ESTADUAL PAULISTA**
**"JÚLIO DE MESQUITA FILHO"**
Câmpus de Jaboticabal

## CEBEA – COMISSÃO DE ÉTICA E BEM ESTAR ANIMAL

## CERTIFICADO

Certificamos que o Protocolo nº 019833-08 do trabalho de pesquisa intitulado **"Metabolismo de cabritos Saanen em diferentes níveis nutricionais e condições sexuais",** sob a responsabilidade do Prof. Dr. Kleber Tomás de Resende, está de acordo com os Princípios Éticos na Experimentação Animal, adotado pelo Colégio Brasileiro de Experimentação (COBEA) e foi aprovado pela COMISSÃO DE ÉTICA E BEM ESTAR ANIMAL (CEBEA), em reunião ordinária de 09 de outubro de 2008.

Jaboticabal, 10 de outubro de 2008.

**Prof. Dr. Marcos Lânia de Araújo**
Presidente - CEBEA

# CAPÍTULO 1 – CONSIDERAÇÕES GERAIS

## Introdução

A caprinocultura é uma atividade econômica explorada em todos os continentes, nos mais diferentes tipos de clima, solo, topografia e vegetação. Com rebanho mundial na ordem de 996 milhões de cabeças (FAO, 2014), os caprinos representam uma importante atividade sócio-econômica, principalmente para as populações dos países em desenvolvimento (NOGUEIRA FILHO, 2003).

Embora parte da produção de caprinos seja destinada à subsistência ou para pequena comercialização local dos produtos (CORDEIRO e CORDEIRO, 2009) nos últimos anos, devido ao aumento da demanda por produtos de origem caprina (RESENDE et al., 2008), a atividade tem despertado interesse por parte de produtores, técnicos e pesquisadores. Atualmente, tem-se observado mudanças significativas na atividade como a absorção de novas tecnologias por parte dos produtores, crescente organização dos mesmos em associações e cooperativas além do aumento do número de pesquisas relacionadas à criação e manejo de caprinos (RESENDE et al., 2010).

Desse modo, visto que a nutrição representa maior parcela dos custos de produção relacionados à caprinocultura (PEREIRA FILHO et al., 2005), pesquisas relacionadas à nutrição de caprinos são de grande importância para a elaboração de dietas de menor custo e que permita melhor desempenho dos animais. No entanto, para tal faz-se necessário o estudo e conhecimento das exigências nutricionais específicas para cada genótipo, condição sexual e fase de crescimento dos animais.

## Composição corporal

O conhecimento da composição corporal é o primeiro passo para a estimativa das exigências nutricionais quando se leva em consideração a utililização do método de abate comparativo para a determinação das exigências. Além disso, a mensuração da composição corporal pode ser utilizada como medida para a avaliação dos alimentos e do potencial de crescimento dos animais uma vez que permite identificar as modificações na composição do ganho em função de diferentes fatores tais como raça, sexo, peso e composição da dieta (RESENDE, 2004).

As taxas e locais de deposição dos nutrientes nos tecidos corporais são influenciadas por fatores fisiológicos, genéticos e nutricionais (OWENS et al., 1993). Com relação aos fatores fisiológicos os hormônios são os que mais exercem influência e a liberação destes pode ser mediada diferentes fatores como: sexo, grau de maturidade e manipulações do ambiente interno (como por exemplo, a utilização de hormônios exógenos) e externo (por exemplo, o fotoperíodo).

Segundo Luchiari Filho (2000), existe uma diferença na curva de crescimento de fêmeas, machos castrados e machos inteiros, sendo que as fêmeas são mais precoces e geralmente de menor tamanho corporal, os machos inteiros são maiores e mais tardios, enquanto os machos castrados apresentam desenvolvimento intermediário. Além disso, dentre animais pertencentes a mesma raça e com peso de corpo vazio similares, fêmeas possuem maior deposição de gordura corporal do que machos castrados e, estes maiores do que machos inteiros (POSADA et al., 2011) (Figura 1).

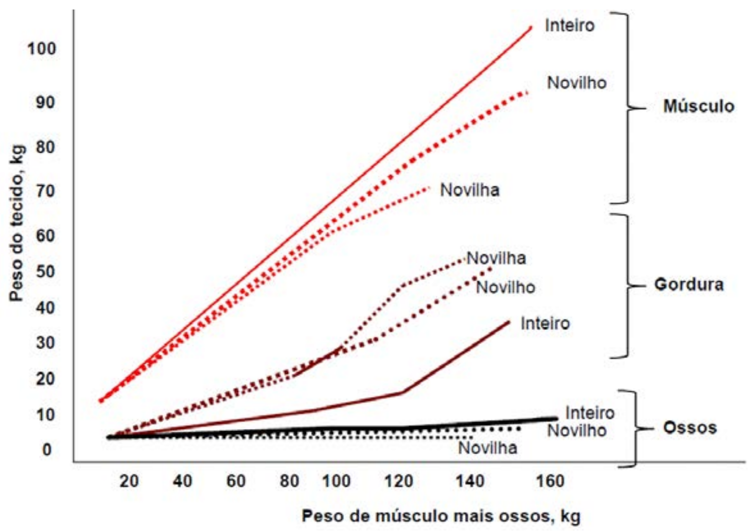


Figura 1. Efeito do sexo sobre as proporções de músculo, osso e gordura na carcaça.
Fonte: Berg and Butterfield (1976).

A menor deposição de gordura no corpo de animais inteiros, seguida por maior concentração protéica do ganho de peso, pode ser explicada pela ação do hormônio masculino testosterona que promove crescimento muscular e esquelético, determinando carcaças mais magras e com maior musculatura nos machos inteiros em relação às fêmeas (JACOBS et al., 1972). A testosterona possui efeito anabólico sobre a proteína corporal (GUYTON e HALL, 2006) e, esse efeito é expresso pela redução da degradação protéica nos músculos (LOBLEY et al., 1990; MORGAN et al., 1993) e, em menor intensidade pelo aumento na taxa de síntese protéica (MARTINEZ et al., 1984). Este hormônio também estimula a proliferação de células satélites, células indiferenciadas e localizadas de forma adjacente às fibras musculares (SPENCER, 1985) que se fundem às fibras musculares doando seus núcleos e, com isso aumentam significativamente a capacidade de síntese protéica do músculo (FLORINI, 1987).

Com relação aos fatores genéticos, o peso à maturidade é a principal diferença entre diferentes genótipos (WEBSTER, 1986). O peso à maturidade é definido como o peso no qual ocorre máxima deposição de proteína e minerais no corpo, independentemente dos aumento de peso corporal que possam ocorrer posteriormente devido à deposição de gordura (OWENS et al., 1993). Desse modo, animais de diferentes genótipos podem apresentar diferentes pesos à maturidade uma vez que este pode ser atingido em diferentes pesos e idades implicando, consequentemente, em diferenças na composição corporal.

A composição corporal de qualquer animal, em qualquer idade, peso ou estágio de maturidade pode ser influenciada tanto pela qualidade quanto pela quantidade de alimento oferecido (WEBSTER, 1986). Ferrell e Jenkins (1998) relataram que novilhos da raça Angus submetidos alimentação restrita apresentaram menores teores de gordura e proteína na carcaça que aqueles sob alimentação ad libitum. Fortin et al. (1980) detectaram que o efeito de sexo sobre as taxas de acréscimo dos principais constituintes químicos do corpo vazio de bovinos foi dependente da raça estudada e do nível de energia da dieta.

Considerando que a determinação da composição corporal é fator determinante na estimativa das exigências nutricionais pode-se inferir que as variações na composição corporal observadas em animais jovens e em animais adultos, como também, em machos inteiros, machos castrados e fêmeas podem conduzir a diferenças nas exigências de nutrientes e energia. No entanto, esses fatores (estágio de crescimento e sexo) não são amplamente abordados pelos principais sistemas de alimentação utilizados no balanceamento de dietas para caprinos.

## Exigências nutricionais

Exigências nutricionais podem ser definidas pela quantidade de nutrientes e ou de energia a serem fornecidos na dieta para atender as necessidades de um animal em condições de ambiente compatível com a boa saúde (SAKOMURA e ROSTAGNO, 2007).

As exigências nutricionais podem ser estimadas a partir do consumo de energia e ou proteina metabolizável em função do ganho de peso corporal (LUO et al., 2004a). Entretanto, a utilização desta metodologia para a estimativa das exigências nutricionais para ruminantes pode ser limitada em função da dificuldade em se mensurar a quantidade exata de alimento digerida por estes animais, das mudanças constantes do conteúdo do trato gastrintestinal e, pelo fato de que esta metodologia não leva em consideração a composição corporal. Ademais, os requerimentos nutricionais fornecidos por este método são específicos para cada animal, condição ambiental e dietas utilizadas (CSIRO, 2007). Entretanto, de acordo com Luo et al. (2004a) a acurácia deste método pode ser alta o que facilita a utilização do ganho de peso diário como variável independente. Além disso, de acordo com estes autores, as mensurações do ganho de peso corporal podem ser facilmente obtidas e, em diferentes condições de produção.

A técnica do abate comparativo também pode ser utlizada na estimativa das exigências nutricionais. Através dessa metodologia a deposição ou a remoção de um nutriente e ou de energia pode ser estimada por meio de abates representativos no inicio e fim do período experimental (SAKOMURA e ROSTAGNO, 2007). Este método é altamente acurado na determinação das exigências nutricionais uma vez que leva em consideração fatores inerentes aos animais tais como, diferenças de pesos e composição corporal. Entretanto, essa metodologia basea-se na premissa de que a composição corporal de um grupo de animais representa a composição da população estudada e, muitas vezes os animais amostrados não representam aqueles do ensaio experimental (SAKOMURA e ROSTAGNO, 2007). Além disso, apresenta-se como uma metodologia cara e laboriosa (LUO et al., 2004a).

**Metabolismo basal e exigências de energia para mantença**

O metabolismo basal reflete a mínima produção de calor necessária para que ocorram os processos vitais de um animal saudável, em jejum e em repouso. Esta mínima produção de calor é referida como taxa metabólica basal e é usada para manter a respiração, circulação sanguínea e atividades celulares vitais (RESENDE et al., 2006). As estimativas dos gastos energéticos inerentes as atividades relacionadas ao metabolismo basal são apresentados na Tabela 1.

Tabela 1. Estimativas dos gastos energéticos inerentes as atividades relacionadas ao metabolismo basal.

| Atividades | % do gasto energético basal |
|---|---|
| Levantado | 13-25 |
| Circulação | 9-11 |
| Respiração | 6-7 |
| Rins | 6-7 |
| Fígado | 5-10 |
| Funções nervosas | 10-15 |
| Síntese de proteínas | 15-25 |
| Síntese de lipídeos | 2-3 |

Adaptado de Gil and Oldham (1993).

Considera-se que o animal está em mantença quando a quantidade de energia ingerida não resulta em acréscimo ou perda de energia nos tecidos corporais do animal (ARC, 1980). Do total da energia requerida para mantença cerca de 50% são gastos pelas paredes do trato gastrointestinal e pelo fígado para absorção e metabolismo dos nutrientes digeridos, um terço é gasto pela pele, rins e tecido nervoso e o restante é gasto nas atividades musculares básicas (SEAL e REYNOLDS, 1993; RESENDE et al., 2008).

As exigências de energia para mantença podem ser afetadas por vários fatores, dentre os quais destaca-se o consumo, genótipo, sexo, idade, peso, estado fisiológico e condições ambientais (RESENDE et al., 2008).

O consumo de energia abaixo das necessidades energéticas pode acarretar decréscimo da taxa metabólica basal (NRC, 2007) principalmente devido a mudanças na massa visceral dos órgãos metabolicamente mais ativos como coração, rins, trato gastrintestinal e fígado (REYNOLDS, 2002). Figueiredo et al. (2011) mostraram que em cabritas Saanen submetidas a restrição alimentar severa o tamanho do coração, rins, trato gastrintestinal e fígado reduziu em aproximadamente 33%, 34%, 22% e 39%, respectivamente. Como grande parte da exigência de mantença dos animais advém da massa visceral dos orgãos metabolicamente mais ativos, a diminuição na disponibilidade de energia afeta marcadamente o tamanho destes órgãos na tentativa do organismo de diminuir seus gastos com a mantença (FLUHARTY e McCLURE, 1997).

Com relação ao genótipo, Sahlu et al. (2004) não encontraram diferenças entre raças específicas, entretanto, as exigências de energia metabolizável para mantença ($EM_m$) foram agrupadas de acordo com as aptidões dos caprinos (corte sendo $\geq$ 50% Boer; raças leiteiras, nativas e Angorá). O NRC (2007) baseando-se nas recomendações feitas por esses autores considera que a $EM_m$ de caprinos leiteiros são maiores (138,6 kcal/kg$^{0.75}$ PC·d) que as de animais da raça Angorá (133,8 kcal/kg$^{0.75}$ PC·d) e, caprinos nativos e com aptidão para corte apresentam a mesma $EM_m$ (116,8 kcal/kg$^{0.75}$ PC·d).

No que tange ao sexo, o NRC (2007) propõem que a $EM_m$ para machos inteiros seja 15% superior à exigência para machos castrados e fêmeas. Segundo este sistema de alimentação a maior exigência dos machos inteiros deve-se ao fato de que estes animais possuem maior quantidade de proteína no corpo e, consequentemente, apresentam maior gasto energético para a renovação proteíca e, também está relacionada ao fato de que machos inteiros, machos castrados e fêmeas a um mesmo peso corporal apresentam diferentes estágios de maturidade. No entanto, esta diferença não foi evidenciada em estudos com caprinos em crescimento (ALMEIDA, 2013) como também com bovinos (CHIZZOTTI et al., 2008), nos quais foi considerado um valor único para $EM_m$ para machos inteiros, machos castrados e fêmeas.

Segundo Blaxter (1962) as exigências de energia para mantença de ovinos decrescem com a idade em uma taxa de 8% ao ano, chegando a estabilização aos seis anos de idade, o que pode estar relacionado à elevada deposição de gordura corporal, aliada ao decréscimo na taxa de renovação protéica no organismo (ATTAIX et al., 2005). Todavia, os principais sistemas de alimentação, exceto o CSIRO (2007), consideram um valor único para a $EM_m$ durante toda a fase de crescimento animal. Desse modo, especula-se que a $EM_m$ para caprinos varie durante toda a fase de crescimento.

As exigências de energia para mantença preconizadas pelo AFRC (1998), NRC (2007) e CSIRO (2007) foram estimadas em países de clima temperado a partir da utilização de animais de raça e composição corporal diferentes. Portanto, utilização das exigências de energia recomendadas por esses sistemas de alimentação não são acuradas para animais criados em condições tropicais (SALAH et al., 2014). Animais submetidos a temperaturas demasiadamente altas ou baixas tendem a alterar a demanda energética com o intuito de garantir a termorregulação podendo afetar o consumo, a eficiência de utilização dos nutrientes ingeridos e, consequentemente as exigências de energia para mantença. Ademais, trabalhos realizados com caprinos no Brasil (ALVES, 2008; FIGUEIREDO, 2011; ALMEIDA, 2013) evidenciaram que a exigência de energia para mantença diferiu dos valores preconizados pelos principais sistemas de alimentação.

**Exigência de proteína para mantença**

Proteínas são compostos orgânicos de alto peso molecular formadas por cadeias polipeptídicas de aminoácidos (LOPES e SANTANA, 2005) e, diferem entre si na forma, tamanho e composição de aminoácidos. São as moléculas orgânicas mais abundantes da matéria viva perfazendo cerca de 50 a 80% do peso seco das células e desempenham diversas funções vitais do organismo, tais como: crescimento e reparo dos tecidos, catálise enzimática, proteção imunitária, geração e transmissão de impulsos nervosos, controle do metabolismo, crescimento e diferenciação celular (GONZAGA NETO et al., 2005).

Nos ruminantes, a proteína bruta contida na dieta é composta pela fração degradável no rúmen (PDR) e pela fração não degradável no rúmen (PNDR) (BOHNERT et al., 2002). A fração PDR sofre ação das enzimas (proteases, peptidases e deaminases) secretadas pelos microrganismos ruminais (KOZLOSKI, 2009) e, os produtos da degradação protéica (peptídeos, AA e $NH_3$) são, posteriormente, utilizados pelos microrganismos para a síntese de proteína microbiana (BACH et al., 2005; SILANO, 2014) e multiplicação celular (NRC, 2001). As proteínas de origem microbiana junto com proporções variáveis de PNDR e de pequenas quantidades de proteína endógena chegam ao abomaso e duodeno onde serão digeridas e absorvidas. No epitélio intestinal, o pool de aminoácidos provenientes da digestão e, disponíveis para absorção irão constituir a proteína metabolizável (SANTOS, 2006).

Do total de proteína metabolizável presente no intestino cerca de 55 a 80% é proveniente da digestão das células microbianas (BACH et al., 2005; KOZLOSKI, 2009) e, tem sido proposto que 80% da proteína microbiana é representada por proteína verdadeira sendo 80% digestível (NRC, 2001). As PNDR, em geral perfazem entre 15 a 40% da proteína duodenal total (KOZLOSKI, 2009) sendo, em geral, 80% digestíveis (NRC, 2000) dependendo da fonte protéica utilizada (GALVANI, 2008). A proteína endógena presente nas secreções gástricas e intestinais e nas células provenientes das descamações epiteliais contém cerca de 50% de proteína verdadeira (NRC, 2001). A contribuição da porção endógena na composição da proteína metabolizável será quantitativamente significativa somente em dietas fibrosas e deficientes em N (KOZLOSKI, 2009).

O organismo animal possui uma demanda diária por aminoácidos e, a maior parte dos aminoácidos presentes no lúmen intestinal éutilizada pelo sistema visceral (GALVANI, 2008) representado pelos tecidos drenados pela veia porta (trato gastrointestinal, gordura mesentérica, pâncreas e baço) e pelo fígado (KOZLOSKI et al, 2009). O trato digestivo dos ruminantes possui apenas 5% de proteína, entretanto, estes orgãos são responsáveis por até 35% da síntese protéica diária no organismo animal. As taxas diárias de renovação protéica nestes tecidos podem variar de 40% (rúmen) a mais de 120% (duodeno) (KOZLOSKI, 2009). O fígado que embora apresente conteúdo proteíco equivalente a apenas 1 a 2% do total de proteína, também, apresenta elevada taxa de renovação proteíca diária de aproximadamente 12 a 15% do total de proteína sintetizada pelo organismo. Além disso, esse órgão tem alta demanda por aminoácidos para a síntese de glicose, proteínas e neutrotransmissores, como também, para atuarem como intermediários no ciclo da uréia (KOZLOSKI, 2009).

Desta forma, as exigências de proteínas dos ruminantes são atendidas pelos aminoácidos absorvidos da luz intestinal (PEREIRA et al., 2005) e, também, por aqueles que chegam com o sangue arterial (KOZLOSKI, 2009). As proteínas de origem microbiana suprem, em geral, de 60 a 80% do total das exigências de proteína para mantença, crescimento, gestação e lactação (TIMMERMANS JR. et al., 2000) e, o restante será suprido pela $PNDR_{digestível}$ e, também, pelas proteínas endógenas digeridas no intestino.

Dada a complexidade das interações existentes entre animal, microrganismos ruminais e alimento cada sistema de alimentação possui uma forma específica de estimar as exigências de proteína (RESENDE et al., 2008). Adicionalmente, devido a escassez de informações relativas às exigências de proteína para caprinos alguns sistemas de alimentação consideram as mesmas exigências de proteína para caprinos, ovinos e bovinos. No entanto, o estudo meta-analítico realizado por Salah et al. (2014) mostrou que as exigências líquidas de proteína para mantença para ovinos criados em regiões tropicais são superiores (3.36 $g/kg^{0.75}$ PC·d) às de caprinos (2.38 $g/kg^{0.75}$ PC·d).

Além disso, fatores como sexo, idade, raça, taxa de crescimento, estágio fisiológico, composição corporal e clima podem interferir na determinação das exigência de proteína para mantença (FERNANDES, 2006; CANNAS et al., 2008). De acordo com Salah et al. (2014) as exigências de proteína para animais criados em clima tropical são diferentes das exigências para animais criados em clima temperado uma vez que as condições climáticas podem interferir na partição de nutrientes, no crescimento animal, na composição corporal e, consequentemente, nas exigências de proteína (BERG e BUTTERFIELD, 1976).

No tocante ao efeito do sexo são incipientes as informações a respeito do efeito da condição sexual na determinação das exigências de proteína para caprinos em crescimento. No Brasil, com o intuito de se preencher esta lacuna foram realizados estudos objetivando-se determinar as exigências de proteína para mantença de caprinos em crescimento com peso corporal variando dos 5 aos 45 kg (FIGUEIREDO, 2011; MENDONÇA, 2010; BOAVENTURA NETO, 2011; ALMEIDA, 2013). Estes estudos não evidenciaram efeito do sexo na determinação das exigências de proteína para caprinos, entretanto, os valores encontrados divergiram dos valores preconizados pelos principais sistemas de alimentação.

**Exigências de energia e proteína para ganho em peso corporal**

A exigência líquida de energia para ganho em peso corporal ($EL_g$) representa a energia retida para determinado ganho em peso corporal. Desse modo, espera-se que o sexo exerça influencia sobre a $EL_g$ uma vez que a composição corporal, principalmente no que tange à retenção energética difere entre machos e fêmeas. Entretanto, os principais sistemas de alimentação não fazem distinção entre machos inteiros, machos castrados e fêmeas e assumem um valor único para a $EL_g$. Estudos recentes com caprinos (ALMEIDA, 2013) e com bovinos de corte (CHIZZOTTI et al., 2007) com o objetivo de avaliar o efeito do sexo na determinação das exigências nutricionais evidenciaram que a $EL_g$ diferiu entre machos inteiros, machos castrados e fêmeas.

Com relação às exigências líquidas de proteína para ganho em peso corporal ($PL_g$) apesar das diferenças na deposição dos tecidos e do turnover protéico observados em machos inteiros inteiros, machos castrados e fêmeas (DEAMBROSIS,1972; JACOBS et al., 1972; BERG e BUTTERFIELD,1976) os sistemas de alimentação consideram um valor único para a $PL_g$. Almeida (2013), Chizzoti et al, (2008) e Marcondes et al. (2009) avaliaram o efeito do sexo na determinação da $PL_g$ de caprinos e bovinos de corte, respectivamente, também, não observaram diferenças na $PL_g$ entre machos inteiros, machos castrados e fêmeas.

Além da diferença na deposição dos tecidos observadas entre machos inteiros inteiros, machos castrados e fêmeas fatores como clima devem ser considerados na determinação das exigências de energia e proteína para ganho em peso corporal. De acordo com Salah et al. (2014) as exigências de energia e proteína para animais criados em clima tropical são diferentes das exigências para animais criados em clima temperado uma vez que as condições climáticas podem interferir na partição de nutrientes, no crescimento animal na composição corporal e, consequentemente, nas exigências de energia e proteína (BERG e BUTTERFIELD, 1976). Neste estudo, os autores evidenciaram que para caprinos criados em regiões tropicais as exigências de energia e proteína para ganho diferiram dos valores recomendados pelos principais sistemas de alimentação (AFRC, 1998; CSIRO, 2007; NRC, 2007).

Até o presente momento o efeito do sexo na determinação das exigências nutricionais de energia e protéina para mantença e ganho de peso de caprinos não foram bem definidos pelos principais sistemas de alimentação (AFRC, 1998; CSIRO, 2007; NRC, 2007). Além disso, as recomendações existentes são baseadas em estudos em que a condição sexual e a fase de crescimento não são claramente definidas ou foram obtidas por extrapolação de outros estudos relacionados à bovinos e ovinos (LUO et al. 2004b, SAHLU et al., 2004). Desse modo, com intuito de preencher parte desta lacuna de conhecimento objetivou-se com este trabalho:

i) Estimar as exigências de energia e proteina para mantença de caprinos Saanen, machos inteiros, machos castrados e fêmeas, com peso corporal variando de 15 a 30 kg.

ii) Estimar a composição corporal e as exigências de energia e proteína para ganho de peso de caprinos Saanen, machos inteiros, machos castrados e fêmeas, com peso corporal variando de 15 a 30 kg.

iii) Avaliar os modelos do AFRC (1998) e NRC (2007) para predizer o consumo de matéria seca (CMS) e ganho de peso (GP) de caprinos Saanen em crescimento.

Esta tese foi redigida em formato de artigo científico, sendo que o primeiro artigo (Capítulo 2) foi redigido de acordo com as normas do Journal Animal Science o segundo artigo (Capítulo 3) foi redigido de acordo com as normas da Revista Ciência e Agrotecnologia.

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# CAPÍTULO 2 - ENERGY AND PROTEIN REQUIREMENTS OF MALE AND FEMALE SAANEN GOATS BETWEEN 15 AND 30 KG OF BODY WEIGHT[1]

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**ABSTRACT:** The objective of this research was to estimate, using the comparative slaughter technique, energy and protein requirements for maintenance and growth of castrated male, intact male and female Saanen goat kids between 15 and 30 kg BW. To determine $NE_m$ and net protein requirements for maintenance (**$NP_m$**) 25 castrate males, 26 intact males and 24 females were used, where 7 castrated males, 8 intact males and 6 females were randomly selected to estimate the initial empty body composition. The remaining animals, 18 castrate males, 18 intact males, and 18 females were fed different dietary treatments that consisted of 3 levels of intake: ad libitum, 75% and 50% of ad libitum intake. Within each sex, six blocks of 3 animals each were formed. Within each block, one animal was randomly assigned to each level of intake. Thus, pair feeding was established within each block based on the intake of the animal fed ad libitum. All animals within a block were slaughtered when the animal fed ad libitum reached 30 kg BW. The 75 and 50% of ad libitum rationing were determined daily based on the DMI of the animal fed ad libitum on the previous day. The $NE_g$ and net protein requirements for gain (**$NP_g$**) were obtained using 20 castrated males, 20 intact males and 18 females. The animals were fed ad libitum and slaughtered at targeted BW of 15, 23, and 30 kg. We found that sex did not affect energy and protein requirements for maintenance as well as protein requirements for growth. However energy requirements for growth ofcastrated males and females were greater than intact males. This study reported the lack of difference among sex in both energy and protein requirements for goats resulting in more adequate estimates of nutritional requirements and reducing the cost of production.

**Key words:** body composition, dairy goats, gain, growth phase, maintenance, sex.

## INTRODUCTION

Several factors are known to affect animal energy and protein requirements such as genotype, age, body composition, and sex. The growth of body tissues is directly affected by sex, as intact males are typically leaner, due to the effect of testosterone, whereas females and castrated males have greater proportion of fat in the body (Herring et al., 2013). In cattle, however, the contribution of sex to energy and protein requirements is controversial: whereas some studies have suggested it affects body tissue growth, influencing carcass composition and feed efficiency (Berg and Butterfield, 1976) and the metabolizable energy requirements for maintenance (ARC, 1980; NRC, 2000), a meta-analysis performed by Chizzotti et al. (2008) does not support this hypothesis.

The potential effects of sex on energy and protein requirements have not been well defined for goats in all current feeding systems. Existing recommendations are based on studies where sex or growth phase were not clearly specified or were obtained from extrapolations of reports involving sheep or cattle (Luo et al., 2004; Sahlu et al., 2004). In addition, the simultaneous evaluation of energy and protein requirements is desirable because the metabolism of fat and protein involves contributions from several organs that are highly dynamic in terms of energy expenditure. However, to date, no reports have attempted to study this combination in goats while taking into consideration the sex effect for both maintenance and growth requirements. Therefore, the objective of this research was to estimate energy and protein requirements for maintenance and gain of castrated males, intact males and females Saanen goat kids between 15 and 30 kg BW.

## MATERIALS AND METHODS

The research was conducted at the goat facility of UNESP - Univ Estadual Paulista, Jaboticabal, Sao Paulo, Brazil (21$^{o}$14'S; 48$^{o}$17'W, 595 m altitude). All animals were registered and cared for according to guidelines approved by the Human Animal Care and handling procedures were followed according to the university's Animal Care Committee on the Ethical and Animal Welfare (Comissão de Ética e Bem Estar Animal - CEBEA), under protocol number 008919-08. During the research, mean daily minimum and maximum temperature was 20.7 and 35.7$^{o}$C, respectively, and minimum and maximum relative humidity of the air was 36.1 and 83.4%, respectively.

***General Procedures***

The factorial approach was used to estimate energy and protein requirements, then net requirements for maintenance and gain were estimated separately. Two trials were conducted using castrated males, intact males, and female Saanen goat kids. The first trial was designed to determine energy and protein requirements for maintenance (Trial 1), while the second trial was designed to estimate requirements for gain (Trial 2).

In both trials the experimental diet (Table 1) was formulated to meet the requirements of growing goat kids (NRC, 2007), and consisted of dehydrated whole corn (*Zea mays)* plants, cracked corn grain, soybean (*Glycine max*) meal, soybean oil, limestone, ammonium chloride (to prevent urinary calculi) and a mineral supplement fed as a total mixed ration. Dehydrated corn plants consisted of whole corn plants (60 to 70% moisture) chopped when the kernel milk line was approximately two-thirds of the way down the kernel. The chopped material was air dried for approximately 72 h or until it reached 10% moisture. The dried, chopped material was then ground to pass through a 10 mm screen (mill hay Mexon charger 15.0, G3 Mexon Maquinas Agricolas, Cajuru, Sao Paulo, Brazil).

Feeds and orts were weighed daily, sampled, and frozen and after dried at 55ºC for 72 h and ground through a 1mm screen using a Wiley mill (Arthur H. Thomas Co., Philadelphia, PA). The samples were analyzed for contents of DM (AOAC, 1990, method number 924.05), ash (AOAC, 1990, method number 924.05), fat (AOAC, 1990, method number 930.15), CP (N analysis performed via Dumas combustion using LECO FP-528LC, LECO Corp., St. Joseph, MI; Etheridge et al., 1998), NDF was mensured in an Ankon 220 Fiber Analyser (Ankon Tecnnology Corp., Fairport, NY) using heat-stable α-amylase without sodium sulphite (Mertens et al., 2002), ADF (Goering and Van Soest, 1970), and GE using a bomb calorimeter (IKA® Calorimeter system C 2000 basic / control, IKA-Works, Cincinnati, USA).

**Table 1.** Ingredient and chemical composition of the diet.

| Ingredient | % in the diet | Ingredient composition[1] (% of DM) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | GE | CP | Fat | NDF | ADF | Lignin | Ash | DM |
| Dehydrated corn plant[2] | 45.35 | 4479 | 8.5 | 2.8 | 59.7 | 31.8 | 4.2 | 3.4 | 84.7 |
| Cracked corn | 26.64 | 4657 | 11.7 | 1.7 | 19.0 | 5.3 | 0.9 | 1.7 | 84.1 |
| Soybean meal | 22.33 | 4732 | 53.6 | 1.2 | 15.3 | 11.7 | 0.6 | 7.0 | 85.7 |
| Soybean oil | 1.57 | 9231 | - | 100 | - | - | - | - | 100 |
| Limestone | 1.02 | - | - | - | - | - | - | 99.6 | 100 |
| Mineral supplement[3] | 2.19 | - | - | - | - | - | - | 86.3 | 97.3 |
| Ammonium chloride | 0.91 | - | 163.6 | - | - | - | - | 5.8 | 98.1 |
| Total diet | 100 | 4473 | 20.3 | 3.3 | 35.9 | 18.6 | 2.3 | 6.2 | 85.4 |

[1]DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; GE = gross energy (Kcal/kg DM).

[2]Dehydrated corn plant consisted of whole corn plants (60 to 70% moisture) chopped when the kernel milk line was approximately two-thirds of the way down the kernel.

[3]Composition, per kg, as-fed basis: 190 g of Ca; 92 g of Cl; 73 g of P; 62 g of Na; 44 g of Mg; 1.35 g of Zn; 1.06 g of Fe; 0.94 mg of Mn; 0.73 g of F ; 0.34 g of Cu; 18 mg of Se; 16 mg of I; 3 mg of Co.

## Requirements for maintenance (Trial 1)

In this trial, a total of 25 castrated male, 26 intact male and 24 female were used. From this initial pool, 7 castrated males (16.4 ± 0.9 kg initial BW and initial age 97 ± 11 d), 8 intact males (16.5 ± 0.7 kg initial BW and initial age 112 ± 30 d) and 6 females (17.3 ± 1.3 kg initial BW and initial age 137 ± 11 d) were randomly selected for slaughter at the trial initiation to allow for the estimation of the initial composition of the empty body weight (**EBW**). Hereafter, these animals will be referred as the baseline (**BL**) group.

A simple linear regression equation was developed using BL group data to get estimates of initial empty body weight from the BW. Likewise, linear regression equations were developed to determine initial energy, protein and fat body composition from initial EBW.

The remaining 18 castrated males (15.5 ± 0.3 kg initial BW and initial age 92 ± 22 d), 18 intact males (15.7 ± 0.5 kg initial BW and initial age 89 ± 17 d) and 18 females (15.2 ± 0.2 kg initial BW and initial age 88 ± 26 d) were used with dietary treatments that consisted of three levels of intake: ad libitum, 75% and 50% of ad libitum intake. Within each sex, 6 blocks of 3 animals each were formed. Within each block, one animal was randomly assigned to each level of intake. Thus pair feeding was established within each block based on the consumption of the animal fed ad libitum. All animals within a block were slaughtered when the animal fed ad libitum reached 30 kg BW. The 75 and 50% of ad libitum rationing were determined daily based on the DMI of the animal fed ad libitum on the previous day. During the course of the experiment one female died.

***Determination of Diet Digestibility***

A total feces and urine collection trial was carried out to determine DE, ME and the metabolizability of energy (**$q_m$**) of the diet of each level of intake. All animals were collected when castrate males, intact males and females fed ad libitum weighted, on average at the beginning of the assay, 23.6 ± 1.7 kg BW, 23.3 ± 1.0 kg BW and 23.9 ± 1.8 kg BW, respectively.

During the digestibility assay, animals were housed in individual metabolic cages. Feed intake, orts, feces, and urine were collected for 5 d after a 3 d adaptation period to the cage. Urine was acidified daily with 20 mL of 20% sulfuric acid. Feeds and orts were sampled daily and immediately stored at –20 °C. Feces and urine were weighed daily. A representative sample of feces and urine approximately 10% of the daily mass where taken and stored at -20ºC.

Composites of diet, orts, and feces were dried at 60 to 65 °C for 72 h and ground through a 1 mm screen using a Wiley mill. Composites of urine were passed through a sieve to remove any large particles, and a subsample was taken for N determination. Gross energy was determined for feeds, orts, feces and, urine using a bomb calorimeter (IKA® Calorimeter system C 2000 basic/ control, IKA-Works, Cincinnati, USA). Digestible energy was computed from the GE of feeds, feed refusals, and feces. Metabolizable energy was determinated from GE of feeds, orts, feces, urine, and the estimated energy from gaseous products. The energy of gaseous products of digestion (**EPG**) was calculated using (Eq. [1]; Blaxter and Clapperton, 1965).

$$EPG = GEI \times (4.28 + 0.059 \times DGE) / 100 \qquad [1]$$

where EPG is energy of gaseous products of digestion (kcal/d), GEI is gross energy intake (kcal/d) and DGE is the coefficient of digestibility of gross energy (%).

### *Slaughter Technique and Body Composition*

Body weight was measured immediately before slaughter. At slaughter, animals were stunned with a captive bolt pistol, followed by severing of the jugular vein and carotid artery. Blood was collected and weighed. The digestive tract was weighed before and after it was emptied and flushed with water. Empty body weight was calculated as BW at slaughter minus the weight of the contents of the digestive tract, gallbladder, and biliary vesicle. The empty whole body was initially frozen at -6°C. And then cut into small pieces, ground with a large screw grinder through a plate with 0.32 cm holes, and mixed by two additional passes through the grinder. After grinding and homogenization, samples were collected, frozen again, and subsamples were freeze-dried for DM determination. These samples, of approximately 30 g, were analyzed for fat, protein, ash, and GE as described previously.

### *Energy Partitioning and Energy Requirements for Maintenance*

Heat production (**HP**, kcal/kg EBW$^{0.75}$·d) was calculated as the difference between ME intake (**MEI**, kcal/kg EBW$^{0.75}$·d) and retained energy (**RE**, kcal/kg EBW$^{0.75}$·d). The antilog of the intercept of the linear regression between the log of HP and MEI was used to estimate $NE_m$ (kcal/kg EBW$^{0.75}$·d). Metabolizable energy requirements for maintenance (kcal/kg EBW$^{0.75}$·d) were calculated as the value at which HP is equal to MEI. The efficiency of energy utilization for maintenance (**$k_m$**) was calculated as $NE_m/ME_m$.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 $k_g$ to compute $NE_m$.

### *Protein Requirements for Maintenance*

A linear regression of retained N (g N/kg EBW$^{0.75}$ ·d) on N intake (g N/kg EBW$^{0.75}$ ·d) was used to calculate net N requirements for maintenance. The intercept of the regression was assumed to be the endogenous and metabolic losses of N, which is assumed to represent the net N requirement for maintenance.

### *Fat and Protein Content in the Body*

Daily fat body gain (**DFG**, g/d), daily protein body gain (**DPG**, g/d) and EBW gain (**EWG**, g/d) were calculated as the difference between the initial and final weights of the respective body components, divided by number of d on trial. Using this information we developed equations to predict DFG and DPG. Fat in gain (**FIG**, % of EWG) and protein in gain (**PIG**, % of EWG) were calculated as observed DFG or DPG divided by EWG (g/d).

### *Requirements for Gain (Trial 2)*

Net energy and protein requirements for gain were estimated using 20 castrated males, 20 intact males and 18 females Saanen goat kids. The animals were fed ad libitum and slaughtered at targeted BW of 15, 23, and 30 kg using the same procedures as described for Trial 1. Within each sex, 7 castrated males, 8 intact males and 6 females were slaughtered at the beginning of the experiment on average BW of 16.6 ± 0.9 kg, and an initial age 114 ± 25 d. Another 7 castrated males, 6 intact males and 6 females were slaughtered when they reached 23.1 ± 1.3 kg BW at 165 ± 33 d age. Lastly, six animals of each sex were slaughtered when they reached 31.3 ± 1.6 kg BW at 202 ± 27 d age.

Energy and protein body composition were estimated by chemical analyses of the whole EBW. Using all animals slaughtered at targeted BW of 15, 23, and 30 kg a linear regression analyses were conducted to express EBW as a function of BW. For each sex the energy and protein content of animals were summarized by allometric regressions of the logarithm of observed energy or protein content on the logarithm of EBW (Eq. [2]).

$$\text{Log}_{10}Y = a + b \times \log_{10} \text{EBW} + e \qquad [2]$$

where $\text{Log}_{10}Y$ is the logarithm of the total amount of body energy (Mcal) or protein (g), $\text{Log}_{10}\text{EBW}$ is the logarithm of EBW (kg), a and b are regression parameters and e is the error.

The first derivative of Y from Eq. [2] with respect to EBW enables estimating the composition of gain at various EBW (Eq. [3]).

$$NY_g = b \times 10^a \times \text{EBW}^{(b-1)} \qquad [3]$$

where $NY_g$ is the net energy requirement for gain (Mcal/kg EBW gain) or protein requirement for gain (g/kg EBW gain ).

***Statistical Analyses***

Data from Trial 1 were analyzed as split plot design using a mixed model with the fixed effects of sex (df = 2), level of intake (df = 2) and their interactions (df = 4) and the random effect of blocks nested within sex (df = 15) and a residual error term. The effect of the level of intake was decomposed into two orthogonal polynomial contrasts (linear and quadratic) and significance was declared at $P \leq 0.05$.

Data for Trial 2 were analyzed as a completely randomized desing with the fixed effects of sex (df = 2), slaugther weight (df = 2) and their interactions (df = 4) and a random residual. When significantly different ($P < 0.05$), effect means were compared using Fisher's protected LSD. Regression analyses were also performed using the MIXED procedure of SAS V9.3 (SAS Inst. Inc., Cary, NC). The statistical models included the fixed effects of sex (df = 2), the regressor (df = 1) and their interactions (df = 2), plus the random effect of blocks if data were from Trial 1. When sex was found significant ($P$ < 0.05), indicating a different intercept for at least one sex, three CONTRAST statements were used to conduct all three pairwise comparisons of sex. Likewise, three CONTRAST statements were used to conduct all three pairwise comparisons when the sex and regressor effect was found to be significant ($P$ < 0.05), indicating that at least one sex had a different slope. Studentized residuals were plotted against predicted values to verify model assumptions. Outliers were defined as those values with a Studentized residual outside ± 2.5 range values.

## RESULTS

### Requirements for maintenance (Trial 1)

***Intake and Digestibility.*** Sex did not affect intake and digestibility variables evaluated (Table 2). During the metabolism trial, DMI of unrestricted animals was 776 g/d and for animals under 75 and 50% intake levels were 606 and 413 g/d, respectively. Animals fed ad libitum and under 75% intake level showed lower DE than those under 50% intake level (mean 3.39 vs. 3.49 Mcal/kg DM). On the other hand ME was not affected by level of intake (mean 2.81 Mcal/kg DM ).

**Table 2.** Intake, energy concentration of diet and digestibility coefficient of castrate males, intact males and females Saanen goat kids fed different levels of intake, during the digestibility trial.

| Item[1] | Level of intake (%)[2] | | | | | | | | | SEM[3] | P-value[4] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Intact Males | | | Castrated males | | | Females | | | | | | | | |
| | AL | 75% | 50% | AL | 75% | 50% | AL | 75% | 50% | | LI | S | LI*S | Lin | Q |
| DMI, g/d | 768.7 | 569.4 | 376.9 | 781.5 | 654.9 | 447.1 | 786.2 | 588.4 | 409.9 | 28.303 | <0.001 | 0.27 | 0.17 | <0.001 | 0.43 |
| CPI, g/d | 177.2 | 118.0 | 77.8 | 186.0 | 135.2 | 91.4 | 181.1 | 121.3 | 84.4 | 6.300 | <0.001 | 0.21 | 0.70 | <0.001 | <0.001 |
| GEI, Mcal | 3.6 | 2.6 | 1.7 | 3.7 | 2.9 | 2.0 | 3.6 | 2.7 | 1.8 | 0.143 | <0.001 | 0.33 | 0.75 | <0.001 | 0.76 |
| MEI, Mcal/d | 2.2 | 1.6 | 1.1 | 2.3 | 1.8 | 1.3 | 2.2 | 1.5 | 1.2 | 0.102 | <0.001 | 0.30 | 0.48 | <0.001 | 0.49 |
| DCP, % | 79.3 | 79.1 | 78.0 | 78.2 | 77.6 | 80.1 | 77.8 | 75.9 | 79.8 | 1.615 | 0.16 | 0.85 | 0.21 | <0.001 | 0.09 |
| DGE, % | 73.5 | 76.1 | 75.6 | 74.2 | 73.5 | 76.7 | 75.1 | 74.1 | 78.8 | 1.296 | 0.03 | 0.50 | 0.25 | 0.03 | 0.09 |
| DE, Mcal/kg | 3.44 | 3.47 | 3.44 | 3.35 | 3.32 | 3.46 | 3.40 | 3.35 | 3.56 | 0.059 | 0.03 | 0.26 | 0.26 | 0.04 | 0.09 |
| ME, Mcal/kg | 2.86 | 2.89 | 2.85 | 2.77 | 2.74 | 2.85 | 2.72 | 2.64 | 2.97 | 0.067 | 0.23 | 0.16 | 0.53 | 0.16 | 0.31 |
| $q_m$ | 0.63 | 0.63 | 0.62 | 0.61 | 0.61 | 0.63 | 0.61 | 0.62 | 0.63 | 0.016 | 0.06 | 0.56 | 0.20 | 0.57 | 0.31 |

[1] MEI = metabolize energy intake; DCP = digestibility of crude protein; DGE = digestibility of gross energy and $q_m$ = metabolizability of energy;

[2] Ad libitum (AL) or 75% or 50% levels of the AL intake.

[3] The SEM was different among sexes because one female died during the trial then we decided to show the highest SEM.

[4] Significance of the main effects of level of intake (LI), sex (S) and their interaction. *P*-value of Linear (Lin) and quadratic (Q) effects of the level of intake.

***Initial body composition***. The initial EBW ($P$ = 0.45) and initial body energy ($P$ = 0.29), fat ($P$ = 0.29), and protein ($P$ = 0.46) were similar in castrated males, intact males and females. Therefore, for these variables an unique equation was developed for all sexes (Eq. [4], $P$ < 0.001; Eq. [5], $P$ < 0.001; Eq. [6], $P$ < 0.001 and Eq. [7], $P$ < 0.001 ). These equations were used to estimate initial body composition of goats in the maintenance requirements experiment, which were used to calculate the energy and protein retention:

$$\text{iEBW} = 1.58\ (\pm\ 0.704) + [0.73\ (\pm\ 0.102) \times \text{iBW}] \qquad [4]$$

$$\text{Log}_{10}\ \text{iEnergy} = 2.55\ (\pm\ 0.609) + [1.65\ (\pm\ 0.533) \times \log_{10}\ \text{iEBW}] \qquad [5]$$

$$\text{Log}_{10}\ \text{iFat} = 0.55\ (\pm\ 0.088) + [2.39\ (\pm\ 0.866) \times \log_{10}\ \text{iEBW}] \qquad [6]$$

$$\text{Log}_{10}\ \text{iProtein} = 1.12\ (\pm\ 0.516) + [1.98\ (\pm\ 0.453) \times \log_{10}\ \text{iEBW}] \qquad [7]$$

where iEBW is initial empty body weight (kg), iBW is initial body weight (kg), iEnergy is initial body energy (kcal), iFat is initial body fat (g) and iProtein is initial body protein (g).

***Fat and protein content***. Sex affected all variables but protein body composition (% EBW) and EWG (kg/d). Castrated males and females showed lower water concentration and greater fat and energy concentration in the body than intact males (Table 3). Intact males showed 53.6% lower FIG (mean, 12.7% EWG) than females and castrated males (mean, 27.4% EWG). On the other hand PIG was not affected by sex (mean, 20.19% EBW; Table 3). Females showed greater RE than intact males irrespective of the level of intake. When fed ad libitum castrated males showed similar RE than females. However, under 75% of level of intake their RE was similar to intact males (Table 3). The RE of castrated males and females fed ad libitum was 33.2% higher than the RE of intact males (mean, 37.9 vs. 25.3 $kcal/kg^{0.75}$ EBW·d). We observed effect of sex for DFG (Eq. [8] and [10] and for DPG (Eq. [9] and [11]).

For castrated males and females:

$$DFG = -17.8\ (\pm\ 2.108) + [0.0004\ (\pm\ 0.0003) \times RE_c + 0.305\ (\pm\ 0.010) \times EWG] \quad [8]$$

$$DPG = 1.7\ (\pm\ 0.986) + [0.205\ (\pm\ 0.088) \times DFG + 0.107\ (\pm\ 0.020) \times EWG] \quad [9]$$

For intact males:

$$DFG = -9.7\ (\pm\ 2.017) + [0.0004\ (\pm\ 0.0003) \times RE_c + 0.146\ (\pm\ 0.013) \times EWG] \quad [10]$$

$$DPG = 1.7\ (\pm\ 0.986) + [0.641\ (\pm\ 0.088) \times DFG + 0.107\ (\pm\ 0.013) \times EWG] \quad [11]$$

where DFG is daily fat body gain (g/d), DPG is daily protein body gain (g/d), $RE_c$ is concentration of RE (kcal/kg EWG) and EWG is empty body gain (g/d).

**Table 3.** Performance and body composition of castrated males, intact males and females Saanen goat kids fed different levels of intake.

| Item[1] | Level of intake (%)[2] | | | | | | | | | SEM[3] | *P*-value[4] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Intact males | | | Castrated males | | | Females | | | | | | | | |
| | AL | 75% | 50% | AL | 75% | 50% | AL | 75% | 50% | | LI | S | LI*S | Lin | Q |
| Days on feed | 105 | 105 | 105 | 92 | 92 | 92 | 98 | 98 | 98 | 7.773 | - | - | - | - | - |
| DMI, g/d | 748.0 | 567.6 | 389.6 | 853.5 | 579.0 | 419.6 | 816.0 | 603.2 | 397.1 | 28.482 | <0.001 | 0.22 | 0.20 | <0.001 | 0.18 |
| CPI, g/d | 161.3 | 117.0 | 80.0 | 185.0 | 119.0 | 85.3 | 172.4 | 122.4 | 80.4 | 6.127 | <0.001 | 0.25 | 0.17 | <0.001 | 0.02 |
| GEI, Mcal/d | 3.40 | 2.40 | 2.02 | 3.88 | 2.62 | 1.99 | 3.68 | 2.58 | 1.98 | 0.354 | <0.001 | 0.78 | 0.92 | <0.001 | 0.23 |
| iBw, kg | 15.75 | 15.40 | 15.65 | 15.58 | 15.67 | 15.30 | 15.26 | 15.15 | 15.22 | 0.150 | 0.39 | 0.12 | 0.52 | <0.001 | 0.06 |
| fBW, kg | $32.64^{aA}$ | $27.93^{bA}$ | $20.34^{cA}$ | $31.22^{aAB}$ | $24.84^{bB}$ | $20.24^{cA}$ | $29.80^{aB}$ | $27.21^{bA}$ | $20.15^{cA}$ | 0.581 | <0.001 | 0.01 | <0.001 | <0.001 | 0.03 |
| EBW, kg | $27.55^{aA}$ | $24.18^{bA}$ | $17.32^{cA}$ | $26.09^{aAB}$ | $19.98^{bB}$ | $16.80^{cA}$ | $25.24^{aB}$ | $22.71^{bA}$ | $16.58^{cA}$ | 0.573 | <0.001 | <0.001 | 0.01 | <0.001 | 0.10 |
| EWG, g/d | 0.124 | 0.111 | 0.042 | 0.121 | 0.100 | 0.045 | 0.147 | 0.080 | 0.045 | 0.013 | <0.001 | 0.95 | 0.12 | <0.001 | 0.25 |
| Water, % EBW | 66.4 | 66.6 | 68.7 | 61.3 | 62.6 | 66.4 | 60.6 | 60.8 | 64.6 | 1.042 | <0.001 | <0.001 | 0.49 | <0.001 | 0.03 |
| Protein, % EBW | 18.57 | 17.80 | 18.55 | 17.90 | 18.21 | 18.17 | 17.15 | 17.16 | 17.16 | 0.514 | 0.79 | 0.06 | 0.73 | 0.80 | 0.53 |
| Fat, % EBW | 13.5 | 14.0 | 11.4 | 21.1 | 17.7 | 13.9 | 20.8 | 20.5 | 17.0 | 1.141 | <0.001 | <0.001 | 0.12 | <0.001 | 0.11 |
| Energy, Mcal/kg EBW | 2.078 | 2.100 | 1.844 | 2.581 | 2.518 | 2.048 | 2.789 | 2.779 | 2.295 | 0.099 | <0.001 | <0.001 | 0.35 | <0.001 | 0.02 |
| FIG, % EWG | 16.0 | 14.6 | 4.0 | 29.4 | 24.9 | 18.8 | 32.0 | 29.9 | 26.8 | 3.236 | 0.001 | <0.001 | 0.66 | <0.001 | 0.34 |
| PIG, % EWG | 20.6 | 18.5 | 21.4 | 19.5 | 23.0 | 22.9 | 18.4 | 19.0 | 17.3 | 1.635 | 0.05 | 0.68 | 0.25 | 0.39 | 0.88 |
| RE, kcal/(kg$^{-0.75}$EBW·d) | $36.2^{aB}$ | $28.3^{bB}$ | $11.4^{cB}$ | $56.5^{aA}$ | $32.5^{bB}$ | $19.3^{cAB}$ | $53.5^{aA}$ | $42.7^{bA}$ | $22.5^{cA}$ | 3.195 | <0.010 | <0.001 | 0.05 | <0.010 | 0.52 |

[a-c] Means within sex at the same row, without a common letter in the subscript are different at P < 0.05 for the level of intake.

[A-C] Means within level of intake at the same row, without a common letter in the subscript are different at P < 0.05 for sex.

[1] iBW = intial body weight; fBW = final body weight; EBW = empty BW; EWG = EBW gain; FIG = fat in gain; PIG = protein in gain; RE = retained energy.

[2] Ad libitum (AL) or 75% or 50% of the AL intake.

[3] The SEM was different among sexes because one female died during the trial then we decided to show the highest SEM

[4] Significance of the main effects of level of intake (LI), sex (S) and their interaction. *P*-value of Linear (Lin) and quadratic (Q) effects of the level

***Energy requirement for maintenance***. We did not find differences among castrated males, intact males and females for $NE_m$ ($P$ = 0.25). Therefore, a general equation (Eq. [12]) for all sexes is presented.The relationship between predicted logarithm of HP and MEI is shown in Fig. 1.

$$\text{Log}_{10}\,\text{HP} = 1.901\ (\pm\ 0.032) + 0.00152\ (\pm\ 0.0002) \times \text{MEI} \qquad [12]$$

where $\text{Log}_{10}$HP is the logarithm of heat production (kcal/kg$^{0.75}$ EBW·d) and MEI is metabolizable energy intake (kcal/kg$^{0.75}$ EBW·d).

Using Eq. [12], the $NE_m$ for castrated, intact males and females was estimated as 79.7 kcal/kg$^{0.75}$ EBW·d or 66.4 kcal/kg$^{0.75}$ BW·d. Metabolizable energy requirements for maintenance was calculated assuming that HP was equal to MEI at maintenance, resulting in 122.0 kcal/kg$^{0.75}$ EBW·d or 101.6 kcal/kg$^{0.75}$ BW·d. The estimated $k_m$ was 0.65.

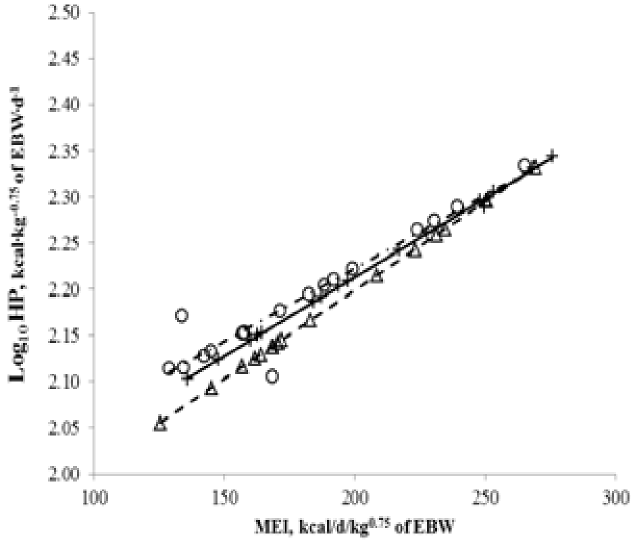


**Figure 1.** Relationship between the logarithm of heat production (HP; kcal/kg$^{0.75}$ EBW·d) and ME intake (MEI, kcal/kg$^{0.75}$ EBW·d) of castrated male, intact male and female Saanen goats kids between 15 and 30 kg of BW (Log10 HP = 1.901 (± 0.032) + 0.00152 (± 0.0002) x MEI). Observations are from castrated males (+), intact males (○) and females (△).

Metabolizable energy requirements for maintenance was also calculated using the regression equation of RE on MEI ($P$ < 0.001; Eq. [13]), resulting in 86.9 kcal/kg$^{0.75}$ EBW·d or 72.4 kcal/kg$^{0.75}$ BW·d. The $k_g$ calculated as the slope of Eq. [13] was 0.29. The relationship between predicted RE and MEI is shown in Fig. 2.

$$RE = -25.5 (\pm 5.974) + 0.294 (\pm 0.029) \times MEI \quad [13]$$

where RE is retained energy (kcal/kg$^{0.75}$ EBW·d) and MEI is metabolizable energy intake (kcal/kg$^{0.75}$ EBW·d).

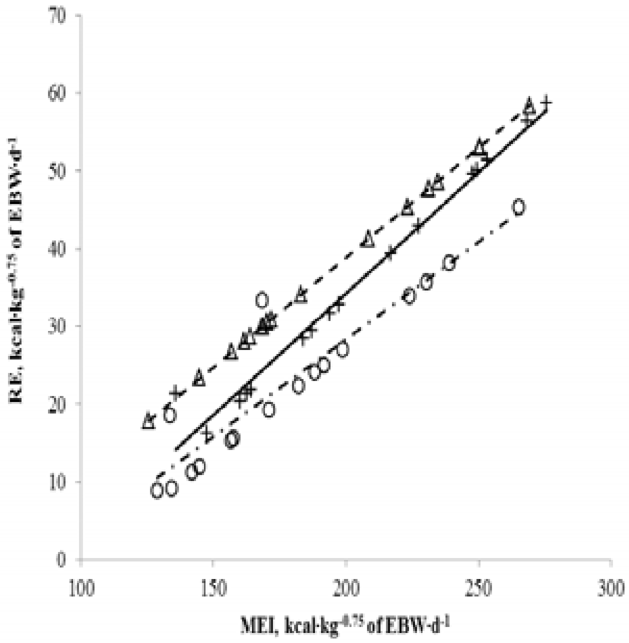


**Figure 2.** Relationship between the retained energy (RE, kcal/kg$^{0.75}$ EBW·d) and ME intake (MEI, kcal/kg$^{0.75}$ EBW·d) of castrated male, intact male and female Saanen goats kids between 15 and 30 kg of BW (RE = -25.5 (± 5.974) + 0.294 (± 0.029) x MEI). Observations are from castrated males (+), intact males (○) and females (△).

***Protein requirements for maintenance***. The $NP_m$ was not affected by sex ($P$ = 0.89). Therefore, a general equation for all sexes is presented Eq. [14]. The relationship between predicted NRet and NI is shown in Fig. 3.

$$NRet = -0.105 (\pm 0.044) + 0.183 (\pm 0.018) \times NI \quad [14]$$

where NRet is nitrogen retained in the body (g N/kg$^{0.75}$ EBW·d) and NI is nitrogen intake (g N/kg$^{0.75}$ EBW·d).

The intercept in Eq. [14] estimates N losses of 105 mg N/kg$^{0.75}$ EBW·d at NI = 0, which corresponds to $NP_m$ of 0.65 g/kg$^{0.75}$ EBW·d or 0.54 g/kg$^{0.75}$ BW·d. The N intake required for maintenance, at which NRet = 0, was 0.58 g N/kg$^{0.75}$ EBW·d, which corresponds to an intake of 3.58 g CP/kg$^{0.75}$ EBW·d or 2.98 g CP/kg$^{0.75}$ EBW·d.

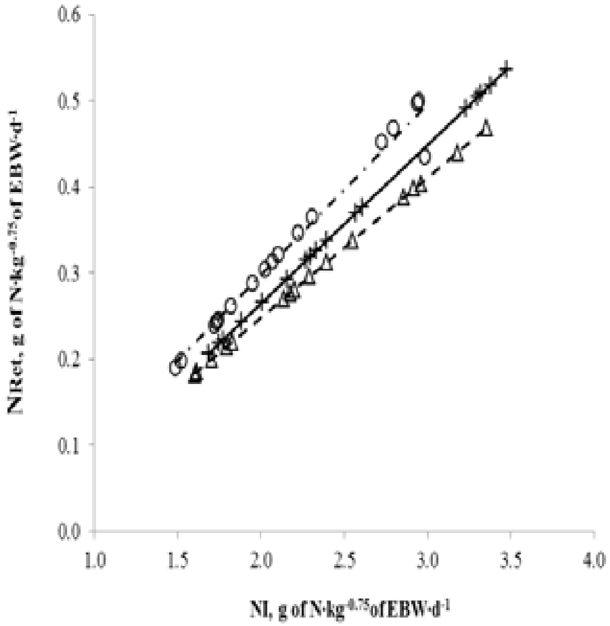


**Figure 3.** Relationship between the N retained (NRet; g/kg$^{0.75}$ EBW·d) and N intake (NI; g/kg$^{0.75}$ EBW·d) of castrated male, intact male and female Saanen goats kids between 15 and 30 kg of BW (NRet = -0.105 (± 0.044) + 0.183 (± 0.018) x NI). Observations are from castrated males ( + ), intact males ( ○ ) and females ( △ ).

## Requirements for gain (Trial 2)

***Body composition.*** In this study sex did not affect total body protein a function of EBW, therefore, only one equation is presented for this variable. On the other hand, sex affected total body energy, fat, and water and the results are presented separately for castrated males and females, and intact males (Table 4). The relationship between the logarithm of total protein and energy in the body and the logarithm of EBW are shown in Fig. 4 and 5.

Table 4. Regression of logarithm of the body water (g), energy (kcal), fat (g) or protein (g) content on the logarithm of empty body weight (EBW) to describe the net retention by castrated male, intact male and female Saanen goats kids.

| Item | Regression equations[1] | | | | *P*-value[2] | | |
|---|---|---|---|---|---|---|---|
| | Intercept | SE | Slope | SE | BW | S | BW*S |
| $Log_{10}$Water, g/kg EBW | | | | | | | |
| Castrated males and females | 3.014 | 0.003 | 0.839 | 0.025 | <0.001 | 0.04 | 0.01 |
| Intact males | 2.885 | 0.037 | 0.957 | 0.029 | | | |
| $Log_{10}$ Energy, kcal/kg EBW | | | | | | | |
| Castrated males and females | 2.741 | 0.084 | 1.481 | 0.066 | <0.001 | <0.001 | 0.01 |
| Intact males | 3.150 | 0.098 | 1.121 | 0.076 | | | |
| $Log_{10}$ Fat, g/kg EBW | | | | | | | |
| Castrated males and females | 1.340 | 0.145 | 1.685 | 0.114 | <0.001 | 0.01 | <0.001 |
| Intact males | 2.031 | 0.169 | 1.073 | 0.131 | | | |
| $Log_{10}$ Protein, g/kg EBW | | | | | | | |
| All sexes | 2.199 | 0.052 | 1.035 | 0.040 | <0.001 | 0.35 | 0.34 |

[1]Linear equation: $Log_{10}Y = a + b \times log_{10}$ EBW where Y is the logarithm of the retained body water (g), energy (kcal), fat (g) or protein (g) and EBW is the empty body weight (kg) estimated by the equation: EBW = -0.56 (± 0.335) + 0.855 (± 0.015) x BW.

[2]Significance of the main effects of BW, sex (S) and their interaction.

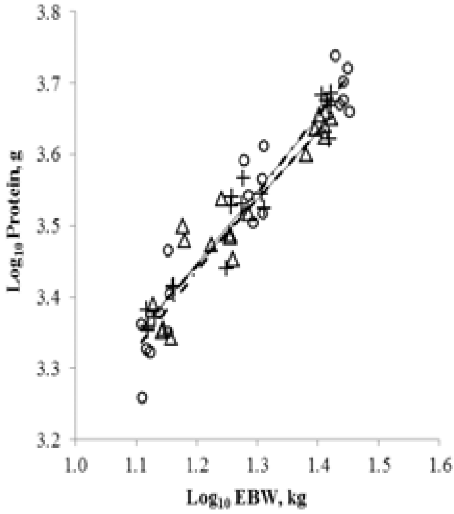


**Figure 4**. Relationship between the logarithm of protein (g) and logarithm  of empty body weigh (EBW; kg) for all Saanen goats kids between 15 and 30 kg of BW ($Log_{10}$Protein = 2.199 (± 0.052) + 1.035 (± 0.040) x $log_{10}$ EBW). Observations are from castrated males (+), intact males (○) and females (△).

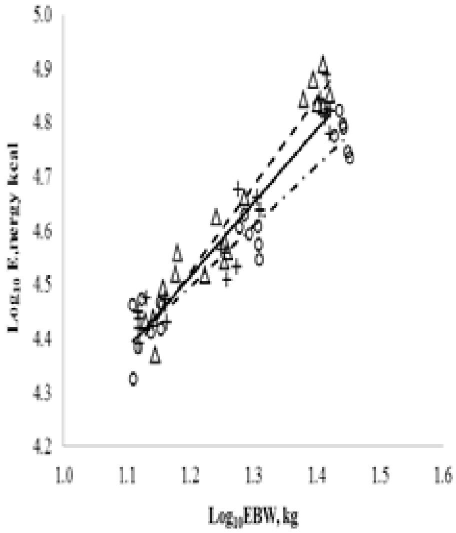


**Figure 5**. Relationship between logarithm of retained energy (RE; kcal) and logarithm of empty body weigh (EBW; kg) for castrated male and female Saanen goats kids ($Log_{10}$ RE = 2.741 (± 0.084) + [1.481 (± 0.066) x $log_{10}$ EBW]) and for intact males ($Log_{10}$ RE = 3.150 (± 0.084) + [1.121 (± 0.076) x $log_{10}$ EBW]) between 15 and 30 kg of BW. Observations are from castrated males (+), intact males (○) and females (△).

***Energy requirements for gain.*** The relationship between $NE_g$ (Mcal/kg EBW gain) and EBW (kg) of castrated male and females and for intact males is shown in Fig. 6. For castrated males and females between 15 and 30 kg EBW, $NE_g$ was estimated applying the first derivative of the equation for $Log_{10}RE$ with respect to EBW yields estimates of net energy requirements for growth (Eq.[15]) and increased from 2.72 to 3.84 Mcal/kg EBW gain or from 2.22 to 3.21 Mcal/kg BW gain. For intact males, $NE_g$ was estimated by the Eq. [16] and increased from 2.13 to 2.32 Mcal/kg EBW gain or from 1.75 to 1.94 Mcal/kg BW gain.

For castrated males and females:

$NE_g = 0.82 \times EBW^{0.481}$ [15]

For intact males:

$NE_g = 1.58 \times EBW^{0.119}$ [16]

where $NE_g$ is net energy requirements for growth (Mcal/kg EBW gain) and EBW is empty body weight (kg).

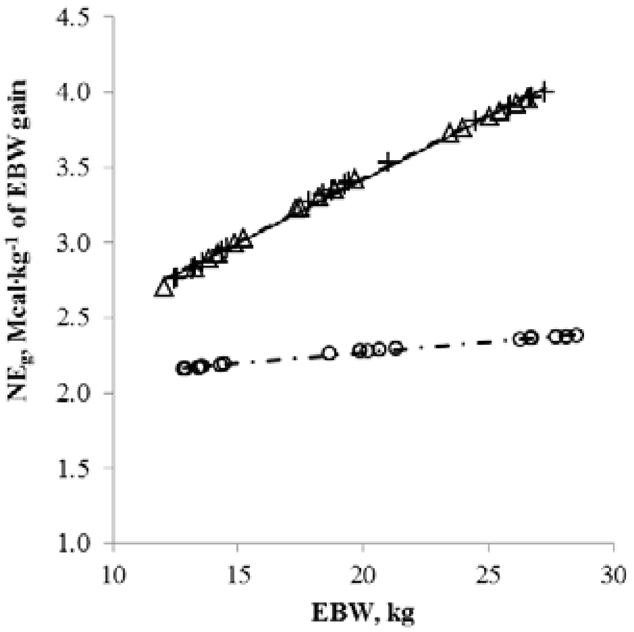


**Figure 6.** Relationship between net energy requirements for gain ($NE_g$; Mcal/kg EBW gain) and empty body weight (EBW; kg) for castrated male and female Saanen goats kids ($NE_g = 0.82 \times EBW^{0.481}$) and for intact males ($NE_g = 1.58 \times EBW^{0.119}$) between 15 and 30 kg of BW. Observations are from castrated males ( + ), intact males ( ○ ) and females ( △ ).

***Protein requirements for gain***. Appling the first derivative of the equation for $Log_{10}$Protein with respect to EBW yields estimates of net protein requirements for growth we obtained the Eq. [17]

$$NP_g = 163.7 \times EBW^{0.035} \qquad [17]$$

where $NP_g$ is net protein requirements for growth (g/kg EBW gain) and EBW is empty body weight (kg).

We did not observe an effect of sex ($P$ = 0.95) on rate of EBW protein accretion between 15 and 30 kg BW in Saanen goats. The $NP_g$ ranged from 178.6 to 183.1 g/kg EBW gain or from 145.8 to 153.0 g/kg BW gain between 15 and 30 kg in Saanen goat kids. The relationship between $NP_g$ (g/kg of EBW gain) and EBW (kg) of castrated male and females and for intact males is shown in Fig. 7.

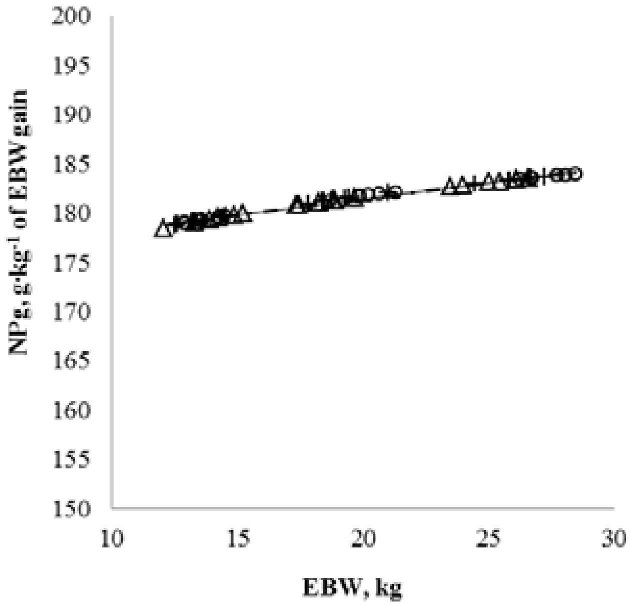


**Figure 7.** Relationship between net protein requirements for gain ($NP_g$; g/kg EBW gain) and empty body weight (EBW; kg) for castrated male, intact male and female Saanen goats kids ($NP_g = 163.7 \times EBW^{0.035}$) between 15 and 30 kg of BW. Observations are from castrated males ( + ), intact males ( ○ ) and females ( △ ).

## DISCUSSION

In this study we analyzed the sex effect on the energy and protein requirements for maintenance and gain of Saanen goat kids, between 15 and 30 kg. Such analyzes are particularly interesting given the existing controversy regarding the nutritional requirements according to sex in goats. We found that sex did not affect energy and protein requirements for maintenance as well as protein requirements for growth however it affected energy requirements for gain.

***Energy Requirements for Maintenance***

The energy maintenance requirements are defined as basal metabolic rate added the energy costs related with eating and feed utilization processes. High rates of metabolism are mostly due to activity of visceral tissues (heart, kidney, gastrointestinal tract, and liver) (Reynolds et al., 2002) whereas the energy expenditure of an organ is the product of organ size and metabolic activity per unit of tissue (Burrin et al., 1990). Since we did not find differences on the relative size of visceral tissues (% of EBW; data not shown) we expected the same metabolic rate in intact males, castrated males and females. In addition, because we did not observe differences on intake among sexes we can suppose that the costs with heat production due digestion were not different. Variation in feed intake is not the only cause of differences in maintenance requirements, but it can make a significant contribution (Baldwin et al., 1980).

The NRC (2007) assumed that maintenance energy requirements of intact males are 15 percent greater than for females and castrated males. The factors apparently responsible for such differences are greater protein content in the body in intact males (Webster, 1986; Robelin and Geay, 1984; Emmans, 1994) and differences in stage of maturity for animals with the same BW. The CSIRO (2007) recommends the same correction factor for sex. Our results do not support this hypothesis, even when considering the females showing greater proportion of mature weight in the same BW than intact and castrated males (considering adult BW as 68, 78 and 91 kg for females, castrated males and intact males, respectively). In addition, no difference for protein body composition among the sex was found.

The $ME_m$ recommendation of NRC (2007) for growing intact males is 149 kcal/kg$^{0.75}$ BW and for castrated males and females $ME_m$ as 128 kcal/kg$^{0.75}$ BW. Our results did not show a difference between sexes. Furthermore, we found $ME_m$ 32% lower for intact males and 21% lower for castrated males and females than those recommended by the NRC (2007), respectively. The AFRC (1998) $ME_m$ requirements for all sexes are 105 kcal/kg$^{0.75}$ BW and our $ME_m$ is 3.6% lower than it. Sahlu et al. (2004) suggested a value of 139 kcal/kg$^{0.75}$ BW of $ME_m$ for growing dairy goats (weaning to 1.5 years of age) irrespective of sex. We found $ME_m$ 27% lower than Sahlu et al. (2004) recommendation. This disparity among the recommendations can be explained by differences between the database used by Sahlu et al. (2004) and the database used herein, such as in genotype, the nature of diet, management and methodologies applied. Birkett and De Lange (2001) pointed out that expressing the requirements in metabolizable terms introduces additional errors related to factors listed above, which may affect $k_m$.

***Protein Requirements for Maintenance***

Protein requirements for maintenance are the sum of endogenous urinary N, metabolic fecal N, and dermal (scurf and hair) N losses (NRC, 1985). Our results did not show a difference among the sexes, corroborating current requirements systems. This may be explained by the fact that we did not find differences on urinary and fecal N (0.28 and 0.45 g N·kg$^{0.75}$ BW of urinary N and fecal N, respectively). Moreover, no evidence for differences of dermal losses across sexes in goats has been published to date.

Our estimates of $NP_m$ produced lower values than those suggested by current requirements systems. This discrepancy may be due to the methodology we used in relation to those employed by the other studies (comparative slaughter vs. nitrogen balance) and the high CPI values observed herein. Indeed, even animals subjected to half of the total level of intake imposed, the CPI was above maintenance. Previous studies reported that high protein intake can affect the protein requirements for maintenance, because it can alter nitrogen balance (Cole et al., 2005; Koenig and Beauchemin, 2013), however the mechanisms accounting for it remain poorly understood. In addition, high protein intake increases satiety (Plantenga and Lejeune, 2005) which can lead to lower DMI. In fact our animals showed DMI lower than DMI suggested by NRC (2007) and CSIRO (2007).

***Energy Requirements for Gain***

As a result of higher proportion of fat in the body of castrated males and females the $NE_g$ was 32% greater for castrated males and females than intact males. It is well known that females have more fat in the body than males, even in early life. This difference may serve reproductive purposes and, leads to changes in energy partitioning and thus greater energy requirements for gain. Furthermore, it is known that the metabolism in animals is regulated by multiple hormones with a complex feedback control mechanism (Renaville et al., 2002). The control of GH is under many factors among them seric testosterone (Owens et al., 1993). Several studies have showed that GH decreases glucose transport and lipogenesis, resulting in a reduction of the lipid content and adipose tissue mass by increasing the release of somatomedins (Louveau and Gondret, 2004). In our study the blood concentration of somatomedins (data not shown) was higher in intact males than females and castrated males (plasmatic concentration of IGF-1 was 81.3 ng/ml for castrated males and females and 106.20 ng/ml for intact males).

The observed $ME_g$ for intact males was 14% higher than to the recommendation of NRC (2007) for all sexes (6.4 vs. 5.5 Mcal/kg BW gain) and the $ME_g$ found of castrated males and females was 30% higher than the $ME_g$ recommended by the NRC (2007). On the other hand, when we compared our results with AFRC (1998) in terms of net energy, we found a similar $NE_g$ for castrated males and females and that reported by the AFRC (1998) whereas for intact males our $NE_g$ was 36% lower. This difference could be explained because the AFRC (1998) recommendation was based mainly on results obtained with castrated males.

***Protein Requirements for Gain***

Our estimate of $NP_g$ did not differ among sexes, following the same trend as for body protein composition. In beef cattle, Geay (1984) found greater protein deposition in intact males than in females. However, in our study with dairy goats we did not observe such difference, indicating that protein deposition in the growth phase analyzed herein was similar across the sexes.

The observed $MP_g$ for all the sexes was 250.5 g/kg BW gain (we assumed $k_{pg}$ as 0.59; AFRC, 1998; NRC, 2007). We found a similar $MP_g$ than reported by the AFRC (240 g/kg$^{-1}$ BW gain; 1998) whereas our $MP_g$ was 14% lower than the reported by NRC (290 g/kg BW gain).

To our knowledge this is the first study verifying the effect of sex on the energy and protein requirements in goats, using the comparative slaughter technique, resulting in more adequate estimates of requirements for energy and protein and reducing the cost of production.

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# CAPÍTULO 3 - ASSESSMENT OF MODELS FOR PREDICTING FEED INTAKE AND AVERAGE DAILY GAIN OF MALE AND FEMALE SAANEN GOAT KIDS

## Avaliação de modelos para predição do consumo e ganho de peso diário de caprinos, machos e fêmeas, da raça Saanen

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**ABSTRACT**

Many feeding systems have been developed for goats in the last decades and they should be able to predict the feed intake and performance, however they were developed using different feeds, animals and climatic conditions which can lead to over or underestimate the dry matter intake (DMI) and the average daily gain (ADG) of the animals. Then, the objective of this study was to evaluate the models from AFRC (1998) and NRC (2007) for predicting DMI and ADG of growing goats, using individual data of 37 Saanen goat kids (12 intact males, 13 castrated males and 12 females) with body weight (BW) ranging from 15.0 ± 0.4 to 31.2 ± 1.6 kg. The feeding systems were evaluated by regressing the residual (observed minus predicted) on the predicted values centered on their means. The comparisons showed that AFRC feeding system was the most accurate for predicting DMI ($P = 0.96$) and ADG predictions ($P = 0.68$). The NRC feeding system is not accurate for predicting DMI ($P < 0.0001$) and ADG ($P < 0.0001$). However, when mature body weight was used as a covariate both AFRC and NRC was accurate in predicting the ADG (and $P = 0.81$ and $P = 0.99$ for NRC).

**Index terms:** dry matter intake, feeding system, performance, small ruminant

**RESUMO**

Nas últimas décadas muitos sistemas de alimentação foram desenvolvidos para caprinos e, estes devem ser capazes de predizer o consumo e a performance dos animais. Entretanto, estes mesmos sistemas de alimentação foram desenvolvidos utilizando diferentes tipos de alimentos, animais e em diferentes condições ambientais, o que pode levar a super ou sub estimativa do consumo de matéria seca (CMS) bem como do ganho de peso (GP) dos animais. Desse modo, o objetivo deste estudo foi avaliar os modelos do AFRC (1998) e NRC (2007) para predizer o CMS e GP de caprinos Saanen em crescimento utilizando observações individuais de 37 caprinos Saanen (12 machos inteiros, 13 machos castrados e 12 fêmeas) com peso corporal variando de 15,0 ± 0,4 to 31,2 ± 1,6 kg. Os sistemas de alimentação foram avaliados pela regressão do resíduo (observado – predito) com os valores preditos centralizados em suas médias. As avaliações mostraram que o AFRC (1998) foi o mais acurado em predizer o CMS ($P = 0,96$) e o GP ($P = 0,68$). O NRC (2007) não foi acurado em estimar o CMS ($P < 0,0001$) e o GP ($P < 0,0001$). Entretanto, quando o peso a maturidade foi utilizado como covariável tanto o AFRC ($P = 0,81$) quanto o NRC foram acurados em estimar o GP ($P = 0,99$).

**Termos para indexação:** ingestão, desempenho, sistemas de alimentação, pequenos ruminantes

## INTRODUCTION

The intake, digestibility and metabolism of diet nutrients have a profound effect on performance of the animals (Machado Neto et al., 2010). The accurate prediction of dry matter intake is fundamental to supply the nutritional requirements and avoid excess or deficiency of a given nutrient or energy.

The AFRC (1998) and NRC (2007) developed models to estimate dry matter intake of goats where in the AFRC model the dry matter intake is predicted based on the body weight and adjusted for metabolizable energy concentration in the diet (Teixeira, et al. 2011) whereas in the NRC model the dry matter intake is predicted based on the current weight as a proportion of animals' mature weight and adjusted for quality constraint based on the digestibility.

Even though these models are widely used, they were developed using different feeds, animals and climatic conditions from those found in Brazil which can lead to over or underestimate the dry matter intake and the average daily gain of the animals and consequently, modify the nutritional requirements. Therefore, the objective of this study was to evaluate the models from AFRC (1998) and NRC (2007) for predicting dry matter intake and average daily gain of growing goats.

## MATERIAL AND METHODS

We evaluated the NRC and AFRC models using individual data from 37 Saanen goat kids (12 weaned intact males, 13 weaned castrated males and 12 weaned females) with body weight (BW) ranging from 15.0 ± 0.4 to 31.2 ± 1.6 kg. All animals were fed ad libitum twice a day, with a total mixed diet (Table 1) that was formulated to meet the requirements of dairy growing goat kids (NRC, 2007) for gain of 200 g/day. The experimental diet consisted of dehydrated whole corn (*Zea mays)* plants, cracked corn grain, soybean (*Glycine max*) meal, soybean oil, limestone, ammonium chloride (to prevent urinary calculi) and a mineral supplement. Dehydrated corn plants consisted of whole corn plants (60 to 70% moisture) chopped when the kernel milk line was approximately two-thirds of the way down the kernel. The chopped material was air dried for approximately 72 h or until it reached 10% moisture. The dried, chopped material was then ground to pass through a 10 mm screen (mill hay Mexon charger 15.0, G3 Mexon Maquinas Agricolas, Cajuru, Sao Paulo, Brazil). The main inputs needed for the models of the feeding systems are reported in Table 2.

Table 1. Ingredient and chemical composition of the diet.

| Item | % in the diet | Ingredient composition[3] (% of DM) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | GE | CP | Fat | NDF | ADF | Lignin | Ash | DM |
| Dehydrated corn plant[1] | 45.35 | 4479 | 8.5 | 2.8 | 59.7 | 31.8 | 4.2 | 3.4 | 84.7 |
| Cracked corn | 26.64 | 4657 | 11.7 | 1.7 | 19.0 | 5.3 | 0.9 | 1.7 | 84.1 |
| Soybean meal | 22.33 | 4732 | 53.6 | 1.2 | 15.3 | 11.7 | 0.6 | 7.0 | 85.7 |
| Soybean oil | 1.57 | 9231 | - | 100 | - | - | - | - | 100 |
| Limestone | 1.02 | - | - | - | - | - | - | 99.6 | 100 |
| Mineral supplement[3] | 2.19 | - | - | - | - | - | - | 86.3 | 97.3 |
| Ammonium chloride | 0.91 | - | 163.6 | - | - | - | - | 5.8 | 98.1 |
| Total diet | 100 | 4473 | 20.3 | 3.3 | 35.9 | 18.6 | 2.3 | 6.2 | 85.4 |

[1]Dehydrated corn plant consisted of whole corn plants (60 to 70% moisture) chopped when the kernel milk line was approximately two-thirds of the way down the kernel.
[2]Composition, per kg, as-fed basis: 190 g of Ca; 92 g of Cl; 73 g of P; 62 g of Na; 44 g of Mg; 1.35 g of Zn; 1.06 g of Fe; 0.94 mg of Mn; 0.73 g of F ; 0.34 g of Cu; 18 mg of Se; 16 mg of I; 3 mg of Co.
[3]GE = gross energy (Kcal/kg DM); DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber.

Table 2. Descriptive statistics of the inputs taken from the database used in the evaluation of AFRC and NRC feeding system.

| Item[1] | Intact males | | | | Castrated males | | | | Females | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.E.[2] | Min.[3] | Max.[3] | Mean | S.E. | Min. | Max. | Mean | S.E. | Min. | Max. |
| Initial age, d | 87 | 12 | 68 | 109 | 85 | 16 | 58 | 105 | 91 | 19 | 57 | 113 |
| Final age, d | 172 | 33 | 124 | 228 | 161 | 32 | 96 | 204 | 168 | 36 | 113 | 218 |
| Initial BW, kg | 15.5 | 0.514 | 15.0 | 16.0 | 15.4 | 0.406 | 14.9 | 16.3 | 15.3 | 0.283 | 15.0 | 15.9 |
| Final BW, kg | 27.2 | 4.845 | 20.9 | 32.0 | 26.7 | 4.455 | 21.5 | 32.5 | 25.6 | 4.314 | 21.0 | 31.8 |
| ADG, kg/d | 0.160 | 0.051 | 0.070 | 0.237 | 0.177 | 0.034 | 0.125 | 0.228 | 0.150 | 0.040 | 0.109 | 0.246 |
| DMI, kg/d | 0.749 | 0.149 | 0.553 | 1.018 | 0.768 | 0.105 | 0.618 | 0.961 | 0.749 | 0.097 | 0.596 | 0.925 |
| ME, Mcal/kg of DM | 2.86 | 0.191 | 2.58 | 3.16 | 2.77 | 0.108 | 2.66 | 2.93 | 2.85 | 0.108 | 2.73 | 2.98 |
| MEI, Mcal/d | 2.20 | 0.147 | 1.92 | 2.51 | 2.26 | 0.212 | 1.99 | 2.88 | 2.14 | 0.133 | 1.91 | 2.38 |
| Dig DM, % | 74.61 | 4.633 | 66.79 | 81.14 | 73.45 | 2.137 | 71,06 | 75.57 | 74.76 | 2.635 | 71.05 | 77.89 |

[1]BW = body weight, ADG = average daily gain, DMI = dry matter intake, ME = metabolizable energy of the diet, MEI = metabolizable energy intake and Dig MS = digestibility of the dry matter.

[2]S.E. = standard errors of the means.

[3]Min. = minimum values and Max. a = maximum values of the variables.

Dry matter intake was predicted considering the equations from AFRC and from NRC.

$$DMI_{AFRC}\ (g/d) = (76.7*BW^{0.75})*(-0.666 + 1.333 * ME - 0.266 * ME^2) \quad (1)$$

$$DMI_{NRC}\ (kg/d) = 0.04 * SRW * (N/SRW) * (1.7 - (N/SRW)) * [(1 - 1.7 * (0.8 - Dig))] \quad (2)$$

where $BW^{0.75}$ is metabolic body weight (kg); ME the metabolizable energy of the diet (Mcal/kg of DM); SRW is standard reference weight (kg); N is normal weight (kg) of an immature animal at given age, and Dig is the digestibility of the diet.

The NRC used the concept of SRW from CSIRO (2007) which is defined as the weight when the animal reaches mature skeletal size and has a condition score in the middle of the range used (0-5). For the present purposes, the SRW is related to the mature weight and in this study we predicted the DMI using the mature body weight of 56 kg for intact males, 42 kg for castrated males and 32 kg for females. These values of mature body weight were obtained from studies with growing goats conducted at UNESP – Univ Estadual Paulista, Jaboticabal, SP, Brazil (unpublished data).

For the comparisons of ADG, to verify the predictions from AFRC and NRC, the ADG predictions were made using the metabolizable energy intake (MEI) observed for each animal. From MEI, we deducted the predicted ME required for maintenance, according to each feeding system; the reminder MEI was divided by predicted EM required for weight gain to obtain the predicted ADG by AFRC and NRC.

The feeding systems were evaluated by regressing residual (observed minus predicted) values on the predicted values centered on their mean values (St-Pierre, 2003). This makes the slope and intercept estimates in the regression orthogonal and, thus, independent. The intercepts of the regression equations were used to estimate mean biases, whereas linear biases were assessed using the slopes of the regression equations.

## RESULTS AND DISCUSSION

Results of the regression of residual DMI on predicted DMI centered on their mean predictions are presented on Table 3.

Table 3. Statistics from regressions of the residual dry matter intake (DMI) on DMI predicted by AFRC and NRC centered on their mean values.

| Model | Adj[a] | Mean bias[b] | | Linear bias[c] | | Residual SE (g/d) | Bias at minimum predicted DMI (g/d) | Bias at maximum predicted DMI (g/d) | P-value | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Estimate (g/d) | P-value | Estimate | P-value | | | | Model | Sex | Model * Sex |
| 1. AFRC | No | 4.18 | 0.84 | -0.148 | 0.66 | 116.3 | -261.8 | -181.0 | 0.66 | 0.74 | 0.19 |
| 2. AFRC | Yes | -0.61 | 0.96 | -0.109 | 0.74 | 115.2 | -264.3 | -176.0 | 0.74 | 0.71 | 0.19 |
| 3. NRC | No | -294.0 | <0.0001 | -0.494 | 0.02 | 116.6 | -261.0 | -5.2 | 0.02 | 0.60 | 0.17 |
| 4. NRC | Yes | -165.3 | <0.0001 | -0.422 | 0.07 | 116.1 | -261.6 | -7.1 | 0.07 | 0.59 | 0.17 |

[a] Adj = adjustments, AFRC adjustment was based on metabolizable energy in the diet (AFRC, 1998) and NRC adjustment was based on quality constraint of the diet (NRC, 2007).
[b] Mean bias was estimated as the intercept of the regression of the residuals (observed – predicted) on the predicted values centered at their means.
[c] Linear bias was estimated by the slope of the regression of the residual (observed – predicted) on the predicted values. It represents the change in the bias of the prediction (g/d) per unit change in the prediction (i.e., per g/d in predicted DMI). Therefore, it is unitless.

The statistics of the relationship between the residuals and predicted DMI for the AFRC (1998) showed that the equation for predicting DMI recommended by this feeding system was accurate (P = 0.84) and the linear bias was not significant (P = 0.66) showing that no adjustment in DMI model is necessary. The good adequacy of this feeding system is probably related to the fact that this feeding system was developed for dairy goats (Teixeira et al. 2011) and although differences in DMI between males and females goats are expected (Grande, et al. 2014) we did not observed effect of sex on DMI (P = 0.74) showing that this model regardless of sex is accurate in predicting DMI of Saanen goats kids weighing from 15 to 30 BW.

Applying the adjustment based on metabolizable energy in the diet suggested by AFRC (1998) the predicting DMI recommended by this feeding system was also accurate (P = 0.96) and no linear bias were found (P = 0.74). This accuracy could be related to the fact that no feed intake variations due to differences in dietary metabolizable energy concentrations were found between this study and AFRC's model.

The DMI predicted by NRC (2007) was not accurate (P < 0.0001) where the DMI was overpredicted on 294 g/d and significant linear bias of -0.494 for each gram of increase in the predicted value was found. Other previous studies also reported that NRC models are biased, accordingly Teixeira et al. (2011) showed that NRC overpredicted DMI of goat kids of different breeds or crossbreds by more than 160 g/d.

On the other hand the adjustment based on the quality constraint of the diet proposed by NRC (2007) decrease means bias with DMI being overpredicted by 165.3 g/d. Thus, the adjusting the NRC seems to benefit the adequacy of prediction of DMI since the systematic bias were eliminated (P = 0.07).

Thereby, the inaccuracy of the NRC model to predict DMI can be related to the fact that the model proposed for goats is the same model proposed for sheep even this feeding system considering that this model had not been tested for goats and justifying this choice with the lack of unequivocal evidence of differences between goat and sheep (NRC, 2007). Considering the differences due to feeding behavior, intake, utilization of nutrients and digestive efficiency between goats and sheep (Devendra, 1989) the use of a model developed from sheep to predicted DMI for goats can result in overprediction or underprediction of the DMI. Moreover, DMI prediction by NRC is very reliant on maturity weight where the use of different values of mature weight will generate different predicted DMI. However, the NRC only describes the concept of mature weight and does not show how to predict this value. According to Regadas Filho et al. (2014) the mature weight of goats is not described in the literature because there are problems associated with the maturity weight as the lack of its definition and how to estimate it.

In addition, complex and multifactorial factors control the DMI by goats (Forbes, 2003) and the interactions between diet, animals, environmental and management factors are also responsible for the significant biases observed in evaluation of the NRC model to predicted DMI of growing goats weighing from15 to 30 kg BW. Thus, to improve the accuracy of DMI prediction from NRC (2007) the factors listed above should be including in the model.

Results of the regression of residual ADG on predicted ADG centered on their mean predictions are presented on Table 4.

Table 4. Statistics from regressions of the residual average daily gain (ADG) on ADG predicted by AFRC and NRC centered on their mean values.

| Model | Mean bias[a] | | Linear bias[b] | | Residual SE (g/d) | Bias at minimum predicted ADG (g/d) | Bias at maximum predicted ADG (g/d) | P-value | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Estimate (g/d) | P-value | Estimate | P-value | | | | Model | Sex | Model * Sex |
| 1. AFRC | 3.66 | 0.683 | -0.73 | 0.003 | 45.66 | 13.87 | 3.71 | 0.003 | 0.45 | 0.94 |
| 2. NRC | -36.43 | <0.0001 | -0.78 | 0.002 | 46.17 | 26.42 | 10.53 | 0.002 | 0.48 | 0.98 |

[a] Mean bias was estimated as the intercept of the regression of the residuals (observed – predicted) on the predicted values centered at their means.
[b] Linear bias was estimated by the slope of the regression of the residual (observed – predicted) on the predicted values. It represents the change in the bias of the prediction (g/d) per unit change in the prediction (i.e., per g/d in predicted ADG). Therefore, it is unitless.

The AFRC (1998) was accurate in predicting ADG of Saanen goats; however, it showed a significant linear bias of -0.73 for each gram of increase in the predicted value. The observed systematic bias can be related to the fact that AFRC under predicted the ADG of some intact males at higher observed ADG and over predicted the ADG of one intact male at lower observed ADG (Figure 1). Once these observations were removed from the model it continues accurate (P = 0.64) and no significant linear bias was found (P = 0.09). When mature body weight was used as covariate no improvement was observed in the model since it remained accurate (P = 0.81) and significant linear bias was also found. (P = 0.002). However, removing the observations listed above we observed improvement in the model where the linear bias was not significant (P = 0.96).

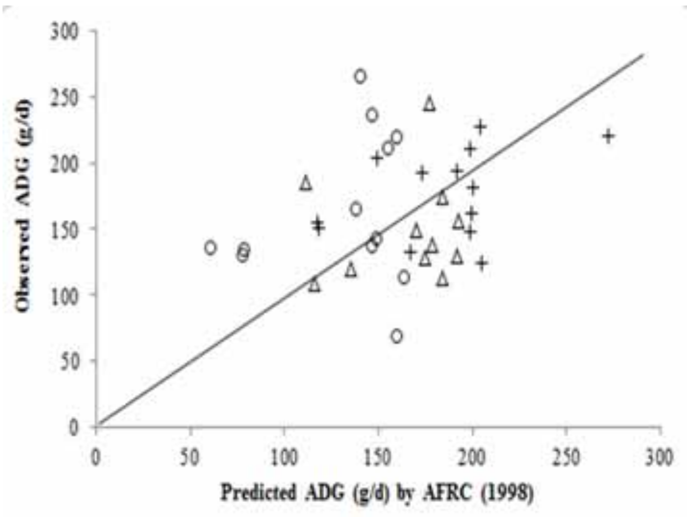


Figure 1 - Predicted values of average daily gain (ADG, g/d) by AFRC versus observed ADG (g/d) from intact male, castrated male and female Saanen goats weighing from 15 to 30 kg of BW. Observations are from intact males (o), castrated males (+) and females (Δ).

One possible explanation for the ADG under prediction by AFRC (1998) for some intact males which resulted in linear bias may be associated with the fact that the metabolizable energy requirements for maintenance recommended by this feeding system were overestimated for these animals. Since the maintenance requirements recommended were greater for these animals the amount of energy available for gain was lower which, consequently, resulted in ADG under prediction by AFRC (1998).

On the other hand the ADG prediction by NRC (2007) obtained when observed MEI was used showed that NRC model was not accurate ($P < 0.001$) over predicting the ADG in 36.4 g/d. The predicted values by NRC (2007) versus observed values are represented graphically in Figure 2.

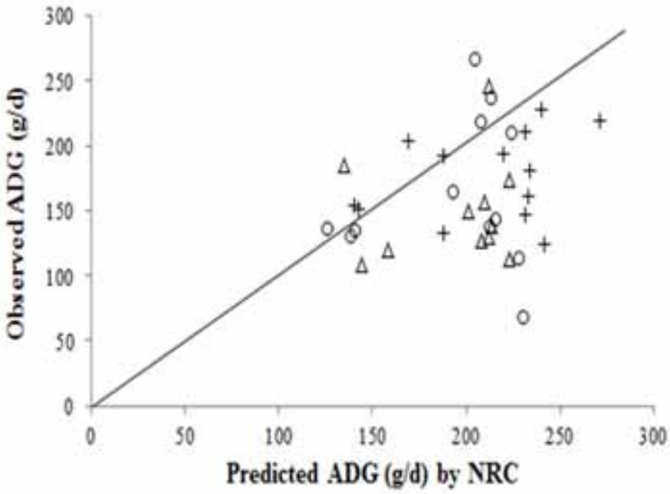


Figure 2 - Predicted values of average daily gain (ADG, g/d) by AFRC versus observed ADG (g/d) from intact male, castrated male and female Saanen goats weighing from 15 to 30 kg of BW. Observations are from intact males (o), castrated males (+) and females (Δ).

Since the average of the MEI used by NRC (2007) to estimate energy requirements (2.24 ± 0.843 Mcal/d; Luo et al. 2004) was similar to the MEI found in this study (2.21 ± 0.173 Mcal/d) the inaccuracy of the ADG prediction by NRC can be associated with the metabolizable energy requirements for maintenance and gain estimated by this feeding system in which these requirements were estimated using a dataset composed of animals at various body weight, age, physiological stage and dairy breeds and crossbred. Thereby, these variations in NRC (2007) dataset can lead to variations in nutritional requirements of dairy goats and, consequently change the accuracy of the model.

Mature body weight was also tested as a covariate in models for prediction ADG of NRC system and absence of mean bias were observed ($P = 0.998$). However, significant linear bias ($P = 0.007$) were found indicating that other factors, besides the mature body weight, should be considered in ADG prediction for intact male, castrated male and female Saanen goats weighing from 15 to 30 kg of BW.

## CONCLUSIONS

The AFRC models was the most accurate system for predicting DMI and ADG of intact males, castrated males and females Saanen goats weighing from 15 to 30 kg of BW. The NRC was not accurate for predicting DMI and ADG. However, when mature body weight was used as a covariate both AFRC and NRC were accurate for predicting ADG.

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