TADEU SILVA DE OLIVEIRA

MOBILIZAÇÃO DE RESERVAS CORPORAIS E EFICIÊNCIAS ENERGÉTICAS DE CABRAS NO INÍCIO DA LACTAÇÃO

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

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APROVADA: 24 de fevereiro de 2014.

Iran Borges

Fernando de Paula Leonel

Ricardo Augusto Mendonça Vieira
(Co-Orientador)

Augusto César de Queiroz
(Co-Orientador)

Marcelo Teixeira Rodrigues
(Orientador)

DEDICO

A Deus a mais essa vitória;

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"Os que se encantam com a prática sem a ciência são como os timoneiros que entram no navio sem timão nem bússola, nunca tendo certeza do seu destino". (Leonardo da Vinci)

BIOGRAFIA

TADEU SILVA DE OLIVEIRA, filho de Paulo César de Oliveira e Maria das Mercês Silva Oliveira, nasceu em 18 de maio de 1982 em Grão Mogol-MG.

Em julho de 2007, concluiu o Curso de Graduação em Zootecnia, pela Universidade Estadual de Montes Claros, Janaúba-MG.

Em fevereiro de 2010, concluiu o Curso de Mestrado em Zootecnia, pela Universidade Federal de Viçosa.

Em março de 2010, ingressou no curso de Doutorado em Zootecnia na Universidade Federal de Viçosa. No período de agosto de 2012 a agosto de 2013, realizou uma parte do seu curso de Doutorado na Universitá degli Studi di Sassari – Itália, através do Programa Ciência sem Fronteiras da CAPES.

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RESUMO

OLIVEIRA, Tadeu Silva de, D.Sc., Universidade Federal de Viçosa, fevereiro de 2014. **Mobilização de reservas corporais e eficiências energéticas de cabras no início da lactação.** Orientador: Marcelo Teixeira Rodrigues. Co-orientadores: Ricardo Augusto Mendonça Vieira e Augusto César de Queiroz.

Objetivou-se com este estudo determinar a magnitude da mobilização das reservas corporais, a eficiência de utilização da energia corporal mobilizada para a produção de leite e as exigências energéticas de cabras para mantença e lactação durante o início da lactação. Utilizou-se 51 cabras multíparas da raça Alpina, alocadas em baias metabólicas individuais providas de cochos para fornecimento de ração e água. As cabras foram distribuídas em um delineamento inteiramente casualizado, com oito tratamentos e seis repetições, sendo os tratamentos constituídos pelas semanas de lactação. Todos os animais receberam uma única dieta experimental à base de silagem de milho e concentrado. Um grupo de três cabras (grupo referência) foram abatidas logo após o parto para estimação da massa de gordura interna e para determinação da energia corporal inicial dos animais que permaneceram no experimento, os demais abates foram realizados com o decorrer da lactação (7º dia ao 56º dias de lactação). Foram realizados abates sequenciais de seis cabras por semanas de lactação, todas as partes do corpo foram pesadas, amostradas para mensuração da massa de gordura interna e determinação da energia corporal dos animais mediante a análise química da matéria seca, proteína bruta, gordura bruta, cinzas e energia dos tecidos corporais. O consumo de matéria seca foi determinado individualmente e diariamente. As cabras eram levadas para a sala de ordenha duas vezes ao dia (6h30 e às 15h30), a produção de leite dos animais foram mensuradas por meio de pesagens diárias e individuais do leite e as amostras de leite foram coletadas semanalmente de cada animal e levadas ao laboratório para para avaliação dos constituintes do leite (gordura, proteína, lactose). Foi realizado um ensaio de digestibilidade no 23º dia experimental utilizando-se seis cabras lactantes para determinação da digestibilidade e do valor energético da dieta. Para determinar a variação de energia corporal foi feita uma regressão múltipla, baseada na massa corporal e nas semanas de lactação, com isso, estimou-se o peso de corpo vazio uma semana antes do abate do animal (PCV SEM-1), assim subtraindo o (PCV SEM-1) com peso de corpo vazio observado no momento em que cada animal foi abatido. Houve uma aumento de forma curvilínea do consumo de matéria seca ($P < 0,001$) e da produção de leite ($P < 0,006$). A gordura e a proteína do leite reduziram ($P < 0,006$) com o avanço da lactação. A massa corporal reduziu ($P < 0,008$) de forma muito intensa durante as primeiras quatro semanas de lactação. As massas de gorduras omental ($P < 0,005$) e visceral ($P < 0,003$) reduziram linearmente durante as oito semanas de lactação. O

peso da carcaça (P <0,002) e dos componentes não-carcaça (P <0,001) também foram afetados de forma negativa com o avanço da lactação. Na massa de gordura da carcaça houve uma redução (P <0,003) de 5,6 para 2,1 kg, entre o parto até a oitava semana, já a massa de gordura dos componentes não-carcaça reduziram (P <0,002) de 8,49 para 2,8 kg. Houve mobilização da proteína da carcaça (P <0,001) de 4,36 para 2,89 kg, também foi observado redução da proteína dos componentes da não-carcaça (P <0,0001) de 3,69 para 2,35 kg, durante oito semanas de lactação. Para determinar as eficiências de utilização da energia da gordura mobilizada e a proveniente da dieta, utilizou-se as seguintes equações: CEM, Mcal = $\beta_0 + \beta_1 \times E_L + \beta_2 \times E_{mob}$ (eq. 1); em que, o CEM é o consumo de energia metabolizável, EL é a energia do leite e o E_{mob} é a energia mobilizada do corpo. CEM, Mcal = $\beta_0 + \beta_1 \times PC^{0,75} + \beta_2 \times E_L + \beta_3 \times E_{mob}$ (eq. 2), em que, o $PC^{0,75}$ é o peso corporal metabólico. A eficiência de utilização da gordura mobilizada (K_{mob}) foi encontrada através da razão entre o β_1/ β_2 da equação 1. A exigência de energia metabolizável para a mantença e para a lactação, são representadas pelos β_1, β_2 da equação 2, já a eficiência de utilização para a lactação (K_L) é a recíproca do $1/ \beta_2$. A eficiência de utilização para a mantença (k_m) foi determinado através da equação $k_m = 0,35 \times q_m + 0,503$, em que, q_m é a mobilizabilidade dos alimentos para mantença. A eficiência de utilização da gordura mobilizada foi de 0,74, para lactação de 0,93 e para a mantença de 0,74. A exigência de energia metabolizável para mantença foi de 0,190 Mcal/ $PC^{0,75}$, onde esta foi dividida em metabolismo basal que foi de 0,0946 Mcal/ $PC^{0.75}$, e energia de suporte para a lactação que foi de 0,0954 Mcal/ $PC^{0.75}$. Outro estudo foi realizado avaliando as predições do *Small Ruminant Nutrition System* (SRNS) sobre digestibilidade dos nutrientes da dieta e nas exigências energéticas de cabras no início da lactação. A avaliação do programa foi feito com base nos valores observados neste estudo e os valores estimados pelo SRNS. Na avaliação dos coeficientes da digestibilidade, NDT, CEM, CEL foram utilizados seis animais. Para avaliação do CMS, CEM, EM_m, EM_L, balanço de EM, variação do ECC, variação da massa corporal, utilizou-se as 51 cabras em início de lactação. Foram utilizados como *inputs* para o programa as seguintes variavéis: massa corporal, idade, consumo de matéria seca, ingestão de nutrientes diários, produção de leite, teor de gordura e proteína no leite, escore de condição corporal (ECC). Para a avaliação do consumo de matéria seca, utilizou-se a equação do AFRC (1998): CMS, kg/d = $0,42 \times PL3,5\% + 0,024 \times PC^{0,75} + 0,4 \times \Delta PC + 0,7 \times$ Proporção de forragem na dieta, em que, ΔPC é variação do peso corporal, devido a equação existente no programa ser desenvolvida para ovelhas. Para avaliação dos modelos foram utilizadas varias técnicas estatíticas, como: coeficiente de determinação, intervalos de confiança dos parâmetros, coeficiente de correlação de concordância, quadrado médio do erro de predição, entre outros. O SRNS tem boa acurácia na predição dos

coeficientes de digestibilidade aparente da matéria seca, matéria orgânica, NDT, CEM e CEL. Entretanto, não faz uma boa predição para os coeficientes de digestibilidade aparente da proteína bruta, gordura e do coeficiente de digestibilidade fibra. Para os coeficientes de digestibilidade aparente da proteína bruta, gordura o SRNS subestimou os valores, por causa dos componentes endogenos. Já para o coeficiente de digestibilidade fibra ocorre o contrário, o SRNS superestimou os valores, por causa da diferente entre as taxas de degradação da fibra de gramíneas de clima temperado com as de clima tropical. A equação do AFRC (1998) não estimou bem o consumo de cabras em início de lactação. Os valores de CEM, balanço de EM e EM_m, foram subestimados pelo SRNS. Entretanto, o SRNS estimou com acurácia os valores EM_L, variação do ECC e variação da massa corporal. As cabras durante as oito semanas pós-parto mobilizaram não apenas gordura, mas também proteína corporal. As cabras mobilizaram em média de 6,48 MJ/d de energia. A eficiência de utilização da energia mobilizada é de 74% e a eficiência de utilização da energia dietética é de 93%. O SRNS tem baixa acurácia para predição da qualidade da dieta e boa acurácia para predição das reservas corporais de cabras em início de lactação.

ABSTRACT

OLIVEIRA, Tadeu Silva de, D.Sc., Universidade Federal de Viçosa, February, 2014. **Mobilization of body reserves and energy efficiency for goats in early lactation**. Advisor: Marcelo Teixeira Rodrigues. Co-advisors: Ricardo Augusto Mendonça Vieira and Augusto César de Queiroz.

The objective of this study was to determine the magnitude of the mobilization of body reserves, the use efficiency of the body energy mobilized for milk production and the energy requirements for maintenance and lactation of goats in early lactation. Fifty-one crossbred Alpine goats were housed in individual metabolic cages provided with troughs for supply of feed and water. The goats were distributed in a completely randomized design with eight treatments and six replicates - treatments consisted of the lactation weeks. All animals received a single experimental diet based on corn silage and concentrate. A group of three goats (control) was slaughtered right after calving to estimate the internal fat mass and to determine the initial body energy of the animals that remained in the experiment. The other slaughters were carried out throughout the lactation period (7th to 56th days in milk). Sequential slaughters of six goats were performed per lactation week; all body parts were weighed and sampled to measure the internal fat mass and determine the body energy of the animals based on the chemical analysis of dry matter, crude protein, ash, and energy of the body tissues. Dry matter intake was determined individually and daily. Goats were transferred to the milking room twice daily (06.30 h and 15.30 h). Milk yield was measured by weighing the milk produced daily per animal, and milk samples were collected from each animal weekly and taken to the laboratory to evaluate the milk components (fat, protein and lactose). A digestibility trial was conducted on the 23rd experimental day using six lactating goats to determine the digestibility and the dietary energy value. To determine body energy variation, a multiple regression was conducted based on the body mass and lactation weeks. Thus, the empty body weight was determined one week prior to the slaughter of the animal (EBW WK-1), then the (EBW WK-1) was subtracted from the empty body weight observed at the moment each animal was slaughtered. There was a curvilinear increase in dry matter intake ($P < 0.001$) and milk yield ($P < 0.006$). Milk fat and protein reduced ($P < 0.006$) as the lactation progressed. Body mass reduced markedly ($P < 0.008$) during the first four weeks of lactation. The masses of omental ($P < 0.005$) and visceral ($P < 0.003$) fat reduced linearly over the eight lactation weeks. The carcass weight ($P < 0.002$) and the weight of the non-carcass components ($P < 0.001$) were also negatively affected by the advance of lactation. The carcass fat mass decreased ($P < 0.003$) from 5.6 to 2.1 kg from calving to the eighth week, and the fat mass of

the non-carcass components reduced (P <0.002) from 8.49 to 2.8 kg. There was a mobilization of carcass protein (P <0.001), from 4.36 to 2.89 kg. The protein of the non-carcass components was also found to reduce (P <0.0001) from 3.69 to 2.35 kg over the eight weeks of lactation. The following equations were used to determine the use efficiencies of the energy from the mobilized fat and the dietary fat: MEI, Mcal = $\beta_0 + \beta_1 \times M_E + \beta_2 \times {}_{mob}E$ (eq. 1), in which MEI is the metabolizable energy intake, M_E is the milk energy and ${}_{mob}E$ is the mobilized body energy; and MEI, Mcal = $\beta_0 + \beta_1 \times BW^{0.75} + \beta_2 \times M_E + \beta_3 \times {}_{mob}E$ (eq. 2), in which $BW^{0.75}$ is the metabolic body weight. The use efficiency of the mobilized fat (K_{mob}) was found as the result of the β_1/β_2 ratio from equation 1. The requirements of metabolizable energy for maintenance and lactation, respectively, are represented by β_1 and β_2 from equation 2; the use efficiency for lactation (K_L) is the reciprocal of $1/\beta_2$. The use efficiency for maintenance (k_m) was determined by the equation $k_m = 0.35 \times q_m + 0.503$, in which q_m is the mobility of the feedstuffs for maintenance. The use efficiency of the mobilized fat was 0.74, 0.93 for lactation, and 0.74 for maintenance. The metabolizable energy required for maintenance was 0.190 Mcal/$BW^{0.75}$, divided into basal metabolism, 0.0946 Mcal/$BW^{0.75}$, and energy required for lactation, 0.0954 Mcal/ $BW^{0.75}$. Another study was carried out evaluating the predictions of the Small Ruminant Nutrition System (SRNS) on the digestibility of dietary nutrients and the energy requirements of goats in early lactation. The software was evaluated based on the values observed in this study and those estimated by the SRNS. Six animals were used in the evaluation of the digestibility coefficients, TDN, MEI and NEI. Fifty-one goats were used to evaluate DMI, MEI, ME_m, ME_L, ME balance, variation in BCS and variation in body weight. The following variables were adopted as input for the program: body mass, age, dry matter intake, daily nutrient intake, milk yield, milk fat and protein contents, and body condition score (BCS). The following AFRC (1998) equation was used to determine dry matter intake: DMI, kg/d = $0.42 \times MY3.5\% + 0.024 \times BW^{0.75} + 0.4 \times \Delta BW + 0.7 \times$ Proportion of forage in the diet, in which ΔBW is the variation in body weight, because the equation present in the software was developed for sheep. Several statistical techniques were used to evaluate the models, e.g. the coefficient of determination, confidence intervals of the parameters, concordance correlation coefficient, mean squared prediction error, among others. The Small Ruminant Nutritional System (SRNS) has good accuracy to predict the apparent digestibility coefficients of dry matter, organic matter, TDN, MEI and NEI; it does not provide, however, good predictions for the apparent digestibility coefficients of crude protein, and the fiber digestibility coefficient. For the apparent digestibility coefficients of crude protein and fat, the SRNS underestimated the values due to the endogenous components. The inverse was true for the fiber digestibility coefficient, however: the SRNS overestimated the

values because of the difference between the degradation rates of the fibers from temperate- and tropical-climate grasses. The equation of the AFRC (1998) did not provide a good estimate for the intake of goats in early lactation. The values of MEI, ME balance and ME_m were underestimated by the SRNS. Nevertheless, the SRNS accurately estimated the ME_L values, variation in BCS and variation in body mass. Goats in the eight postpartum weeks mobilized not only fat but also body protein. The goats mobilized 6.48 MJ/d energy, on average. The use efficiency of the mobilized energy is 74% and the use efficiency of the dietary energy is 93%. The Small Ruminant Nutritional System has low accuracy in predicting the body reserves of goats in early lactation.

INTRODUÇÃO GERAL

A caprinocultura constitui um importante setor do agronegócio mundial, contribuindo para o fornecimento de couro, fibra, carne, leite e derivados (RESENDE et al., 2005) além de conceder benefícios sociais e econômicos para diversas regiões em desenvolvimento. Por estes motivos, é uma das alternativas mais indicadas para a geração de emprego e renda no campo, especialmente nos programas de fortalecimento da agricultura familiar.

Porém para que sejamos competitivos torna-se necessário estudar e pesquisar as diversas áreas, objetivando produções mais eficientes, conseqüentemente maiores produtividade e economicidade. Entre as diversas áreas, sem dúvida, a nutrição merece destaque.

A eficiência na produção animal somente pode ser obtida se houver conhecimento adequado das exigências nutricionais dos animais e da composição dos alimentos, evidentemente associado a outras práticas de manejo (COELHO DA SILVA, 1995). Durante um longo tempo às exigências para caprinos foram baseadas nos valores estimados para bovinos e ovinos, que apesar da similaridade do trato digestório dessas espécies, há diferenças significativas entre elas, tais como: hábito alimentar, atividades físicas, requerimento de água, seletividade alimentar, composição do leite e corporal, desordens metabólicas e parasitas. Estas diferenças justificam o estudo isolado da espécie (NRC, 2007).

Caprinos acumulam suas reservas de energia em tecido adiposo em torno das vísceras, o que os difere sobremaneira dos grandes ruminantes, fato este de importância a ser considerado nos estudos de transferência de energia nos processos metabólicos.

Além disso, as determinações das exigências nutricionais devem considerar as condições climáticas, os animais (raças e cruzamentos) e os alimentos disponíveis no Brasil.

O fornecimento de alimentos para animais depende da simultaneidade em suprir as exigências nutricionais para determinada produção conjuntamente com a otimização do lucro obtido em função desta produção. Isto requer informações específicas sobre a exigência nutricional para cada função produtiva e sobre a ingestão dos alimentos e a contribuição de cada um para atingir esta exigência. Neste contexto, alguns comitês, de diversos países, agregaram informações e compilaram dados sobre as exigências nutricionais de caprinos, para serem utilizados por produtores e pesquisadores.

REVISÃO DE LITERATURA

Mobilizaçao de Reservas Corporais

Durante o início da lactação, cabras, vacas, ovelhas e outras fêmeas entram em balanço negativo de energia o qual é ocasionado pela produção de leite associada a um limitado consumo de alimento. Esse balanço negativo entre a energia para produção de leite e energia consumida na forma de alimento é compensada pela mobilização de reservas de tecido corporal (protéico e adiposo), principalmente o tecido adiposo. O resultado final é a perda de peso e redução da condição corporal desses animais.

KOMARAGIRI & ERDMAN (1995) observaram que cerca de 92% da energia mobilizada de reservas corporais durante o início da lactação é originado do tecido adiposo e o restante de massa muscular (proteína) em vacas. Utilizando 11 estudos diferentes com 208 vacas, os mesmos autores verificaram que no período entre 2 semanas antes do parto e 5 a 12 semanas após o parto, a mobilização de gordura corporal foi de 47,4 kg e a de proteína foi de 11 kg por vaca.

De acordo com o NRC (1989) e KOMARAGIRI & ERDMAN (1995), cada kg de tecido mobilizado durante o período de transição é equivalente a cerca de 6 Mcal. de energia líquida para lactação. Portanto, cada kg de peso vivo mobilizado seria capaz de fornecer energia para a produção de 8 kg de leite. Baseado nos dados de SANTOS (1996), cada unidade de condição corporal equivale a aproximadamente 50 a 60 kg de massa corporal em vacas holandesas de grande porte, o que forneceria energia necessária para a produção de 400 a 480 kg de leite. No entanto, quando a produção é mantida através de profunda mobilização de reservas corporais, a incidência de distúrbios metabólicos como fígado gorduroso e cetose pode ser dramaticamente aumentada (GRUMMER, 1995).

A intensidade com que a energia é mobilizada na fase inicial da lactação depende do grau de adiposidade no momento do parto, o potencial genético do animal em produzir leite e o consumo de matéria seca durante a fase final da gestação e no início da lactação. A mobilização da energia corporal para a produção de leite depende de alguns fatores como: composição corporal da fêmea, ingestão de matéria seca e a eficiência energética de utilização de gordura corporal (MOE et al., 1971).

Cabras leiteiras apresentam constantes alterações na composição corporal principalmente no início da lactação e no período seco, refletindo, primariamente, a mobilização ou reposição de tecidos corporais quando as dietas contêm energia insuficiente ou em excesso para o atendimento das exigências nutricionais (KOMARAGIRI et al., 1998).

MOE et al. (1971) relataram que a intensa seleção para produção de leite resultou em uma situação em que a capacidade genética para produção de leite, no pico da lactação excede a capacidade de ingestão de alimentos suficientes para satisfazer as necessidades de energia. Isto porque a lactação é prioridade para a fêmea, apesar da ingestão insuficiente de energia alimentar. Assim, a cabra utiliza suas reversas corporais para suprir a energia que falta na dieta.

Embora a mobilização de reservas corporais contribua com quantidades significativas de energia para a produção de leite, uma mobilização excessiva pode causar problemas de saúde e piorar o desempenho dos animais (KOMARAGIRI et al., 1998).

A glândula mamária funcional é um dos tecidos mais metabolicamente ativos do corpo animal (BAUMAN & CURRIE, 1980). O período de lactação, em que os animais têm habilidade para coordenar a partição dos nutrientes, assume um papel crítico durante o início da secreção do leite. A iniciação à lactação promove profundas alterações na partição geral dos nutrientes e no metabolismo do corpo animal para atender a demanda da glândula mamária.

As principais alterações metabólicas envolvendo mobilização de reservas corporais em animais de alta produção no início de lactação para a síntese do leite são: mobilização de lipídios (lipólise), grande aumento da taxa de gliconeogênese (podendo ocorrer mobilização de glicogênio e aminoácidos) (BAUMAN & CURRIE, 1980; OLDHAM, 1984) e a mobilização de nitrogênio (proteólise) a partir da proteína corporal, necessária para a síntese de aminoácidos para suportar o aumento da gliconeogênese durante o início da lactação (BELL, 1995).

A mobilização de lipídios do tecido adiposo (lipólise) para ser utilizado onde o corpo necessita requer a hidrólise dos triacilgliceróis em ácidos graxos livres e glicerol.

Nos monogástricos o processo se inicia através da divisão do triacilglicerol para diacilglicerol, catabolizado pela ação da enzima lipase sensível a hormônio. O diacilglicerol é então hidrolisado pela ação de uma lipase, normalmente resultando em uma hidrólise completa do triacilglicerol para ácidos graxos livres livres (AGL) e glicerol. Em ruminantes provavelmente a lipólise ocorra de maneira similar (CHILLIARD, 1993). Entretanto, aproximadamente 50% dos ácidos graxos presentes no leite são oriundos a partir da dieta ou dos triglicerídeos do sangue. Os ácidos graxos usados pela glândula mamária, durante a síntese do leite, também podem ter sido provenientes dos ácidos graxos não esterificados (AGNE) do sangue, liberados durante a mobilização do tecido adiposo (OVERTON, 2000).

BELL (1995) sugeriu que acima de 40% dos ácidos do leite, durante a primeira semana de lactação, possa vir do AGNE do sangue.

Hormônios como as catecolaminas, epinefrina ou norepinefrina em ruminantes resulta em um aumento quase instantâneo na concentração de ácidos graxos livres (AGL) no plasma. A resposta para as catecolaminas é influenciada pelo estado do animal (gestação, lactação, jejum) e provavelmente modificada pela concomitante hipercalcemia. Há também um correspondente aumento dos níveis de glicerol no plasma após a administração de catecolamina, provavelmente devido ao aumento no fluxo de glicerol para o fígado. As catecolaminas estimulam a lipólise em ruminantes pela ativação da adenilato ciclase (VERNON, 1981).

No entanto, a insulina é o principal hormônio antilipolítico em ruminantes e monogátricos, pois afeta os níveis de AMP cíclico no tecido adiposo. A secreção de insulina nos ruminantes é estimulada pela alimentação e absorção dos produtos da digestão. Sua ação primária é promover o transporte de glicose, aumentando a disposição da glicose extracelular através da ativação da glicogeniosintetase e inibição da glicogenólise, junto com a ativação da glicólise e lipólise, ou usando a glicose como um combustível oxidativo (VERON, 1981).

Um outro hormônio relacionado com a mobilização das reservas corporais é o hormônio do crescimento (GH) que está correlacionado positivamente com os níveis plamáticos dos ácidos graxos livres sob várias condições (BAUMAN & CURRIE, 1980).

Geralmente, se considera que os efeitos do GH são mediados pelas somatomedinas e em particular, o fator de crescimento semelhante à insulina (IGF-I) (McDOWELL & ANNISON, 1989), o qual decresce, significativamente nas últimas 3 semanas pré-parto (MOORBY et al., 2000).

O GH possui diversos efeitos biológicos em numerosos tecidos que estão altamente envolvidos em mudanças na utilização de nutrientes para suportar incrementos na síntese de leite na lactação. Este hormônio apresenta grande influência sobre o tecido adiposo e o metabolismo lipídico, alterando as respostas frente à insulina e atividades de enzimas chave no tecido adiposo (ETHERTON & BAUMAN, 1998).

A glicose é requerida pela glândula mamária para sintetizar a lactose, que é o controlador osmótico primário do volume de leite. Consequentemente, animais leiteiros estão sujeitas a um grande aumento na demanda de glicose durante o início da lactação. O aumento na ingestão de matéria seca e o potencial da dieta em suprir a demanda de glicose após o parto são inferiores ao aumento da exigência de glicose, embora ocorra uma grande coordenação do metabolismo no sentido de direcionar para a glândula mamária para suportar a síntese do leite.

Algumas destas coordenações envolvem mudanças na utilização da glicose não-mamária, mas o fígado, maior produtor de glicose, também adapta seu metabolismo para suportar o aumento na demanda de glicose (OVERTON, 2000).

A regulação da gliconeogênese em ruminante não é bem entendida como em não ruminantes. Os ruminantes são melhor equipados para superar deficiências de precursores gliconeogênicos do que o excesso dos mesmos, principalmente do propionato. A gliconeogênese é controlada pelos hormônios insulina, glucagon, epinefrina e glicocrticóides (VAN SOEST, 1994).

A mobilização de proteína corporal para a produção de leite é possível em animais no início da lactação, quando a ingestão de alimento é insuficiente para satisfazer as necessidades de energia das mesmas (NRC, 1989). O significado desta mobilização é prover uma fonte de animoácidos prontamente disponível durante no período em que ocorre a privação de proteína. BOTTS et al. (1979) sugeriram que a absorção de proteína do músculo para suprir a exigência de aminoácidos para a produção de proteína do leite é um mecanismo normal de adaptação metabólica. Parte das reservas de proteína podem ser utilizadas também para a síntese de lactose, uma vez que os amimoácidos constituem aproximadamente 12% da lactose do leite.

O tecido mais importante como fonte de aminoácidos a ser mobilizado é o músculo esquelético. A proteína mobilizada deste tecido pode levar a uma redução de até 25% do diâmetro da fibra muscular em vacas leiteiras imediatamente após o parto (BELL, 1995).

BELL (1995) postulou que o músculo esquelético serve como um "*pool*" de aminoácidos que serão utilizados para suportar o aumento da gliconeogênese durante o início da lactação. Em suporte a esta hipótese, OVERTON (2000) usaram a alanina como um indicador da gliconeogênese a partir dos aminoácidos e relataram que a conversão do propionato a glicose, entre o 1º e 21º dia pós-parto, foi de 119 a 129% do que foi até 21 dias pré-parto, mas a conversão da alanina a glicose, no mesmo período, foi de 198 a 150%. Confirmando esses dados, GREENFIELD et al. (2000) determinaram que a enzima piruvato carboxilase, enzima chave na conversão da alanina a glicose, foi aumentada logo após o parto. Ao contrário, o metabolismo do propionato teve pouca influência sobre o metabolismo da alanina OVERTON (2000).

A mobilização periferal de aminoácidos parece ser acompanhada por um aumento da atividade sintética e uso mais eficiente dos aminoácidos no fígado. A síntese hepática de proteína aumenta muito, em vacas leiteiras, logo após o parto. Isto deve ser um prelúdio necessário ao crescimento hipertrófico do fígado durante o início da lactação (BELL, 1995).

Modelos Nutricionais para avaliação da dieta de ruminantes

Com o mercado cada vez exigente pela busca de alimentos de qualidade e com menor impacto ambiental, é fundamental que produtores possam produzir de forma mais eficiente e sustentável. A fim de alcançar este objetivo, a modelagem é uma técnica para ampliar e aplicar uma abordagem sistemática para um objeto complexo ou problema (ROUNTREE, 1977). A construção de um modelo envolve intuição, imaginação e habilidade com base na extensão e aplicação dos princípios biológicos (SAHIN et al., 1991). Os modelos matemáticos estão sendo empregados na nutrição e produção de animal a mais de 30 anos (CHALUPA & BOSTON, 2003). Para TEDESCHI et al. (2005) os modelos matemáticos na nutrição de ruminantes são ferramentas valiosas para estimar as exigências do animal em condições específicas dentro de um sistema de produção, desempenhando importante papel ao fornecer informações que podem ser usadas no processo de tomada de decisões para melhorar a eficiência produtiva.

Devido limitações do sistema de formulação de ração o National Research Council (NRC), um grupo de pesquisadores da Cornell University - USA criaram o *Cornell Net Carbohydrate and Protein System* (CNCPS) um programa desenvolvido a partir dos princípios básicos de função ruminal, crescimento microbiano, fisiologia animal, digestão e fluxo dos alimentos. Esse sistema inclui ainda características de manejo, condições climáticas e a caracterização dos alimentos e dos animais (Fox et al., 2004).

Além do CNCPS, RESENDE et al. (2008) listaram os principais sistemas de alimentação utilizados no país para pequenos ruminantes, entre eles estão: o britânico AFRC (1993, 1998), o americano NRC (2007), o francês INRA (1989) e o australiano CSIRO (1990). Porém os sitemas acima são considerados empíricos e pouco flexíveis em relação aos atuais modelos utilizados para os pequenos ruminantes.

Com a necessidade de se desenvolver um novo sistema de formalação de rações para pequenos ruminantes que superasse as limitações dos outros sistemas (Cannas et al., 2004), desenvolveram um novo modelo específico para ovinos apartir do modelo do CNCPS-C, isso por que as equações deste foram considerado inadequado para modelo de pequenos ruminantes. Assim, novas equações foram desenvolvidas conforme a necessidade de adaptar-se o CNCPS-SHEEP.

Utilizando como base o CNCPS-S pesquisadores da Texas A&M University, da Cornell University e da Università degli Studi di Sassari na Itália desenvolveram o *Small Ruminant Nutritional System* (SRNS), este modelo prediz as exigências nutricionais e o valor

biológico dos alimentos, sendo que neste houve o acréscimo de equações que possibilitem formulações de rações para caprinos e ovinos em diversar condições práticas. TEDESCHI et al. (2010) descrevem o SRNS como o sistema de formulação de rações mais avançado para pequenos ruminantes, apesar das limitações de todo modelo.

Exigências nutricionais de cabras em lactação

O fornecimento de alimentos para animais depende do sincronismo entre suprir as exigências nutricionais para determinada produção conjuntamente com a otimização do lucro obtido em função desta produção. Isto requer informações específicas sobre a exigência nutricional para cada função produtiva e sobre a ingestão dos alimentos e a contribuição de cada um para atingir esta exigência.

No Brasil são poucos os dados referentes às exigências nutricionais de caprinos e quase escasso na fase de lactação. Para formulação adequada de rações tem-se utilizado resultados obtidos com caprinos de raças européias, geralmente criados em regiões de clima e de temperaturas diferentes (ALVES et al., 2008). Estudos tem demonstrado que em regiões temperadas, os caprinos apresentam menores exigências de manutenção e melhor eficiência digestiva e metabólica na utilização da energia da dieta, que animais criados e adaptados aos ambientes tropicais (MEDEIROS, 2001).

Segundo GARRET et al. (1959) dentre as possíveis fontes de alteração nas exigências nutricionais dos animais pode-se destacar a idade, peso, espécie, raça, classe sexual, atividade muscular, estágio fisiológica, nível de ingestão alimentar e o clima. Algumas características morfológicas respondem por grande variação nas exigências nutricionais como, por exemplo, a atividade e tamanho visceral. Fisiologicamente, também observam-se diferenças na atividade metabólica dos tecidos que compõem o corpo do animal. Embora o fígado e o tratogastrintestinal (TGI) representem apenas 8 a 14% do peso do animal, a energia consumida por esses tecidos representa cerca de 40 a 50 % da exigência para mantença (SEAL & REYNOLDS, 1993), isso porque possuem alta atividade metabólica em função da alta taxa de *turnover* protéico e transporte iônico ativo. O balanço síntese/degradação mobiliza grande aporte energético principalmente em órgãos que, sabidamente, apresentam alta taxa de reciclagem protéica. Nestes órgãos, o fluxo sanguíneo e o consumo de oxigênio são indicadores da acentuada atividade metabólica. Isto estaria relacionado com o consumo de matéria seca visto que a atividade digestiva (absorção e metabolismo), a manutenção da estrutura do epitélio intestinal, a manutenção das atividades do sistema imune e as atividades

celulares como metabolismo e síntese de novos compostos, são maiores em situações de maiores consumos.

A demanda dos diferentes órgãos é quem define a partição de utilização dos nutrientes sejam para síntese ou para catabolismo (REYNOLDS, 2002). Sendo assim, tecidos com alta taxa metabólica têm prioridade no suprimento. Para cabras em lactação, o úbere (glândulas mamárias) seria um destes tecidos com prioridade de alocação de nutrientes. O suprimento de nutrientes para esses tecidos seria determinado pelo fluxo sanguíneo e pela concentração de nutrientes, e a utilização de aminoácidos estaria relacionada à capacidade de síntese de proteína no tecido mamário (METCALF et al., 1996).

O conhecimento de como o animal utiliza a energia metabolizável (EM) para suas diferentes funções metabólicas é de extrema importância, pois a eficiência varia de acordo com o tipo de exigência (mantença, gestação, lactação, etc), com a concentração de EM na dieta, também varia com relação à metodologia de determinação e entre os sistemas de avaliação de alimentos e exigências nutricionais. A partir do conhecimento das exigências líquidas e levando-se em consideração os fatores de eficiência de utilização da energia metabolizável (EUEM) do alimento para mantença (k_m) e lactação (k_l), são obtidas as exigências dietéticas.

As EUEM da dieta não estão muito bem estabelecidas para ruminantes (SILVA et al., 2002). Isto é claramente observado quando se comparam as metodologias de estimativas de eficiências de utilização da EM entre os principais sistemas utilizados hoje no mundo. O AFRC (1993, 1998) e o INRA (1978) estimam as eficiências de mantença a partir de equações que fazem uso da metabolizabilidade (qm) das dietas como variável independente, sendo esta qm a relação entre a energia metabolizável e a energia bruta das dietas.

Normalmente há um aumento na eficiência de utilização de energia quando se aumenta a concentração de EM na dieta, devido principalmente à redução na produção de metano, diminuição da ruminação e do incremento calórico (VAN SOEST, 1994). Este efeito foi demonstrado por LANA et al. (1998) que avaliaram o efeito de níveis de concentrado em dietas para bovinos, observaram diminuição na metanogênese e na desaminação de aminoácidos, o que ocasionaria maior disponibilidade de energia para o animal e aumentaria a eficiência de uso da mesma.

Portanto, os dados encontrados na literatura sobre exigência de caprinos são escassos e alguns contraditórios. Além disso, pouca ênfase foi dada para estimar exigências de cabras em lactação ficando evidente a maior preocupação pela fase de crescimento.

Neste contexto, há necessidade de se concentrar esforços em pesquisas com animais em diferentes momentos da lactação para elaborar com segurança uma tabela de exigências nutricionais de caprinos e o desenvolvimento de modelos com base mecanicista que possam ser utilizados em sistemas de decisão para calculo de dietas.

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

- Determinar a magnitude da mobilização das reservas corporais durante o início da lactação;
- Determinar a eficiência de utilização da energia corporal mobilizada para a produção de leite;
- Determinar as exigências energéticas de cabras para mantença e lactação;
- Avaliar acurácia das predições do *Small Ruminant Nutrition System* (SRNS) na digestibilidade da dieta e nas exigências energéticas de cabras no início da lactação.

Essa tese foi redigida no formato de artigo cientifícos. Os artigos 1 e 2 foram redigidos de acordo com as normas do Journal of Dairy Science e o artigo 3 de acordo com as normas da Revista Brasileira de Zootecnia.

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Mobilization of body reserves and body composition of Alpine goats in early lactation

T. S. Oliveira, * R. A. M. Vieira,† A. Cannas,‡ M. C. Lima, * J. G. L. Regadas-Filho, *and M. T. Rodrigues*

*Departamento de Zootecnia, Univerdidade Federal de Viçosa, Avenida Peter Henry Rolfs, 36570-900 Viçosa, MG, Brazil

†Laboratório de Zootecnia, Universidade Estadual do Norte Fluminense, Avenida Alberto Lamego, 28013-602 Campos dos Goytacazes, RJ, Brazil

‡ Dipartimento di Scienze Zootecniche, Università degli Studi di Sassari, Via E. De Nicola 9, 07100 Sassari, SS, Italy

ABSTRACT

The objective of this study was to trace the trajectory of the variables body energy and protein in Alpine goats during the first eight weeks of lactation using the comparative-slaughter technique. Fifty-one multiparous Alpine goats were used to determine body composition of animals. After parturition, three goats (control group) were slaughtered to estimate the initial body composition of the animals that remained in the experiment. Forty-eight goats were assigned to a completely randomized design in which the treatments were the eight subsequent weeks of lactation (7th, 14th, 21st, 28th, 35th, 42nd, 49th, and 56th days). Six goats were slaughtered per week. All animals received a single experimental diet. There was a decrease in body weight (67.0 to 46.5 kg) and empty body weight (56.8 to 35.6 kg) during the eight weeks of lactation. The masses of omental and visceral fat reduced linearly (3.8 to 1.1 kg and 4.3 to 1.4 kg, respectively) over the eight weeks of lactation. However, fat (13.65 to 4.9 kg), protein (8.9 to 5.2 kg) and total energy in the empty body (726.47 to 316.20 MJ) decreased linearly with the advance of the lactation weeks. The amount of water in the empty body decreased curvilinearly (32.90 to 23.88 kg). There was a linear reduction in fat mass in the carcass (5.6 to 2.1 kg) and non-carcass components (8.49 to 2.8 kg) as the lactation period advanced. The protein mass reduced linearly in the carcass (4.36 to 2.89 kg) and non-carcass components (3.69 to 2.35 kg) over the eight weeks of lactation. Ash and energy showed the same trend as fat and protein in the carcass and non-carcass components. Water also reduced curvilinearly in the carcass (16.3 to 11.9 kg) and in the non-carcass components (16.56 to 11.98 kg). There was a much greater mobilization of energy in non-carcass (420.75 to 165.60 MJ) than carcass (305.71 to 150.60 MJ) components in the 8 weeks of lactation. In conclusion, Alpine goats in early lactation mobilize energy not only from reserves of internal fat, but also from the carcass and non-carcass components. The body

energy of Alpine goats is mobilized with greater intensity in the first eight weeks of lactation, due to the greater protein mobilized: 2.22 kg, on average 0.050 kg/d of empty body weight. Body energy decreases linearly, and the total amount of energy mobilized during the first eight weeks of lactation is very large: 410.27 MJ; with an average of 6.84 MJ/d.
Key words: Dairy goats, energy variation, lactation

INTRODUCTION

Goat, sheep and cattle herds of high milk production require an appropriate nutritional balance, especially in early lactation. Eknas et al. (2006) report that there is a trend for goats to reach the peak of milk production 60 days postpartum though their dry matter intake is depressed, resulting in a mobilization of their body reserves to supply the high metabolic requirements.

Sutton and Mowlem (1991) reported that the goat lactation cycle is similar to that of dairy cows, with production peak occurring between 6 and 8 weeks of lactation and a slow reduction of production until 9 or 10 months of lactation. Morand-Fehr et al. (1999) suggested that goats drop around 1 kg of body weight per week in the first month postpartum and 0.5 kg/wk in the subsequent month. Sutton and Mowlem (1991) showed that the live weight of goats has a steady decline of 1 kg/wk in the 4 weeks postpartum, similar to dairy cows.

However, according to the AFRC (1993), the mobilization of energy and protein for goats in the first 40 days of lactation has not been well defined. The AFRC (1993) considers a fixed loss of 4.6 MJ of ME/d and 30 g of MP/d in the first month of lactation, based on reduction of body mass of 1 kg/wk as proposed by INRA (1989).

The use of a constant value to represent the loss of energy due to mobilization of fat and protein as considered by INRA (1989), Sutton and Mowlem (1991), AFRC (1993) and Morand-Fehr et al. (1999) does not reflect in a reliable dynamic mobilization. It should be considered that most data used for that inference were based on short-term calorimetric studies. Hence a better approach would be the slaughtering technique, which allows for long-term studies in addition to the partition of energy losses between fat and protein. Thus, it is essential to know the daily intensities with which this energy is transferred from the animal body for the synthesis of milk as well as whether the phase of negative energy and protein balance influences the mass of internal fat and energy released from some specific organs such as the liver and gastrointestinal tract, which are metabolically active during this phase, together with the mammary gland.

The objective of this study was to trace the trajectory of the variables body energy and protein of Alpine goats during the first eight weeks of lactation through the comparative-slaughter technique.

MATERIAL AND METHODS

Animals and Management

The experiment was conducted at the experimental station of the Federal University of Viçosa, located in the municipality of Viçosa, Minas Gerais State, Brazil, (20°46'19"S and 42°51'12"W; mean altitude 707 m). According to the Köppen classification, the climate type is Cwa (tropical, high altitude), with rainy summers and dry winters. The annual average temperature is 18.5 ºC, ranging from 8.2 °C to 28.5 ºC. The annual average precipitation rate in this region is 1,203 mm, with an average relative air humidity of 80%.

Fifty-one multiparous Alpine goats were allocated in individual metabolic pens provided with troughs for supply of feed and water *ad libitum*. The goats were selected so as to provide homogeneity among the experimental units at parturition. Selection required an initial group of 250 goats that were inseminated simultaneously, which allowed for all suggested variables to be contemplated.

After parturition, three goats (control group) were slaughtered to estimate the initial body composition of animals that remained in the experiment. Forty-eight goats were assigned to a completely randomized design where the treatments were the subsequent eight weeks of lactation. Six goats were slaughtered per week. All animals received only one experimental diet (Tables 1 and 2), different from that of gestation, and formulated according to recommendations of NRC (2007).

The diet was fed twice daily (07.00 h and 16.00 h), always after the animals were milked. The volume supplied was adjusted daily to allow for approximately 20% of orts. Before the morning feeding, the orts corresponding each experimental unit were weighed, sampled and stored in a freezer (–10 ºC). Samples of corn silage and concentrate fed to each animal were collected on a weekly basis. At end of the experimental period composite samples were formed per animal to determine the chemical composition of the diet. The animals were individually weighed weekly.

Estimation of Diet Digestibility

A digestibility trial was conducted starting on the 23rd experimental day using six lactating goats. The trial was set in a completely randomized design with six replicates and one experimental diet. Goats were housed in metabolic cages that allowed the separation of feces and urine. After an adaptation period of 21 days total fecal collection was performed during five consecutive days, with feces being collected every 2 hours. Fecal samples were stored in a freezer at –20 ºC and then dried at 55 °C in a forced-ventilation oven for 72 h prior to grinding through a 1-mm screen Wiley mill for chemical analysis.

All samples were analyzed for moisture, nitrogen, EE, ash, calcium, and phosphorus according to the procedures of the Association of the Official Analytical Chemists (1990). Neutral detergent fiber and ash-free neutral detergent fiber (aNDFom) were determined with sodium sulfite and heat-stable alpha amylase and expressed including residual ash and lignin, and analyzed according to Van Soest et al. (1991). Non-fibrous carbohydrates (NFC) were calculated as 100 – (% CP + % EE + % NDF + % Ash) (Hall, 2003).

Apparent total digestible nutrients (TDN) were calculated as follows:

TDN = CP intake – fecal CP + NDF intake – fecal NDF + NFC intake – fecal NFC + 2.25 × (EE intake – fecal EE).

The digestible energy (DE) and metabolizable energy (ME) values, expressed as Mcal/kg of DM, were estimated using the equations suggested by NRC (2001):

DE = (dNFC/100) × 4.2 + (dDNF/100) × 4.2 + (dCP/100) × 5.6 + (dEE/100)× 9.4-0.3; and

ME = 1.01 × DE (Mcal/kg) – 0.45.

TDN_{3x} was converted to NE using the equation of NRC (2001):

NE = 0.0245 × TDN (%) – 0.12

Milk Yield and Composition

The goats were milked twice daily (06.30 h and 15.30 h). Milk was sampled weekly from each animal and then preserved with 2-bromo-2-nitropropane-1,3-diol until it was analyzed for fat, protein and lactose content on an infrared analyzer (Minor Milko ScanTM;

255A/B-Foss Electric, Hillerød, Denmark) in accordance with the International Dairy Federation (1996).

The net energy required for lactation was calculated using the equation:

$$NE_L, \text{ Mcal/d} = (289.72 + 71.93 \times PQ + 48.28 \times (PP/0.92)) \times Yn,$$

where: Yn is the true milk yield on a particular day of lactation (kg/d); PQ is the measured milk fat for a particular day of lactation (%); PP is the measured milk true protein for a particular day of lactation (%); and 0.92 was used to convert milk true protein to CP for goats (Pulina et al., 1992). The factor 4.184 was used to transform calories into joules.

Slaughter

This study was approved by the Ethics Committee on Animal Use of the Department of Animal Science of the Federal University of Viçosa, protocol no. 61/2013.

A group of three goats were slaughtered right after parturition (control group) to estimate the mass of fat and protein and to determine the initial body energy of the animals that remained in the experiment. The other slaughters were carried out every seven days (six goats per week) during the eight weeks of lactation (from the 7th to the 56th days of lactation) to measure the mass of internal fat and to determine the body energy by chemical analysis of body tissues.

After slaughter the goats were bled by sectioning the jugular and carotid arteries. All the blood was collected and weighed. Subsequently, they were skinned, and their carcass was separated into hot carcass and internal organs and viscera (liver with gallbladder, kidneys, heart, pancreas, spleen, tongue, lungs, diaphragm, esophagus, trachea, bladder, and uterus; the bladder and the gallbladder were weighed full and empty). Then the mammary gland was removed, weighed, and dissected. The internal fat was divided into omental and visceral fat (mesenteric, perirenal, and pericardial fat). The organs of the gastrointestinal tract (rumen-reticulum, omasum, abomasum, small intestine, and large intestines) were weighed empty and full). Head, legs, and skin were weighed and conditioned in labeled plastic bags and frozen at –15 °C.

The empty body weight (EBW) was determined as the difference between body weight at slaughter and content of the gastrointestinal tract.

Individual parts of the body, namely carcass, head, limbs, viscera, organs, blood, and mammary gland were ground separately in a cutting mill (30 HP, 1775 rpm), whereas skins were ground using a ball mill for further chemical analyses.

The samples were composed of four parts: a) viscera, organs, blood, and internal fat; b) carcass; c) head and legs; and d) mammary gland. One-hundred grams of samples were lyophilized for 48 to 72 hours to determine the fat dry matter (FDM).

Subsequently, the samples were successively washed with petroleum ether. The resulting material was the solids non-fat (SNF). Then the samples were ground in a ball mill for subsequent determinations of dry matter, total nitrogen, and ether extract, according to AOAC (1990). The fat removed during pre-defatting was calculated as the difference between FDM and SNF, whose result was added to those obtained for the residual ether extract in the SNF to determine the total fat content.

Variation in Body Energy

The variation in energy retained in or lost from the body was estimated by multiple regressions based on observed empty body weight (EBW) at the time the goat was slaughtered and the estimated body weight of the same animal one week before the slaughter (**EBW WK–1**) as expressed in (Equation 1). The body energy (**BE**) was estimated by a linear regression between EBW and body energy at slaughter (Equation 2); the energy variation during the seven days was estimated accordingly.

EBW (WK–1), kg = 6.86 (2.91) + 0.72 (0.04) × BW – 0.76 (0.16) × WK, $r^2 = 0.90$; $P < 0.0001$; root mean square error, RMSE = 2.58; n = 51) (**eq.1**)

Whole body energy content was calculated based on the body protein and fat contents, using the caloric values of 5.64 and 9.40 kcal/g of protein and fat, respectively (ARC, 1980). The factor 4.184 was used to transform calories into joules.

BE (WK–1), MJ = –363.41 (37.21) + 19.68 (0.88) × EBW, $r^2 = 0.91$; $P < 0.0001$; RMSE = 49.63; n = 51) (**eq.2**)

Energy Balance (EB)

Net energy intake was determined by multiplying the daily DMI by the calculated energy value of the diet based on NRC (2001) values, as previously reported. The requirements of energy for maintenance (NE_M) were calculated as: NE_M = 0.315 MJ/kg $BW^{0.75}$ (AFRC, 1998). The energy required for milk production was calculated using the equation:

$$NE_L, \text{Mcal/d} = (289.72 + 71.93 \times PQ + 48.28 \times (PP/0.92)) \times Yn,$$

where Yn is actual milk yield on a particular day of lactation, kg/d; PQ is measured milk fat for a particular day of lactation (%); PP is the measured milk true protein for a particular day of lactation (%); and 0.92 was used to convert milk true protein to CP for goats (Pulina et al., 1992). The estimated EB was calculated on a weekly basis using the equation EB = NEI – (NE_M + NE_L). The factor 4.184 was used to transform calories into joules.

Statistical Analyses

The variables were analyzed according to the following statistical model:

$$y_{ij} = \mu + \tau_i + e_{ij},$$

where y_{ij} represents the measured value on the j-th animal in the i-th week of lactation; μ is the overall mean; τi corresponds to the i-th week of lactation; and eij is the random error. Six goats (j = 1, 2, ..., 6) were slaughtered in each lactation week. Therefore, no measure was taken repeatedly in experimental units. On the other hand, the experimental units were completely independent for each week of lactation (i = 1, 2, ..., 8). The statistical model was adjusted to the data using the PROC REG procedure of SAS software (version 9, SAS Institute Inc., Cary, NC, USA), considering the *P*-values for linear and quadratic effects. The data with a Student's residue outside the ranges of (- 2, 2) were considered outliers according to criteria described by Draper and Smith (1996).

RESULTS

Dry Matter Intake, Milk Yield and Composition, Body Weight, BCS and Energy Balance

Dry matter intake increased significantly ($P < 0.001$) and curvilinearly over the 60 days postpartum. There was a greater increase during the first 30 days of lactation and soon after this period the intake showed a trend toward stabilization (Figure 1A).

Milk yield also increased ($P < 0.006$) curvilinearly as the lactation advanced (Figure 1A). Body weight had a marked decline ($P < 0.008$) in the first four weeks of lactation, and then it leveled off (Figure 1B). Body condition score decreased linearly ($P < 0.001$; Figure 1C) and milk fat content also showed a linear decrease ($P < 0.006$; Figure 1D) as the lactation progressed. Milk protein and milk energy also decreased ($P < 0.006$), but with more markedly during the first 21 days, stabilizing thereafter (Figure 1D). Milk lactose was not significantly affected ($P > 0.05$) by the advance of the lactation period. The energy balance was negative in all of the eight weeks of lactation ($P < 0.001$), approaching zero in the first 5 weeks and then stabilizing in the subsequent weeks (Figure 1E).

Organs and Tissue Mass

There was a decrease in body weight (BW) ($P < 0.008$) and empty body weight (EBW) of the goats ($P < 0.007$) (Table 4) over the eight weeks of lactation. The decrease was more significant in the first five weeks of lactation. The masses of omental fat ($P < 0.005$) and visceral fat ($P < 0.003$) reduced linearly in the eight weeks of lactation. The weeks of lactation also negatively affected the mass of carcass ($P < 0.02$) and non-carcass components ($P < 0.001$). The other organs (tongue + esophagus, lungs + trachea, spleen, diaphragm, pancreas, and bladder) had their weight reduced over the eight weeks of lactation ($P < 0.005$). Rumen + reticulum, omasum, abomasum, and large intestine were not affected ($P > 0.05$) in the eight weeks of lactation (Table 4).

Body Composition and Mobilization of Body Reserves

Empty body weight decreased considerably in the first five weeks, stabilizing thereafter (Figure 2A). However, fat (Figure 2B), protein (Figure 2C) and total energy (Figure

2D) in the empty body decreased linearly with the advance of the eight weeks of lactation. Water in the empty body reduced curvilinearly (32.90 to 23.88 kg) ($P < 0.002$) (Figure 2E).

In this phase the goats expended a large amount of body reserves, with particularly high mobilization of internal reserves in terms of carcass components.

There was a linear reduction in fat mass in the carcass (5.6 to 2.1 kg) ($P < 0.003$) and non-carcass components (8.49 to 2.8 kg) ($P < 0.002$) as the lactation phase progressed (Figure 2H). The protein mass reduced linearly in the carcass (4.36 to 2.89 kg) ($P < 0.001$) and non-carcass components (3.69 to 2.35 kg) ($P < 0.0001$) over the eight weeks of lactation (Figure 2G). Ash and energy showed the same trend as fat and protein in the carcass and in the non-carcass components (Table 5). Water content reduced curvilinearly in the carcass (16.3 to 11.9 kg) ($P < 0.01$) and in the non-carcass components (16.56 to 11.98 kg) ($P < 0.001$; Figure 2I). There was a much greater mobilization of non-carcass (420.75 to 165.60 MJ) than carcass energy (305.71 to 150.60 MJ) in the 8 weeks of lactation (Figure 2J).

DISCUSSION

There are few studies published addressing the mobilization of body reserves of goats during the first eight weeks of lactation (phase of negative energy balance).

The most part of studies on mobilization of body reserves during lactation were conducted with sheep. However, it is known that one of the many differences between goats and sheep lies in the form of deposition of their reserves. Goats accumulate their energy reserves in adipose tissue in the viscera more intensively than other ruminants. This is an important fact to be considered in studies of energy transfer in the metabolic processes.

Dry Matter intake, Milk Yield and Composition, Body Weight, BCS and Energy Balance

The voluntary intake of dry matter has been negatively correlated with body reserves postpartum in many studies with cattle (Holter et al., 1990; Emery, 1993), sheep ((Ingvartsen and Andersen, 2000) and goats (Rodrigues et al., 2007). In the present study, milk yield increased rapidly, reaching its peak between the third and fourth week of lactation (Figure 1A), whereas the dry matter intake increased in the first 4 weeks and then tended to stabilize (Figure 1A). This is because the rate of lipolysis and lipogenesis overlaps a greater amount of non-esterified fatty acids (NEFA) available in the energy supply to the peripheral tissues. In the liver, the NEFA metabolism depends on the availability of glucose and its rate of

mobilization (Head and Gulay, 2001). Lima (2013), in an experiment using the same animals as those in this study, observed that up to the fifth week of lactation animals reached the limit (0.6 mmol/L) of NEFA in the blood; in the first week the goats had reached 0.9 mmol/L.

Studies have shown an inverse relationship between dry matter intake and plasma NEFA (Bertics et al., 1992; Studer et al., 1993; Vazquez-Anon et al., 1994; Grummer, 1995; Barbosa et at., 2009), and that this is related to the increased mobilization of adipose tissue during periods of limited energy intake (Pethick and Dunshea, 1993). For Kennedy (1953), the high concentration of NEFA in the blood acts on the neural circuitry controlling intake and energy balance (the "Lipostatic Theory").

Milk yield (Figure 1A) increased curvilinearly along with the lactation weeks. However, the dry matter intake increase only began to slow down after the fifth week of lactation, and body weight loss was on average 5 kg during the eight weeks of lactation, which may consequently have helped to maintain milk yield. Barbosa et al. (2009), working with Alpine goats at eight weeks postpartum, did not observe increase in milk yield in the first eight weeks of lactation, but the dry matter intake of these goats stabilized or decreased in the third week. Moreover, there was no marked weight loss (2 kg, on average) during the eight weeks of lactation.

The milk fat content (Figure 1D) reduced linearly over the eight weeks of lactation. Some factors can influence the milk composition of goats, such as: breeds, genetic selection, age and number of parturition, stage of lactation, health, nutrition, and photoperiod. Moreover, for some authors (Chilliard et al., 1986; Sauvant et al., 1991), this decrease in the milk fat content can be also related to at least two phenomena: can be also related to at least two phenomena: first because of the dilution effect due to the increased volume of milk at the peak of lactation, and second because of the reduction of fat mobilization with the advance of the lactation weeks. So there is a reduction of non-esterified fatty acids (NEFA) in the mammary gland and it can cause a decrease in the synthesis of milk fat.

Eknæs et al. (2006) observed that the milk fat content decreased until the lactation peak, but the inverse occurred subsequently, due to the decrease in milk yield. The milk protein content reduced in the first four weeks (Figure 1D); afterwards, it tended to stabilize, which is contrary to the results found by Corrales et al. (1994), in which the milk protein content followed the same trend as milk fat, because it can be influenced by the milk yield. The milk energy (Figure 1E) had the same behavior as the milk protein.

Live weight and BCS responded differently: regarding the weight (Figure 1B), the reduction was more marked in the first 4 weeks of lactation, and then this loss became slow,

because, in addition to fat, these animals lost body protein over the weeks (Figure 2B and 2C). There was also a great loss in the water content (Figure 2E) in the first three weeks, which then stabilized, because water accounts for 60 to 70% of the body, so the weight is influenced by the water content in body.

Although water is available *ad libitum* to the animals, the mobilization of water may have been caused by the insufficient intake during the first three weeks of lactation. This is a way to support the increase in milk production caused by the increase in the uterus volume and compression of the rumen-reticulum, forcing the animal to use the metabolic water. The metabolic water is generated from the oxidation of proteins, carbohydrates and fats in the organic metabolism. For instance, the oxidation of 100 g carbohydrate, 100 g protein, and 100 g of fat generates 60, 42 and 110 g of water, respectively. Yet, there is water loss during the oxidation process (Aganga et al., 1989). Body condition score (Figure 1C) followed the body protein and fat very precisely, with the same linear response, showing a high correlation with the energy depots of the animal.

Animals that are in a negative energy balance cannot meet their energy requirements during this time to support the energy-demanding process of milk synthesis. Early-postpartum does respond to negative energy balance by mobilizing large amounts of stored fats, and elevated levels of fatty acids may sometimes be a problem. The energy balance reached the highest loss between first and second lactation weeks (–5.24 MJ/d) (Figure 1E). The energy balance was reached in the six week of lactation, when it stabilized at 0.28 MJ/d. The goats had their lactation peak from the fifth to the eighth week of lactation.

Organ and Tissue Mass

The mass of internal fat at parturition and early lactation is very important to minimize the mobilization of tissue protein. Yet, Barnes and Brown (1990) reported the importance of protein mobilization for the synthesis of this nutrient in the milk and to support the increased gluconeogenesis (Bell, 1995), given that this intake is limited at this stage. For Ngwa et al. (2009), a low body condition score at the time of kidding would restrict this pool of nutrients available for use to support milk production.

Ngwa et al. (2009) observed a decrease in body mass of 2.3 kg/wk in Alpine goats in early lactation, which corroborates the results found herein (2.56 kg/wk). For Dunshea et al. (1990) and AFRC (1998), the variation in body mass does not give conclusive information about changes in the body composition of animals.

A change in the masses of visceral ($P < 0.003$) and omental fats ($P < 0.005$) (Table 4) was observed in our study. Likewise, Eknæs et al. (2006) observed a constant decrease in the mass of fat tissue of Norwegian dairy goats from 11 to 125 days of lactation (7.35 to 3.87 kg).

In this phase the mass of the internal organs is reduced by 0.72 kg/wk, which corresponds to 12.85 MJ/wk of energy. The change in energy between the first and eighth weeks of lactation in the organs (e.g. gastrointestinal tract, liver, kidney, and heart) was approximately 1.03, 2.47, 0.33, and 1.51 MJ/wk of energy, respectively. These organs accounted for 41.5% the energy expended by all the organs. Particularly at this stage these organs are more active metabolically and represent approximately 40% of maintenance energy of these animals (Koogan et al., 1985).

During the first week, uterine involution occurred and there was also a decrease in the weight of this organ ($P < 0.001$) (Table 4), especially during the first two weeks of lactation. This may have been a result of the elimination of fluids and residues from uterine tissue at kidding.

Body Composition and Mobilization of Body Reserves

The total energy in the empty body (Figure 2D) decreased linearly over the eight weeks of lactation. The fat in the empty body followed the same trend (Figures 2A and 2B) mainly because of a reduction in the mass of internal fat (omental and visceral) (Table 4). This fact was also observed by Ngwa et al. (2009) and Eknæs et al. (2006). A study conducted by Ngwa et al. (2007) showed that the concentration of energy in the tissue to be mobilized or increased is not constant during the lactation period, contrarily to what is assumed in most of the recommendations of goat requirements (AFRC, 1998; Sahlu et al. 2004; NRC, 2007).

The protein in the empty body also decreased linearly throughout the eight weeks of lactation (Figure 2C). Bell (1995) showed that the skeletal muscle, liver, and blood serve as a pool of amino acids that will be used to support the increased gluconeogenesis in early lactation. Greenfield et al. (2000) observed that the pyruvate carboxylase enzyme, a key element to conversion of alanine to glucose, increased after parturition. The concentration of 3-methyl histidine in the urine, used as a protein degradation index in the skeletal muscle, increased after parturition, but decreased 14 to 21 days postpartum (Overton, 1998).

Another important consideration regarding tissue loss during lactation by dairy goat breeds like Alpine is the initial carcass mass and composition. Considerable amounts of fat and protein were mobilized not only from the carcass in early lactation, but also from the non-

carcass components, where there was actually greater mobilization. A low body condition at the time of kidding would restrict this pool of nutrients available for use in support of milk production. However, because the does of this experiment after kidding had an average BCS slightly lower than the moderate score of 3.0, it would appear that a very low body condition is necessary to minimize carcass tissue protein mobilization in early lactation.

In this study the goats lost a high amount of protein during the first eight weeks of lactation (8.05 to 5.23 kg of the EBW, average 0.050 kg/d); fat also followed the same trend (13.65 to 4.90 kg of the EBW, average 0.150 kg/d). Analyzing the protein and fat of the carcass and non-carcass components separately, there is a greater loss in non-carcass compared with carcass components (0.047 kg/d protein and 0.07 kg/d fat from non-carcass components, and 0.028 kg/d protein and 0.024 kg/d fat from the carcass).

Goats mobilized almost twice as much water in non-carcass components compared with carcass components in the first four weeks of lactation, which stabilized thereafter (Figure 2I). Ngwa et al. (2007) also observed greater water reduction in carcass than non-carcass components in goats in early lactation Although water was available *ad libitum* to the animals, the mobilization of water may have been caused by the insufficient intake during the first three weeks of lactation, so the animal used the metabolic water, and the water of non-carcass components is easier to be used.

Dunshea et al. (1990) demonstrated that goats fed *ad libitum* can mobilize energy during early lactation, which allows them to display a performance close to their maximum milk-production potential due to the dry matter intake being low during this phase, forcing them to use their body reserves.

CONCLUSIONS

Alpine goats in early lactation mobilize not only energy reserves of internal fat, but also from the carcass and non-carcass components.

The body energy of Alpine goats is mobilized with greater intensity in the first eight weeks of lactation due to the greater mobilization of protein: 2.22 kg, with an average of 0.050 kg/d in the empty body weight.

Body energy decreased linearly, and the total amount of energy mobilized during the first eight weeks of lactation was very large: 410.27 MJ, with an average of 6.84 MJ/d.

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Table 1. Ingredients of the diet supplied during the lactation period

Ingredients	DM diet g.kg^{-1}
Corn silage	415
Ground corn	257.5
Soybean meal	156.1
Wheat bran	123.7
Oil	21.8
Calcitic lime	11.5
Sodium bicarbonate	10.1
Salt	4.3

Table 2. Chemical composition of the feeds supplied during the lactation period (g.kg^{-1})

Nutrients	Corn Silage	Concentrate	Diet
Dry matter	263.3	867.5	617
Crude protein	78.4	184.1	140
aNDFom	431.5	181.6	285
Acid detergent fiber	279.4	45.2	142
Lignin	36.1	4.8	18
NDICP (g.kg^{-1} CP)	29.4	99.8	71
ADICP (g.kg^{-1} CP)	28.5	97.3	69
Fat	37.6	74.6	59
Ash	50.6	63.6	58
NFC	291.3	616.9	482
Calcium	2.84	4.05	3.5
Phosphorus	0.56	2.82	1.9
Available-energy values			
Total digestible nutrients g.kg^{-1}			828.8
Metabolizable energy (Mcal.kg^{-1}DM)			2.91
Net energy (Mcal.kg^{-1}DM)			1.89

aNDFom = ash-free neutral detergent fiber; NDICP = neutral detergent insoluble crude protein; ADICP = acid detergent Insoluble crude protein; NFC = non-fibrous carbohydrates.

Table 3. Effects of weeks of lactation on dry matter intake, milk composition and milk yield, body weight, body condition score and energy balance

Item	Weeks of lactation										*P*-value	
	0	1	2	3	4	5	6	7	8	SEM[1]	L[2]	Q[3]
n	3	6	6	6	6	6	6	6	6			
Dry matter intake, kg/d	0.54	0.82	1.30	1.34	1.58	1.45	1.37	1.62	1.57	0.069	0.005	0.001
Milk yield, kg/d	1.62	2.03	2.23	2.27	2.84	2.10	2.11	2.71	2.42	0.131	0.005	0.006
Protein, %		4.92	4.89	3.66	3.13	3.41	3.24	3.22	3.05	0.273	0.008	0.006
Fat, %		6.02	5.15	5.52	5.10	4.81	4.74	4.30	4.28	0.209	0.006	NS
Lactose, %		4.10	4.04	4.36	3.93	4.12	4.30	4.31	4.17	0.053	NS	NS
Protein, g/d		99.88	109.05	83.08	88.89	71.61	68.36	87.26	73.81	5.008	NS	NS
Fat, g/d		122.21	114.85	125.30	144.84	101.01	100.01	116.53	103.58	5.334	NS	NS
Lactose, g/d		83.23	90.09	98.97	111.61	86.59	90.73	116.80	100.91	4.247	NS	NS
Milk energy, MJ/kg		5.44	4.52	3.81	3.35	3.14	4.14	3.64	3.47	0.265	NS	0.03
Body weight, kg	67.0	61.4	53.1	47.8	52.8	50.8	52.2	47.8	46.5	0.453	0.007	0.008
Body Condition Score	3.0	2.75	2.75	2.67	2.72	2.50	2.45	2.3	2.25	0.027	0.001	NS
Energy balance	–8.59	–3.35	–2.97	–1.29	–1.94	–0.62	0.28	–0.41	–0.62	0.888	0.001	0.01

[1]SEM = *standard error of the mean,* [2]L = linear model, [3]Q = quadratic model.

Table 4. Effects of weeks of lactation on BW and mass of the carcass and non-carcass tissues and organs of Alpine goats, measured at slaughter (kg)

Item	Weeks of lactation										Regression coefficients					*P*-values	
	0	1	2	3	4	5	6	7	8	SEM[1]	β0 (SE[2])	β1 (SE)	β2 (SE)	R^2	RMSE[3]	L[4]	Q[5]
n	3	6	6	6	6	6	6	6	6								
Mass, kg																	
Body	67.0	61.4	53.1	47.8	52.8	50.8	52.2	47.8	46.5	1.25	66.09 (1.32)	–3.89 (0.80)	0.19 (0.09)	0.97	1.592	0.003	< 0.001
Empty body	56.8	51.9	43.5	36.6	42.0	40.1	40.9	35.0	35.6	1.13	56.35 (1.36)	–4.18 (0.82)	0.20 (0.10)	0.97	1.623	0.002	0.007
Carcass	27.1	24.1	19.4	17.7	20.2	19.6	20.3	17.1	17.8	0.57	24.0 (1.39)	–0.91 (0.29)		0.58	2.262	0.02	NS
Non-carcass	29.7	28.1	24.1	18.9	21.8	20.5	20.6	17.9	17.8	0.66	27.73 (1.31)	–1.39 (0.28)		0.78	2.140	0.002	NS
Head + feet	3.3	3.1	2.8	2.8	2.9	2.8	2.8	2.7	2.7	0.041	3.21 (0.07)	–0.14 (0.04)	0.01 (0.005)	0.82	0.092	0.006	0.006
Omental fat	3.8	3.9	2.4	1.3	2.2	1.7	2.2	0.6	1.1	0.195	3.50 (0.41)	–0.35 (0.09)		0.69	0.674	0.005	NS
Visceral fat	4.3	4.1	2.8	1.8	3.0	2.3	2.4	1.2	1.4	0.182	3.97 (0.36)	–0.34 (0.07)		0.75	0.580	0.003	NS
Liver	1.2	1.0	1.0	0.9	0.8	0.9	0.9	1.0	1.0	0.028	1.16 (0.03)	–0.11 (0.02)	0.01 (0.002)	0.86	0.041	NS	0.003
Rumen + reticulum	1.1	1.1	1.1	1.0	1.1	1.1	1.1	1.2	1.1	0.026						NS	NS
Omasum	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.007						NS	NS
Abomasum	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.4	0.008						NS	NS
Small Intestine	0.7	0.7	0.9	0.9	1.0	0.9	0.9	0.8	0.9	0.025	0.69 (0.04)	0.09 (0.02)	–0.01 (0.002)	0.76	0.049	NS	0.01
Large Intestine	0.8	0.6	0.8	0.8	0.7	0.9	0.7	0.8	0.7	0.018						NS	NS
Uterus	1.9	0.8	0.5	0.6	0.2	0.1	0.1	0.1	0.1	0.076	1.63 (0.18)	–0.54 (0.10)	0.05 (0.01)	0.90	0.218	0.008	< 0.001
Blood	3.0	2.9	2.8	2.4	2.5	2.5	2.6	2.5	2.4	0.049	2.89 (0.09)	–0.07 (0.002)		0.60	0.162	0.014	NS
Heart	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.008	0.32 (0.009)	–0.03 (0.005)	0.002 (0.0006)	0.93	0.011	0.002	< 0.001
Kidneys	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.004	0.16 (0.007)	–0.004 (0.001)		0.46	0.011	0.04	NS
Skin	4.5	4.4	3.8	3.1	3.5	3.4	3.5	3.1	3.0	0.099	4.29 (0.19)	–0.17 (0.04)		0.72	0.312	0.004	NS
Mammary gland	2.8	3.0	3.2	1.7	1.7	1.8	1.5	1.7	1.5	0.114	2.95 (0.24)	–0.21 (0.05)		0.71	0.391	0.004	NS
Other organs[6]	1.3	1.3	1.2	1.2	1.2	1.1	1.2	1.1	1.1	0.023	1.29 (0.04)	–0.03 (0.009)		0.16	0.154	0.005	NS

NS = $P > 0.5$; [1]SEM = *standard error* of the *mean;* [2]*SE = standard error of the regression coefficients;* [3]*RMSE = r*oot mean square error; [4]L = linear model; [5]Q = quadratic model; [6]Other organs = Tongue+ esophagus; Lungs + trachea; Spleen; Pancreas; Bladder; Diaphragm.

Table 5. Effects of weeks of lactation on body composition of Alpine goats, measured at slaughter

Item	Weeks of lactation										Regression coefficients					*P*-values	
	0	1	2	3	4	5	6	7	8	SEM[1]	β0 (SE[2])	β1 (SE)	β2 (SE)	R^2	RMSE[3]	L[4]	Q[5]
Empty body weight																	
Crude protein, kg	8.05	7.08	6.18	5.21	6.32	6.05	6.01	5.31	5.23	0.144	7.48 (0.26)	–0.29 (0.05)		0.84	0.40	0.001	NS
Fat, kg	13.65	12.27	9.06	6.10	9.27	7.52	7.92	3.90	4.90	0.516	13.00 (0.77)	–0.08 (0.16)		0.89	1.20	0.005	NS
Ash, kg	2.17	2.16	1.96	1.57	1.73	1.77	1.68	1.43	1.54	0.050	2.18 (0.05)	–0.09 (0.01)		0.93	0.08	0.001	NS
Water, kg	32.90	30.44	26.28	23.73	24.65	24.78	25.28	24.34	23.88	0.501	32.41 (0.87)	–0.69 (0.53)	0.22 (0.06)	0.92	1.07	0.005	0.002
Energy, MJ	726.47	649.03	501.72	362.67	513.36	438.25	452.92	278.48	316.20	5.548	687.50 (35.38)	– 9.20 (7.17)		0.89	54.98	0.005	NS
Empty body weight																	
Crude protein, %	14.18	13.62	14.33	14.39	15.07	15.08	14.73	15.19	14.75	0.001	13.74 (0.27)	0.22 (0.06)		0.73	0.32	0.01	NS
Fat,%	24.13	23.45	20.07	15.46	22.08	18.52	18.90	11.05	13.51	0.008	24.34 (1.1)	–1.14 (0.24)		0.82	1.87	0.005	NS
Ash, %	3.85	4.15	4.53	4.26	4.14	4.42	4.12	4.08	4.33	0.001						NS	NS
Water, %	57.84	58.77	61.07	65.89	58.70	61.98	62.26	69.68	67.41	0.007	57.60 (1.43)	1.23 (0.28)		0.79	2.17	0.007	NS
Energy, MJ/kg	12.83	12.43	11.27	9.47	12.23	10.84	10.90	7.93	8.79	0.072	12.84 (0.56)	–0.51 (0.11)		0.81	0.86	0.006	NS
Δ Body energy, MJ/d		–11.59	–4.37	–3.59	–1.49	–0.15	–0.06	–0.66	–0.88	0.519	–15.03 (1.62)	5.17 (0.83)	–0.43 (0.09)	0.93	1.16	0.005	0.001
Carcass mass																	
Crude protein, kg	4.36	3.82	3.07	2.81	3.30	3.33	3.29	2.85	2.89	0.095	4.15 (0.12)	–0.17 (0.02)		0.91	0.17	0.01	NS
Fat, kg	5.16	4.60	2.92	2.38	3.56	2.96	2.89	1.57	2.10	0.187	5.11 (0.25)	–0.42 (0.04)		0.94	0.35	0.003	NS
Ash, kg	1.23	1.20	1.20	0.94	1.00	1.04	0.97	0.80	0.89	0.033	1.25 (0.03)	– 0.05 (0.007)		0.90	0.05	0.004	NS
Water, kg	16.33	14.51	12.21	11.54	12.35	12.27	13.15	11.87	11.90	0.294	15.83 (0.65)	– 0.60 (0.39)	0.14 (0.05)	0.84	0.79	0.04	0.01
Energy, MJ	305.71	270.66	187.40	159.96	217.90	194.76	191.25	128.68	150.60	2.228	298.76 (11.51)	–0.38 (0.02)		0.94	16.15	0.002	NS
Non-carcass mass																	
Crude protein, kg	3.69	3.26	3.11	2.40	3.01	2.72	2.72	2.46	2.35	0.068	3.53 (0.07)	–0.15 (0.01)		0.95	0.11	0.001	NS
Fat, kg	8.49	7.67	6.13	3.72	5.71	4.56	5.03	2.33	2.80	0.356	8.26 (0.43)	–0.71 (0.09)		0.92	0.67	0.002	NS
Ash, kg	0.95	0.96	0.76	0.63	0.73	0.73	0.71	0.62	0.65	0.023	0.89 (0.03)	– 0.03 (0.006)		0.86	0.04	0.003	NS
Water, kg	16.56	16.21	14.08	12.20	12.30	12.50	12.13	12.47	11.98	0.293	16.85 (0.52)	– 0.63 (0.30)	0.13 (0.04)	0.91	0.63	0.005	0.01
Energy, MJ	420.75	378.37	314.32	202.71	295.46	243.49	261.66	149.81	165.60	3.642	408.08 (17.94)	–31.37 (3.63)		0.93	27.88	0.001	NS

NS = $P > 0.5$; [1]SEM = *standard error of the mean;* [2]*SE = standard error of the regression coefficients;* [3]*RMSE = root* mean square error; [4]L = linear model; [5]Q = quadratic model.

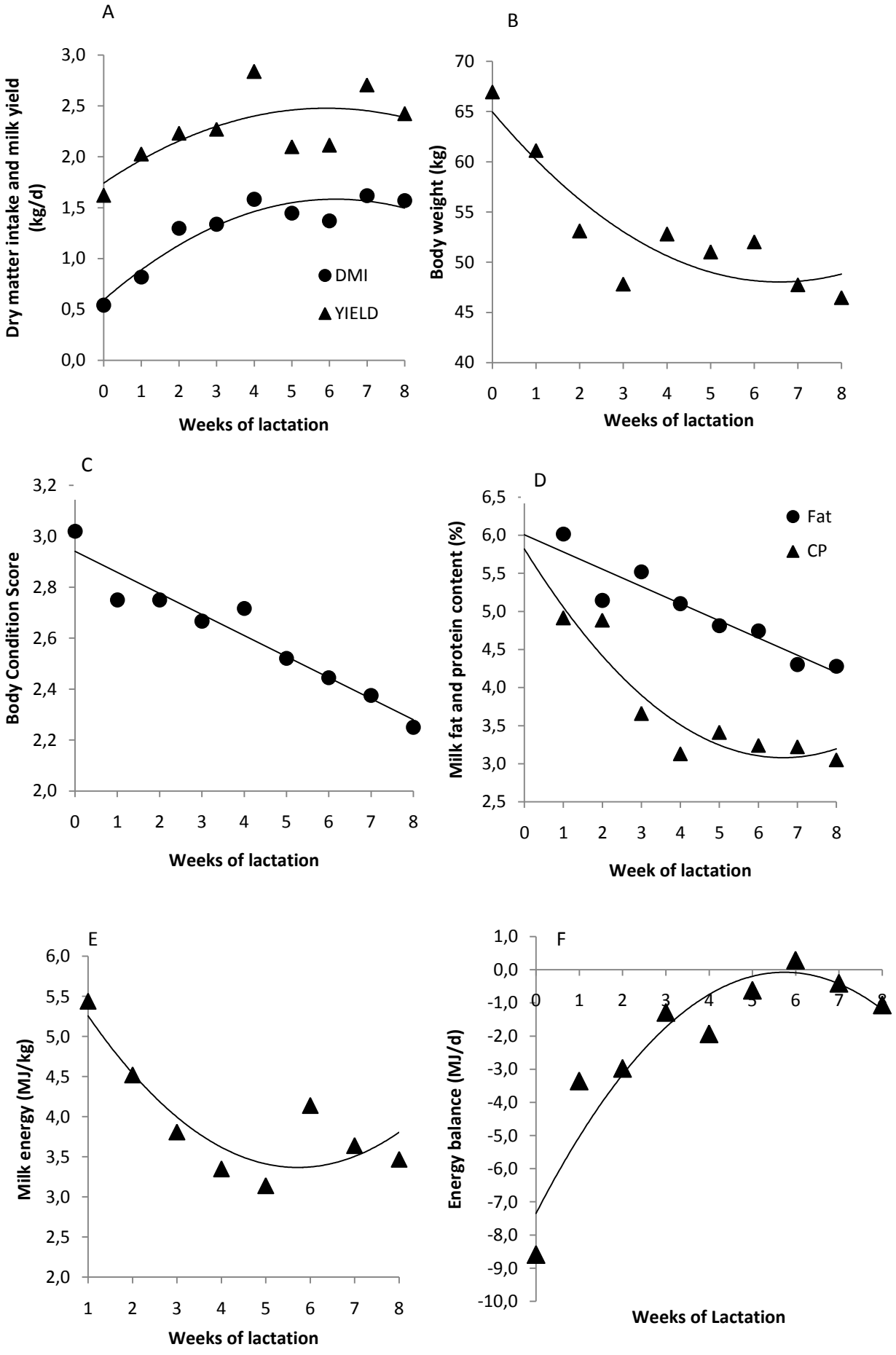
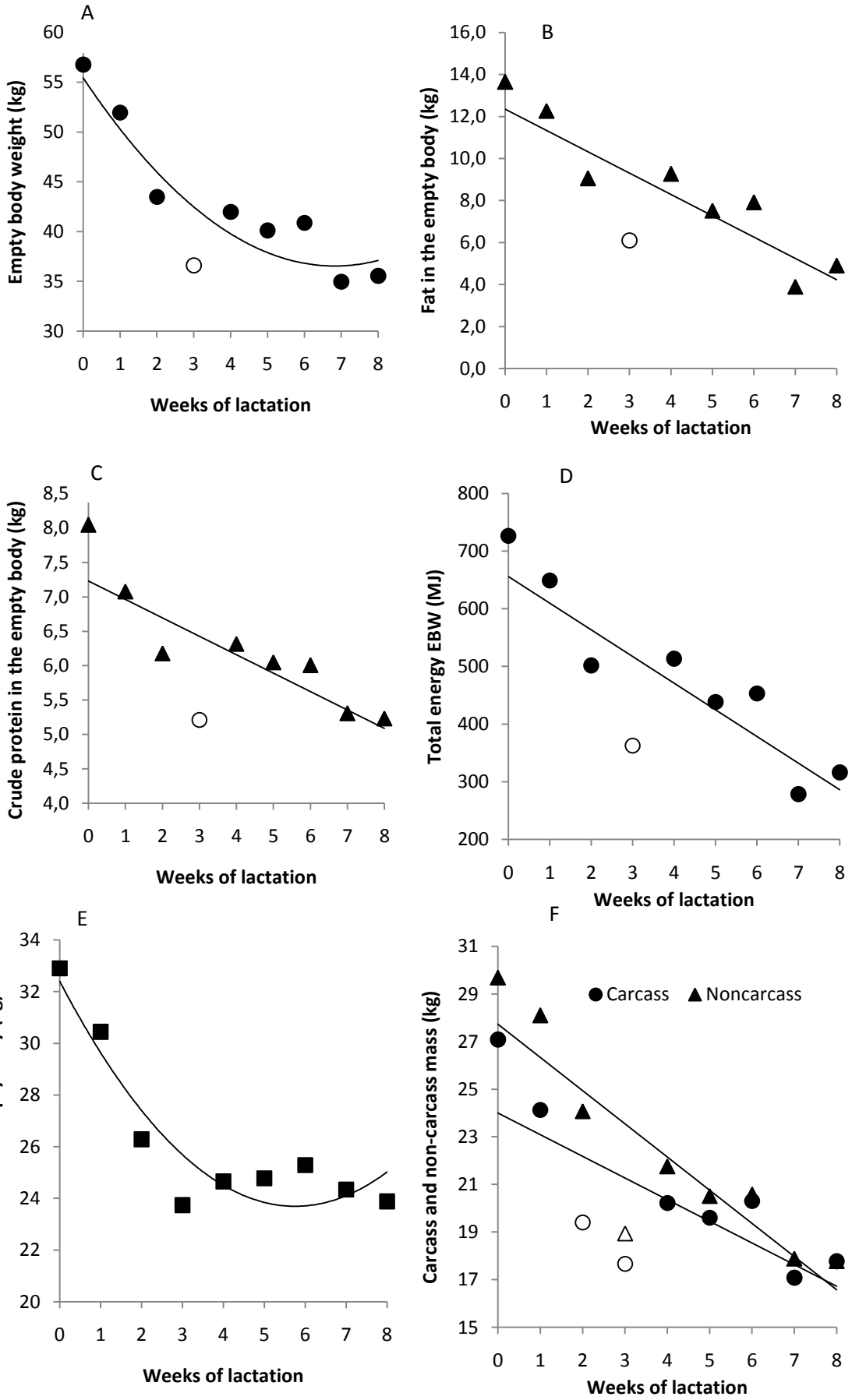
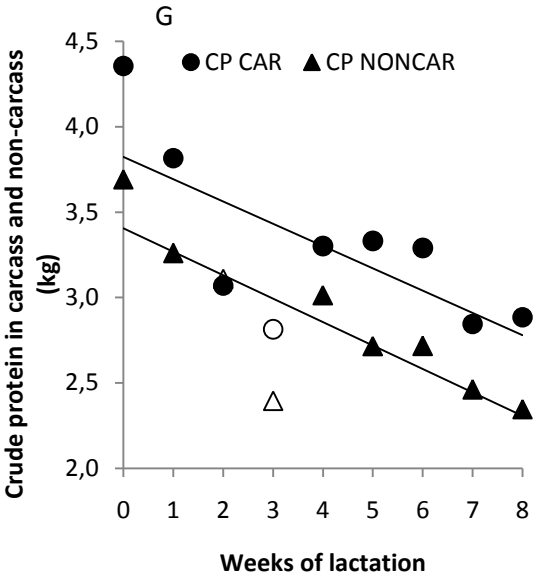
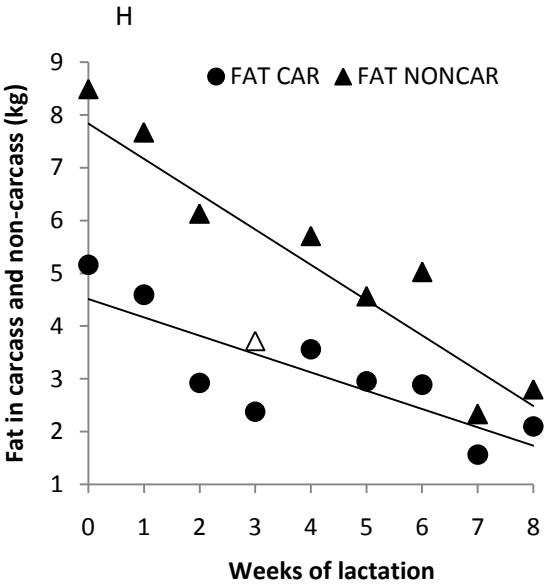
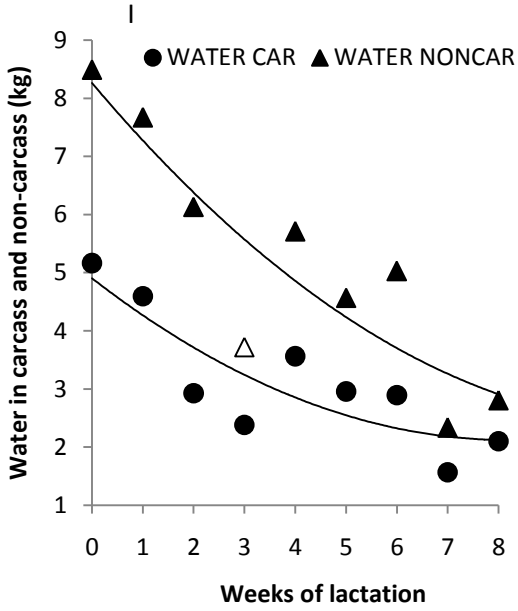

A
Dry matter intake and milk yield (kg/d)
3,0
2,5
2,0
1,5
1,0
0,5
0,0
DMI
YIELD
0 1 2 3 4 5 6 7 8
Weeks of lactation
B
Body weight (kg)
70
65
60
55
50
45
40
0 1 2 3 4 5 6 7 8
Weeks of lactation
C
Body Condition Score
3,2
3,0
2,8
2,6
2,4
2,2
2,0
0 1 2 3 4 5 6 7 8
Weeks of lactation
D
Milk fat and protein content (%)
6,5
6,0
5,5
5,0
4,5
4,0
3,5
3,0
2,5
Fat
CP
0 1 2 3 4 5 6 7 8
Week of lactation
E
Milk energy (MJ/kg)
6,0
5,5
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1 2 3 4 5 6 7 8
Weeks of lactation
F
Energy balance (MJ/d)
1,0
0,0
-1,0
-2,0
-3,0
-4,0
-5,0
-6,0
-7,0
-8,0
-9,0
-10,0
0 1 2 3 4 5 6 7 8
Weeks of Lactation

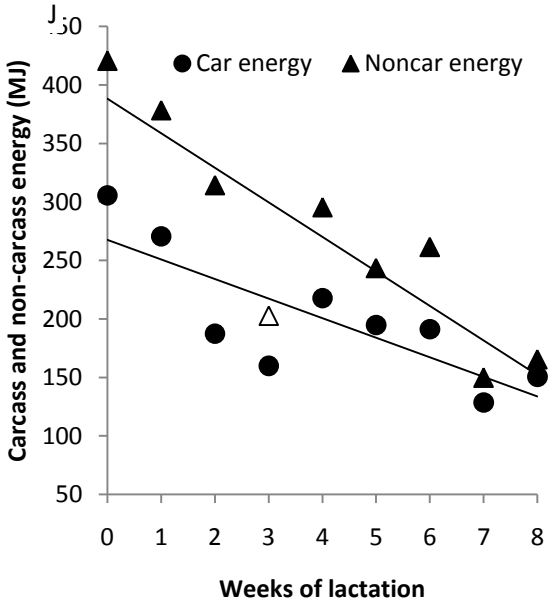
Figure 1. Dry matter intake and milk yield (A), body weight (B), Body Condition Score (C), milk fat content (D), milk protein content (D), milk energy (E) and balance energy (F) of Alpine goats in the first 8 weeks of lactation, with group means (6 goats), in which (○) is considered outliers. Regression equations (numbers in parentheses are standard errors of the coefficients), root mean square error, **RMSE**: **DMI** = 0.59 (0.11) + 0.32 (0.06) × wk – 0.03 (0.007) × wk^2, r^2 = 0.89, $P < 0.001$, RMSE = 0.137 (A); **Milk yield** = 1.74 (0.24) + 0.25 (0.06) × wk - 0.02 (0.007) × wk^2, r^2 = 0.50, $P < 0.006$, RMSE = 0.302 (A); **BW** = 64.96 (2.8) – 5.14 (1.63) × wk + 0.39 (0.19) × wk^2, r^2 = 0.80, $P < 0.007$ RMSE = 3.44 (B); **BCS** = 2.94 (0.04) – 0.08 (0.008) × wk, r^2 = 0.9266, $P < 0.0001$, RMSE = 0.068 (C); **Milk fat** = 5.73 (0.36) – 0.22 (0.08) × wk, r^2 = 0.5509, $P < 0.022$, RMSE = 0.592 (D); **Milk CP** = 5.87 (0.62) – 1.11 (0.37) × wk + 0.10 (0.004) × wk^2, r^2 = 0.7235, $P < 0.0211$, RMSE = 0.773 (D); **Milk energy** = 6.14 (0.60) – 0.97 (0.31) × wk + 0.08 (0.003) × wk^2, r^2 = 0.76, $P < 0.03$ RMSE = 0.43 (E); **BE** = –7.35 (0.83) + 2.53 (0.48) × wk - 0.22 (0.06) × wk^2, r^2 = 0.88, $P < 0.002$, RMSE = 1.029 (F).


A
Empty body weight (kg)
60
55
50
45
40
35
30
0 1 2 3 4 5 6 7 8
Weeks of lactation
B
Fat in the empty body (kg)
16,0
14,0
12,0
10,0
8,0
6,0
4,0
2,0
0,0
0 1 2 3 4 5 6 7 8
Weeks of lactation
C
Crude protein in the empty body (kg)
8,5
8,0
7,5
7,0
6,5
6,0
5,5
5,0
4,5
4,0
0 1 2 3 4 5 6 7 8
Weeks of lactation
D
Total energy EBW (MJ)
800
700
600
500
400
300
200
0 1 2 3 4 5 6 7 8
Weeks of lactation
E
Water in the empty body (kg)
34
32
30
28
26
24
22
20
0 1 2 3 4 5 6 7 8
Weeks of lactation
F
Carcass and non-carcass mass (kg)
Carcass
Noncarcass
31
29
27
25
23
21
19
17
15
0 1 2 3 4 5 6 7 8
Weeks of lactation


G
CP CAR
CP NONCAR
Crude protein in carcass and non-carcass (kg)
Weeks of lactation


H
FAT CAR
FAT NONCAR
Fat in carcass and non-carcass (kg)
Weeks of lactation


I
WATER CAR
WATER NONCAR
Water in carcass and non-carcass (kg)
Weeks of lactation


Car energy
Noncar energy
Carcass and non-carcass energy (MJ)
Weeks of lactation

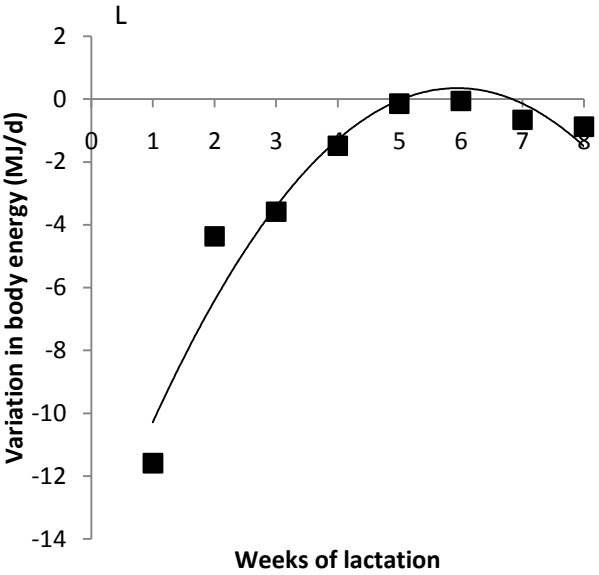

L
Variation in body energy (MJ/d)
Weeks of lactation

Figure 2. Empty body weight (A), fat in the empty body (B), crude protein in the empty body (C), total energy in the empty body (D), water in the empty body (E), carcass and non-carcass mass (F), crude protein in carcass and non-carcass (G), fat in carcass and non-carcass (H), water in carcass and non-carcass (I), carcass and non-carcass energy (J), and variation in energy (L) in Alpine goats in the first 8 weeks of lactation, with group means (6 goats), in which (○, Δ) are considered outliers.

Energy requirements and efficiency of Alpine goats in early lactation

T. S. Oliveira,* R. A. M. Vieira,† A. Cannas,‡ and M. T. Rodrigues*

*Departamento de Zootecnia, Univerdidade Federal de Viçosa, Avenida Peter Henry Rolfs, 36570-900 Viçosa, MG, Brazil
†Laboratório de Zootecnia, Universidade Estadual do Norte Fluminense, Avenida Alberto Lamego, 28013-602 Campos dos Goytacazes, RJ, Brazil
‡ Dipartimento di Scienze Zootecniche, Università degli Studi di Sassari, Via E. De Nicola 9, 07100 Sassari, SS, Italy

ABSTRACT

The objective of this study was to determine the energy requirements and efficiency of use of the body reserves of goats in the first eight weeks of lactation using the comparative-slaughter technique. Fifty-one multiparous Alpine goats were used to determine body composition of animals. After parturition, three goats (control group) were slaughtered to estimate the initial body composition of the animals that remained in the experiment. Forty-eight goats were assigned to a completely randomized design where the treatments were the subsequent eight weeks of lactation (7th, 14th, 21st, 28th, 35th, 42nd, 49th, and 56th days). Six goats were slaughtered per week. All animals received a single experimental diet. The efficiency of conversion of tissue energy to milk was estimated by using a multiple linear regression. The efficiency was given by the ratio between the β1/β2 of the equation (1.21/1.60), resulting in 0.76. The efficiency also was tested more directly with the same set of data, with milk as the dependent variable, yielding 0.74. The partial coefficient of 0.74 indicates more directly the efficiency of conversion of body tissue to milk. The metabolizable energy required for maintenance in goats at the first eight weeks of lactation was 0.190 Mcal/$BW^{0.75}$ and the use efficiency of the MEI for lactation was 0.93. Net energy requirements for maintenance and lactation in this phase were high, decreasing by 76.04% (3.38 to 2.57 Mcal/$BW^{0.75}$) and 63.84% (1.30 to 0.83 Mcal/kg), respectively. However, the equation used in this study does not take into account the energy to support lactation, with overestimation of the metabolizable required for maintenance, in which the heat increment above the maintenance level is attributed to the heat increments of the productive functions and to energy support expending processes that are not part of the production-related pathways. In conclusion, Alpine goats have high energy requirements during the first eight weeks of lactation, when the energy required for maintenance is reduced from 3.38 to 2.57

Mcal/$BW^{0.75}$ and lactation requirements decrease from 1.30 to 0.83 Mcal/kg. The use efficiency of mobilized energy was 0.74, the use efficiency of dietary energy was 0.93, and the efficiency for maintenance was 0.76, which is lower than the recommended values by nutritional systems.
Key words: Dairy goats, lactation, energy

INTRODUCTION

Dairy cows, ewes, and goats may rely heavily on body fat and protein reserves as energy sources in early lactation. The extent to which milk can be produced from this energy source is restricted by the condition of the animal at the time of parturition (Moe et al., 1971).

The amount of tissue energy used during early lactation for milk production depends upon factors such as the influence of body composition on the health and feed intake of cows and goats, the energy efficiency of body fat deposition and subsequent mobilization for milk production, and the corresponding efficiency of milk production directly from dietary energy (NRC, 2007).

Few experiments have been carried out with goats, cows, or sheep in the phase of negative energy balance measuring specifically the mobilization of body reserves using the comparative-slaughter method.

Feeding systems like ARC (1980), CSIRO (1990), AFRC (1993, 1998) and NRC (1989, 2001) for dairy cows are based on calorimetric methods, and the NRC (2007) for dairy goats involves a database of treatment means from the literature, according Nsahlai et al. (2004). NRC (2007) employs a constant efficiency of use of mobilized-tissue-energy for lactation of 84%, whereas the value adopted by AFRC (1993, 1998) is slightly lower than the 80% used by INRA (1989, 2007), is both estimated with room calorimeter.

The objective of this study was to determine the energy requirements and the use efficiency of the reserves in the body of goats in the first eight weeks of lactation using the comparative-slaughter technique.

MATERIAL AND METHODS

Animals and Management

The experiment was conducted at the experimental station of the Federal University of Viçosa, located in the municipality of Viçosa, Minas Gerais State, Brazil, (20°46'19"S and 42°51'12"W; mean altitude 707 m). According to the Köppen classification, the climate type is Cwa (tropical, high altitude), with rainy summers and dry winters. The annual average temperature is 18.5 ºC, ranging from 8.2 °C to 28.5 ºC. The annual average precipitation rate in this region is 1,203 mm, with an average relative air humidity of 80%.

Fifty-one multiparous Alpine goats were allocated in individual metabolic pens provided with troughs for supply of feed and water *ad libitum*. The goats were selected so as to provide homogeneity among the experimental units at parturition. Selection required an initial group of 250 goats that were inseminated simultaneously, which allowed for all suggested variables to be contemplated.

After parturition, three goats (control group) were slaughtered to estimate the initial body composition of animals that remained in the experiment. Forty-eight goats were assigned to a completely randomized design where the treatments were the subsequent eight weeks of lactation. Six goats were slaughtered per week. All animals received only one experimental diet (Tables 1 and 2), different from that supplied during gestation, and formulated according to NRC (2007) recommendations.

The diet was fed twice daily (07.00 h and 16.00 h), always after the animals were milked. The diet was adjusted daily to allow for approximately 20% of orts. Before the morning feeding, the orts corresponding each experimental unit were weighed, sampled and stored in a freezer (–10 ºC). Samples of corn silage and concentrate fed to each animal were collected on a weekly basis. At end of the experimental period composite samples were formed per animal to determine the chemical composition of the diet. The animals were individually weighed weekly.

Estimation of Diet Digestibility

A digestibility trial was conducted starting on the 23rd experimental day using six lactating goats. The trial was set in a completely randomized design with six replicates and one experimental diet. Goats were housed in metabolic cages that allowed the separation of

feces and urine. After an adaptation period of 21 days total fecal collection was performed during five consecutive days, with feces being collected every two hours. Fecal samples were stored in a freezer at –20 ºC and then dried at 55 °C in a forced-ventilation oven for 72 h prior to grinding through a Wiley mill with 1-mm mesh sieve for chemical analysis.

All samples were analyzed for moisture, nitrogen, EE, ash, calcium, and phosphorus according to the procedures of the Association of the Official Analytical Chemists (1990). Neutral detergent fiber and ash-free neutral detergent fiber (aNDFom) were determined with sodium sulfite and heat-stable alpha amylase and expressed including residual ash and lignin, and analyzed according to Van Soest et al. (1991). Non-fibrous carbohydrates (NFC) were calculated as 100 – (% CP + % EE + % NDF + % Ash) (Hall, 2003). Gross energy was analyzed on feed, orts, and feces samples using an adiabatic bomb calorimeter PARR (Model No. 2081).

The total digestible nutrients (TDN) were calculated as follows:

$$\text{TDN} = \text{CP intake} - \text{fecal CP} + \text{NDF intake} - \text{fecal NDF} + \text{NFC intake} - \text{fecal NFC} + 2.25 \times (\text{EE intake} - \text{fecal EE}).$$

The digestible energy (DE) and metabolizable energy (ME) values were calculated using the equations suggested by NRC (2001):

$$\text{DE} = (\text{Mcal/kgDM})\ (\text{dNFC}/100) \times 4.2 + (\text{dDNF}/100) \times 4.2 + (\text{dCP}/100) \times 5.6 + (\text{dEE}/100) \times 9.4\text{-}0.3;\ \text{and}$$

$$\text{ME} = 1.01 \times \text{DE (Mcal/kg)} - 0.45.$$

Milk Yield and Composition

The goats were milked twice daily (06.30 h and 15.30 h). The milk production of the animals was measured by daily weighings, and milk samples were collected weekly from each animal in the morning and afternoon. Milk samples were stored with 2-bromo-2-nitropropane-1,3-diol and transferred to the Laboratory of Animal Nutrition - LAN/UFV (Viçosa, Minas Gerais, Brazil). Milk composition (fat, protein and lactose) was determined using an infrared analyzer (Minor Milko ScanTM; 255A/B-Foss Electric, Hillerød, Denmark), according to the International Dairy Federation (1996).

Milk energy was calculated using the equation:

$$NE_L, Mcal/d = (289.72 + 71.93 \times PQ + 48.28 \times (PP/0.92)) \times Yn,$$

where Yn is the true milk yield on a particular day of lactation (kg/d); PQ is the measured milk fat for a particular day of lactation (%); PP is the measured true milk protein for a particular day of lactation (%); and 0.92 was used to convert milk true protein to CP for goats (Pulina et al., 1992). The factor 4.184 was used to transform calories into joules.

Slaughter

This study was approved by the Ethics Committee on Animal Use of the Department of Animal Science of the Federal University of Viçosa, protocol no. 61/2013.

A group of three goats were slaughtered right after parturition (control group) to estimate the mass of fat and protein and to determine the initial body energy of the animals that remained in the experiment. The other slaughters were carried out every seven days (six goats per week) during the eight weeks of lactation (from the 7th to the 56th days of lactation) to measure the mass of internal fat and to determine the body energy by chemical analysis of body tissues.

After slaughter the goats were bled by sectioning the jugular and carotid arteries. All the blood was collected and weighed. Subsequently, they were skinned, and their carcass was separated into hot carcass and internal organs and viscera (liver with gallbladder, kidneys, heart, pancreas, spleen, tongue, lungs, diaphragm, esophagus, trachea, bladder, and uterus; the bladder and the gallbladder were weighed full and empty). Then the mammary gland was removed, weighed, and dissected. The internal fat was divided into omental and visceral fat (mesenteric, perirenal, and pericardial fat). The organs of the gastrointestinal tract (rumen-reticulum, omasum, abomasum, small intestine, and large intestines) were weighed empty and full). Head, legs, and skin were weighed and conditioned in labeled plastic bags and frozen at –15 °C.

The empty body weight (EBW) was determined as the difference between body weight at slaughter and content of the gastrointestinal tract.

Individual parts of the body, namely carcass, head members, viscera, organs, blood and mammary gland were ground separately in a cutting mill (30 HP, 1775 rpm), whereas skins were ground using a ball mill for further chemical analysis.

The samples were composed of four parts: a) viscera, organ, blood, and internal fat; b) carcass; c) head and legs; and d) mammary gland. One-hundred grams of samples were lyophilized for 48 to 72 hours to determine the fat dry matter (FDM).

Subsequently, the samples were successively washed with petroleum ether. The resulting material was the solids non-fat (SNF). Then the samples were ground in a ball mill for subsequent determinations of dry matter, total nitrogen, and ether extract, according to AOAC (1990). The fat removed during pre-defatting was calculated as the difference between FDM and SNF, whose result was added to those obtained for the residual ether extract in the SNF to determine the total fat content.

Data Calculations

Mobilization of Body Reserves (Tissue Loss)

The initial EBW was calculated from the initial BW by using a general equation obtained with data from the group of control animals. The intercept of the equation did not differ from zero (–10.60, $P = 0.19$) and was removed from the model (Eq. 1; $R^2 = 0.99$; root mean square error, RMSE = 0.848; $P < 0.001$; n = 3). Regression equations (numbers in parentheses are standard errors of the coefficients):

Initial EBW, kg = 0.85 (0.007) × initial BW **(Eq.1)**

Full-body energy content was calculated based on the body protein and fat contents, using the caloric values of 5.64 and 9.40 kcal/g of protein and fat, respectively (ARC, 1980). The variation in body energy was determined as the difference between final and initial body energy contents divided by the days in feedlot. The latter were estimated from data from control animals, by regressing body energy contents in the empty body. The obtained equation was: (Eq. 2; $R^2 = 0.53$; RMSE = 27.561; $P < 0.001$; n = 51):

Initial body energy, Mcal = –85.02 (26.60) + 3.99 (0.54) × initial EBW **(Eq.2)**

Energy Requirements and Efficiencies

The energy requirement and its efficiencies were determined by the equations of Moe et al. (1971).

The efficiency of conversion of energy mobilized for milk production was estimated using a multiple linear regression equation between mobilization of body reserves (**Tissue Loss**), metabolizable energy intake (**MEI**) and milk energy (**MILK**). Metabolizable energy intake was determined by multiplying the daily DMI by the calculated energy value of the diet based on NRC (2001) values as described before. Milk energy was calculated using the equation:

$$\mathbf{NE_L}, \text{Mcal/d} = (289.72 + 71.93 \times PQ + 48.28 \times (PP/0.92)) \times Yn,$$

where Yn is the milk true yield at a particular day of lactation (kg/d); PQ is the measured milk fat for a particular day of lactation (%); PP is the measured milk true protein for a particular day of lactation (%); and 0.92 was used to convert milk true protein to CP for goats (**MILK**) (Pulina et al., 1992). Variables MEI, MILK and TISSUE LOSS were expressed as kcal/$kg^{0.75}$/d.

$$MEI = \beta_0 + \beta_1 \times MILK + \beta_2 \times TISSUE\ LOSS + e_{ij} \quad \textbf{(Eq.3)}$$

In this equation, the estimate of the efficiency of conversion of tissue energy to milk (**k_{mob}**, expressed as %) is β_1/β_2.

Also, according to Moe et al. (1971), the efficiency was tested with milk as the dependent variable, in which MEI, MILK and TISSUE LOSS are also expressed as kcal/$kg^{0.75}$ of BW (**Eq. 4**).

$$MILK = \beta_0 + \beta_1 \times MEI + \beta_2 \times TISSUE\ LOSS + e_{ij} \quad \textbf{(Eq.4)}$$

The following model represented the relationship between dietary energy intake and the use of energy by lactating goats, where body size is body weight in kilograms raised to the 0.75 power (**MBS**).

$$MEI, Mcal = \beta_0 + \beta_1 \times MBS + \beta_2 \times MILK + \beta_3 \times TISSUE\ LOSS + e_{ijk} \quad \textbf{(Eq.5.}$$

In this model β_1, β_2, and β_3 represent the amount of ME required for maintenance, milk production, and the amount of dietary MEI which is spared per unit of body tissue energy loss. The reciprocals $1/\beta_2$ represent the efficiency of milk production (**k_L**, expressed in %).

The efficiency of energy use for maintenance (**k_m**, expressed as %) described by ARC (1980) was used based on the following equation: $k_m = 0.35 \times q_m + 0.503$, where q_m is the metabolizability of the diet at maintenance. The net energy for maintenance (NE_M) was calculated by multiplying the metabolizable energy for maintenance by the efficiency of energy use for maintenance: NE_M, Mcal = $ME_M \times k_m$. The energy retained in milk (i.e., lactation; NE_L) was previously described. The metabolizable energy for lactation (ME_L) was calculated by dividing the net energy for lactation by the efficiency of energy use for lactation, ME_L, Mcal = NE_L/k_L.

Statistical Analyses

The variables were analyzed according to the following statistical model:

$$y_{ij} = \mu + \tau_i + e_{ij},$$

where y_{ij} represents the measured value on the j-th animal in the i-th week of lactation; μ is the overall mean; τi corresponds to the i-th week of lactation; and eij is the random error. Six goats (j = 1, 2, ..., 6) were slaughtered in each lactation week. Therefore, no measure was taken repeatedly in experimental units. On the other hand, the experimental units were completely independent for each week of lactation (i = 1, 2, ..., 8). The statistical model was adjusted to the data using the PROC REG procedure of SAS software (version 9, SAS Institute Inc., Cary, NC, USA), considering the *P*-values for linear and quadratic effects. The data with a Student's residue outside the ranges of (- 2, 2) were considered outliers according to criteria described by Draper and Smith (1996).

RESULTS

Dry matter intake and metabolizable energy intake varied significantly ($P < 0.001$) and curvilinearly throughout the 60 days postpartum (Table 3). Milk yield also increased ($P < 0.006$) curvilinearly as the lactation period advanced. Milk fat content ($P < 0.006$) and milk protein ($P < 0.006$) varied significantly with the lactation period. Milk lactose was not significantly affected ($P > 0.05$) by the advancement of the lactation period (Table 3). Body weight and empty body weight decreased ($P < 0.008$) curvilinearly over the lactation period (Table 3). Fat, protein and energy decreased linearly over the eight weeks of lactation, but the water in the empty body decreased curvilinearly ($P < 0.0001$) (Table 3).

The efficiency of conversion of tissue energy to milk was estimated using a multiple linear regression, according to Moe et al. (1971) (**Eq. 3**, Table 4).

Thus, the β_1/β_2 ratio from the previous equation (1.21/1.60) indicates the efficiency, which was 0.76 (Table 4).

The efficiency was also tested more directly with the same set of data, with milk as the dependent variable, resulting in 0.74 (**Eq. 4**, Table 4). For Moe et al. (1971), the partial coefficient of 0.74 indicated most directly the efficiency of conversion of body tissue to milk.

The metabolizable energy required for lactation and the energy use efficiency for lactation were estimated using a multiple linear regression, according to Moe et al. (1971) (**Eq. 5**, Table 4). However, the intercept of the equation did not differ from zero (–2.14, P = 0.23).

Using this equation, the obtained metabolizable energy required for maintenance of goats in the first eight weeks of lactation was 0.190 Mcal/ $kg^{0.75}$ of BW, and the use efficiency of the MEI for lactation 0.93.

The net energy requirements for maintenance and lactation in this phase are high; however, these variables decreased by 76.04% (3.38 to 2.57 Mcal/$BW^{0.75}$) and 63.84% (1.30 to 0.83 Mcal/kg), respectively. Those values are higher than those found in the literature, though these studies were not conducted specifically in this phase, which comprises greater negative energy balance.

DISCUSSION

The voluntary intake of dry matter has been negatively correlated with body reserves postpartum in many studies with cattle (Holter et al., 1990; Emery, 1993), sheep ((Ingvartsen

and Andersen, 2000) and goats (Rodrigues et al., 2007). In the present study, milk yield increased rapidly, reaching its peak between the third and fourth week of lactation, whereas the dry matter intake increased in the first four weeks and then tended to stabilize. This is because the rate of lipolysis and lipogenesis overlaps a greater amount of non-esterified fatty acids (NEFA) available in the energy supplied to the peripheral tissues. In the liver, the NEFA metabolism depends on the availability of glucose and its rate of mobilization (Head and Gulay, 2001). Lima (2013), in an experiment using the same animals as those in this study, observed that before the fifth week of lactation animals reached the limit (0.6 mmol/L) of NEFA in the blood; in the first week the goats had reached 0.9 mmol/L.

Studies have demonstrated an inverse relationship between dry matter intake and plasma NEFA (Bertics et al., 1992; Studer et al., 1993; Vazquez-Anon et al., 1994; Grummer, 1995; Barbosa et at., 2009), and that this is related to the increased mobilization of adipose tissue during periods of limited energy intake (Pethick and Dunshea, 1993). For Kennedy (1953), the high concentration of NEFA in the blood acts on the neural circuitry controlling intake and energy balance (the "Lipostatic Theory").

Milk yield increased throughout the lactation weeks. However, the dry matter intake increase only began to slow down after the fifth week of lactation, and body weight loss was on average 5 kg during the eight weeks of lactation, which may consequently have helped maintain the milk yield. Barbosa et al. (2009), working with Alpine goats at eight weeks postpartum, did not observe increase in milk yield in the first eight weeks of lactation, but the dry matter intake of these goats stabilized or decreased in the third week. Moreover, there was no marked weight loss (2 kg, on average) during the eight weeks of lactation.

The milk fat content reduced over the eight weeks of lactation. Some factors can influence the milk composition of goats, such as: breed, genetic selection, age and number of parturition, stage of lactation, health, thermal stress, nutrition, and photoperiod. Moreover, for some authors (Chilliard et al., 1986; Sauvant et al., 1991), this decrease in milk fat content can also be related to at least two phenomena: the dilution effect due to the increased volume of milk at the peak of lactation, and the reduction of fat mobilization with the advance of the lactation weeks. Consequently there is a reduction of non-esterified fatty acids (NEFA) in the mammary gland that can cause a decrease in the synthesis of milk fat.

Eknæs et al. (2006) observed that the milk fat content decreased until the lactation peak, but the inverse occurred afterwards, due to the decrease in milk yield. The milk protein content reduced in the first four weeks, and then it tended to stabilize, which is contrary to the results found by Corrales et al. (1994), in which the milk protein content followed the same

trend as milk fat, because it can be influenced by the milk yield. The milk energy had the same response as the milk protein.

The total energy in the empty body decreased over the eight weeks of lactation, from 173.63 to 75.57 Mcal, with an average of 1.75 Mcal/d (Table 3), mainly because of a reduction in the energy from internal fat of 1.96 Mcal/d. This fact was also observed by Ngwa et al., who obtained 1.04 Mcal/d in the EBW. A study conducted by Ngwa et al. (2007) showed that the concentration of energy in the tissue to be mobilized or increased is not constant during the lactation period, contrarily to what is assumed in most of the recommendations of goat requirements (AFRC, 1998; Sahlu et al. 2004; NRC, 2007).

In this study the goats lost a high amount of protein during the first eight weeks of lactation (8.05 to 5.23 kg of the EBW, averaging 0.050 kg/d). Fat also showed the same trend (13.65 to 4.90 kg of the EBW, averaging 0.150 kg/d). Bell (1995) showed that the skeletal muscle, liver, and blood serve as a pool of amino acids that will be used to support the increased gluconeogenesis in early lactation. Greenfield et al. (2000) observed that the pyruvate carboxylase enzyme, a key element to conversion of alanine to glucose, increased after parturition. The concentration of 3-methyl histidine in the urine, used as a protein degradation index in the skeletal muscle, increased after parturition, but decreased 14 to 21 days postpartum (Overton, 1998).

The efficiency of conversion of energy to tissue milk in this study was 74%, although Moe et al. (1971) and ARC (1980) described 84%, a difference of ten percentage points. However, the confidence interval of the efficiency of –0.80 > –0.84 > –0.88 found by Moe et al. (1971) is within the range found in this study (–0.34 > –0.74 > –1.15). But such a difference may have reasons: first, the methods of measurement adopted (comparative slaughter and room calorimeter) - the comparative slaughter method was adopted in the Californian Net Energy System, proposed by Lofgreen and Garrett (1968), which served as the basis for the NRC (1996), and has the advantage over the calorimetric method of allowing the determination of the requirements in conditions closer to the animal exploitation; second because they are different species of ruminants (goats and cattle), mainly regarding the different location of their energy reserves, with goats having larger depots of internal fat, and cattle, subcutaneous fat. The internal fat is mobilized with greater intensity than subcutaneous fat. This can be explained by the order of body fat deposition, in which the internal fat (abdominal, pelvic and thoracic) is the first to be deposited, followed by intermuscular fat, subcutaneous fat and finally intramuscular fat (marbling), as well as by the proximity to the organs metabolically active in this phase, e.g. liver, heart, kidneys, gastrointestinal tract, and

mammary gland (Koogan et al., 1985), which require a large amount of energy in this phase.

For Moe et al. (1971), the partial regression coefficient for metabolic body size cannot, however, be interpreted independently from the regression constant (**Eq.5**, Table 4). The constant represents the amount of ME intake which was not attributable to any specific variable in the model. It seems most logical to assign this amount of energy to the maintenance term. However, in our study the constant of the equation did not differ from zero (P = 0.23), and it was considered that the value of the metabolic body size is that of metabolizable energy for maintenance.

Metabolizable energy required for maintenance was 0.190 Mcal/kg of $BW^{0.75}$ (Table 4), which is much higher than the values reported in the literature (0.101, NRC (1981); 0.096, Aguilera et al. (1990); 0.105, AFRC (1998); 0.139, NRC (2007); and 0.121, Tovar-Luna et al. (2010)). However, these studies were not conducted with goats in early lactation but with goats at intermediate and late stages of lactation and non-lactating goats. Also, the equation described by Moe et al. (1971) does not take into account the support energy for lactation, with the metabolizable energy required for maintenance being overestimated. Milligan and Summers (1986), Baldwin (1995), and Williams and Jenkins (2003) asserted that the heat increment above the maintenance level is attributed to the heat increments of the productive functions and to -energy-expending processes that are not part of the production-related pathways.

Assuming that the basal metabolism is 0.07 Mcal kg of $BW^{0.75}$ (Kleiber, 1947), with an efficiency of use of energy for maintenance of 0.74, the ME_M is 0.0946 Mcal/kg of $BW^{0.75}$. Therefore, the 0.190 Mcal/ kg of $BW^{0.75}$ found in our study represents the ME_M value, and the energy support for lactation was 0.0954 Mcal/ kg of $BW^{0.75}$ (0.190 - 0.0946).

In this study it was observed that the goats mobilized not only fat but also body protein, and with greater intensity in the first three weeks of lactation, which then tended to stabilize. For Webster (1980), this stabilization of body protein requires a high energy cost, increasing the energy requirement for maintenance of these animals. Emmans (1997) also suggests that the heat production for maintenance is directly proportional to body protein.

In addition, the energy required to repair the reproductive tissue following parturition could elevate the ME_M requirement in early lactation. Moe et al. (1971) noted that factors like pregnancy, nutrient imbalances, disease, tissue-energy gain, environmental stress, and exercise tend to increase the amount of energy expended for maintenance. Consequently, applying a single ME_M throughout lactation could result in underestimation of energy required for the milk synthesis in early lactation and later overestimation.

The efficiency of use of the MEI for lactation was 0.93 (Table 4), which is very high compared with the literature values (0.66, Moe et al. (1971); 0.67, Aguilera et al. (1990); 0.67, AFRC (1998) (for high-quality diets), 0.56 to 0.64, INRA (1989, 2007), depending on the q_m; and 0.67, Tovar-Lunar et al. (2010)).

The intercept of equation 5 was not significant and, together with the metabolic weight, represents the metabolizable energy for maintenance as previously cited. This can be justified by the energy intake not being sufficient to maintain the high energy requirement of milk at this stage, which forces the use of body energy. But despite not meeting the nutritional requirements of these animals, the efficiency with which energy intake was used was very high, thereby reducing the maximum mobilization of body reserves.

The requirements and efficiency values found in the current study (Table 4) are very high compared with those in the literature; this may be because of the use of animals in subsequent stages of lactation (middle and late lactation), which does not require so much energy for milk production, and the energy intake of these animals may supply their nutritional requirements.

The efficiency of energy use for lactation is normally assumed to be constant over production levels and stages of lactation for both energy system, in which ME_M is assumed constant (AFRC, 1998; NRC, 2001), and level of intake for production relative to ME_M (SCA, 1990). Consequences of an assumed constant kl may be relatively minor because of changes in energy expenditure by splanchnic tissues. For example, in early lactation, the energy use by the liver may be greater than expected based on MEI as a result of nutrient-processing associated with tissue mobilization (NRC, 2007).

In the estimation of the efficiency for maintenance (km), the metabolizability of the diet was 0.73, and this value was used to adjust the equation described by AFRC (1993), resulting in an efficiency of 0.76 for maintenance, which is close to the 0.74 efficiency of use of energy mobilized for milk. This proves that goats at the eight weeks postpartum use energy intake for maintenance with the same efficiency as they use the body energy mobilized for milk production. Luo et al. (2004) assumed that the use efficiency of mobilized-tissue-energy for maintenance (k_{mt}) is the same as k_m for dairy goats. Cannas et al. (2004) reported a similarity between k_{mt} and the efficiency of use of mobilized-tissue energy for lactation (k_{mob}) in sheep.

Compared with the literature values, ours were not near to those recommended by AFRC (1993, 1998) (0.64-0.75) or Aguilera (2001) (0.73), and were higher than the 0.68

estimated by Nsahlai et al. (2004) and found by Lunar-Tovar et al. (2010) using non-lactating goats in a room calorimeter.

With the advance of lactation, NE_M decreased from 3.38 to 2.57 Mcal/$BW^{0.75}$; this can be explained by the reduction of the mass of high-metabolic-rate organs like liver, kidneys, heart, mammary gland, and gastrointestinal tract, due to the energy mobilization during this phase. According to Ferrel and Jenkins (1984) the reduction of the mass this directly or indirectly associated with the high rate of protein synthesis in this organs .

CONCLUSIONS

Alpine goats have high energy requirements during the first eight weeks of lactation, when the energy required for maintenance is reduced from 3.38 to 2.57 Mcal/$BW^{0.75}$ and the energy required for lactation decreases from 1.30 to 0.83 Mcal/kg.

The use efficiency of mobilized energy was 0.74, the use efficiency of dietary energy was 0.93, and efficiency of maintenance was 0.76, which are lower values than those recommended by nutritional systems.

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Table 1. Ingredients of the diet supplied during the lactation period

Ingredients	DM diet g.kg^{-1}
Corn silage	415
Ground corn	257.5
Soybean meal	156.1
Wheat bran	123.7
Oil	21.8
Calcitic lime	11.5
Sodium bicarbonate	10.1
Salt	4.3

Table 2. Chemical composition of the feeds supplied during the lactation period (g.kg^{-1})

Nutrients	Corn silage	Concentrate	Diet
Dry matter	263.3	867.5	617
Crude protein	78.4	184.1	140
aNDFom	431.5	181.6	285
Acid detergent fiber	279.4	45.2	142
Lignin	36.1	4.8	18
NDICP (g.kg^{-1} CP)	29.4	99.8	71
ADICP (g.kg^{-1} CP)	28.5	97.3	69
Fat	37.6	74.6	59
Ash	50.6	63.6	58
NFC	291.3	616.9	482
Calcium	2.84	4.05	3.5
Phosphorus	0.56	2.82	1.9
Available-energy values			
Total digestible nutrients g.kg^{-1}			828.8
Metabolizable energy (Mcal.kg^{-1}DM)			2.91
Net energy (Mcal.kg^{-1}DM)			1.89

aNDFom = ash-free neutral detergent fiber; ADF = acid detergent fiber; NDICP = neutral detergent insoluble crude protein; ADICP = acid detergent insoluble crude protein; NFC = non-fibrous carbohydrates.

Table 3. Effects of weeks of lactation on dry matter intake and metabolizable energy intake (MEI), milk composition and milk yield, body weight (BW), empty body weight (EBW) and fat, protein, and energy in the empty body

	Weeks of lactation										*P*-values	
	0	1	2	3	4	5	6	7	8	SEM[1]	L[2]	Q[3]
Goats, n	3	6	6	6	6	6	6	6	6			
Dry matter intake, kg/d	0.54	0.82	1.30	1.34	1.58	1.45	1.37	1.62	1.57	0.069	0.005	0.001
MEI, Mcal/d	1.58	2.38	3.77	3.89	4.60	4.21	3.99	4.70	4.57	0.150	0.005	0.001
Milk yield , kg/d	1.62	2.03	2.23	2.27	2.84	2.10	2.11	2.71	2.42	0.131	0.005	0.006
Milk protein content, %		4.92	4.89	3.66	3.13	3.41	3.24	3.22	3.05	0.150	0.008	0.006
Milk fat content, %		6.02	5.15	5.52	5.10	4.81	4.74	4.30	4.28	0.197	0.006	NS
Lactose, %		4.10	4.04	4.36	3.93	4.12	4.30	4.31	4.17	0.053	NS	NS
Protein, g/d		99.88	109.05	83.08	88.89	71.61	68.36	87.26	73.81	5.008	NS	NS
Fat, g/d		122.21	114.85	125.30	144.84	101.01	100.01	116.53	103.58	5.334	NS	NS
Lactose, g/d		83.23	90.09	98.97	111.61	86.59	90.73	116.80	100.91	4.247	NS	NS
Milk energy, Mcal/kg		1.30	1.08	0.91	0.80	0.75	0.99	0.87	0.83	0.063	NS	0.03
Final BW, kg	66.97	61.41	53.12	47.83	52.81	50.83	52.24	47.76	46.49	0.453	0.007	0.008
Final EBW, kg	56.92	51.57	43.48	36.61	41.97	40.11	40.88	34.97	35.56	1.038	<0.0001	0.02
Energy in the empty body, Mcal	173.63	155.12	119.91	86.68	122.70	104.74	108.25	66.56	75.57	4.934	<0.0001	NS
Crude protein in the empty body, kg	8.05	7.08	6.18	5.21	6.32	6.05	6.01	5.31	5.23	0.131	<0.0001	NS
Fat in the empty body, kg	13.65	12.27	9.06	6.10	9.27	7.52	7.92	3.90	4.90	0.449	<0.0001	NS
Water in the empty body, kg	32.90	30.44	26.28	23.73	24.65	24.78	25.28	24.34	23.88	0.451	<0.0001	<0.0001

[1]SEM = standard error of the mean, [2]L = linear model, [3]Q = quadratic model.

Table 4. Multiple regression analysis of energy balance in 51 Alpine goats in early lactation

	Intercept	95% CI		MBS	95% CI		Milk energy	95% CI		Tissue loss	95% CI		R^2	RMSE	*P*-value	n
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper				
Eq.3	177.28	94.41	260.15				1.21	0.57	1.85	1.60	0.91	2.29	0.57	60.95	<0.001	51
Eq. 4	7.43	–52.96	67.83				0.34	0.16	0.51	–0.74	–1.15	–0.34	0.47	32.32	<0.001	51
Eq.5				0.190	0.103	0.276	1.07	0.41	1.73	1.39	0.78	2.01	0.96	1.15	<0.001	51

CI = 95% highest posterior density (HPD) confidence intervals, MBS = body weight in kilograms raised to the 0.75 power, RMSE = root mean square error.
The intercept of Equation 5 did not differ from zero (–2.14, P = 0.23).

Table 5. Energy requirements and use efficiencies of goats during the first eight weeks of lactation

		Weeks of lactation									
		0	1	2	3	4	5	6	7	8	SEM[1]
ME_m, Mcal/$BW^{0.75}$	0.190	4.45	4.15	3.74	3.46	3.72	3.63	3.68	3.45	3.38	0.049
NE_m, Mcal/$BW^{0.75}$		3.38	3.16	2.84	2.63	2.83	2.76	2.80	2.62	2.57	0.037
NE_L, Mcal/kg		1.75	1.30	1.08	0.91	0.80	0.75	0.99	0.87	0.83	0.106
ME_L, Mcal/kg		1.88	1.39	1.16	0.98	0.86	0.81	1.06	0.94	0.89	0.113
Milk from tissue loss, k_{mob} %	0.74										
Milk from MEI, k_L %	0.93										
Gross energy, Mcal/kg DM	3.99										
ME, Mcal/kg DM	2.91										
q_m, %	0.73										
k_m, %	0.76										

[1]SEM = standard error of the mean.

Evaluation of diets and energy requirements of Alpine goats in the first 60 days of lactation by the Small Ruminant Nutrition System

Tadeu Silva de Oliveira[1], Antonello Cannas[2], Tiago Martins Oliveira Alves[1], Marcelo Teixeira Rodrigues[1], Ricardo Augusto Mendonça Vieira[3]

[1] *Universidade Federal de Viçosa, Viçosa, MG, Brasil.*
[2] *Università degli Studi di Sassari, Sassari, SS, Italia.*
[3] *Universidade Estadual do Norte Fluminense Darcy Ribeiro, Campos dos Goytacazes, RJ, Brasil.*

ABSTRACT - The objective in this study was to evaluate the predictions of the Small Ruminant Nutrition System (SRNS) for digestibility of the dietary nutrients and energy requirements of goats in early lactation. Fifty-one multiparous Alpine goats were used. After parturition, three goats (reference group) were slaughtered to estimate the initial body composition of the animals that remained in the experiment. Forty-eight goats were assigned to a completely randomized design where the treatments were eight subsequent weeks of lactation and six goats were slaughtered per week. All animals received only one experimental diet based on corn silage and a concentrate mix. A digestibility trial using six alpine goats in early lactation was conducted. Digestibility coefficients, total digestible nutrients, metabolizable energy intake, and net energy intake were measured and then compared with the values predicted by the SRNS. The variables dry matter intake, metabolizable energy required for maintenance, metabolizable energy balance, metabolizable energy for lactation, and variation in body condition score and body weight were compared with the values predicted by the SRNS. The SRNS accurately predicted the apparent digestibility of DM and OM, total digestible nutrients, metabolizable energy intake, and net energy intake. The SRNS underestimated the apparent digestibility of fat and protein, but overestimated the neutral detergent fiber digestibility. The predictions of metabolizable energy required for maintenance and metabolizable energy balance were underestimated by the SRNS. The SRNS accurately predicted metabolizable energy for lactation and variation in body condition score and body weight. The Small Ruminant Nutrition System has low accuracy in predicting diet quality but is highly accurate to predict body reserves of goats in early lactation.

Key Words: body reserves, dairy goats, digestibility

Introduction

To precisely and accurately determine the energy and nutrients required by domesticated small ruminants is important so as to ensure minimal waste of these resources. Mathematical models have been proven to be powerful tools for improving animal performance while reducing nutrient excretion (Tedeschi et al., 2005).

The overall production efficiency of ruminants can be improved by using biological models to predict the use of feed by these animals in specific production settings and their nutrient requirements (Cannas, 2000).

Several mathematical models based on feeding standards or feed evaluation systems for sheep and goats have been developed by different countries. The INRA (1989, 2007) system is based on research data from dairy and meat breeds for sheep and on dairy breeds for goats. The AFRC (1993) system is based on research data from meat and wool breeds for sheep and on dairy breeds for goats. The NRC (2007) system adopts Cannas et al. (2004) for sheep, whereas for goats it utilizes publications of the Institute for Goat Research, based on research published on the requirements of meat, wool, and dairy sheep breeds, and on dairy, meat, and indigenous goat breeds.

The Small Ruminant Nutrition System (SRNS) model was developed based on the Cornell Net Carbohydrate and Protein System for sheep (CNCPS-S). This model was modified to account for energy and protein requirements of sheep and goats under diverse practical conditions. Comparative information about energy and protein requirements for goats of current feeding systems has been extensively discussed (Cannas et al., 2008).

The digestibility is an important factor in the assessment of energy intake and energy balance of animals. However, no evaluations using the SRNS have been carried out in the early lactation phase, when the digestibility can be affected by the low intake of the goats and by their average size.

Therefore, the objective of the present study is to evaluate the predictions of the Small Ruminant Nutrition System (SRNS) for digestibility of the dietary nutrients and energy requirements of goats in early lactation.

Material and Methods

The experiment was conducted at the experimental station of Universidade Ferderal de Viçosa, located in the municipality of Viçosa, Minas Gerais State, Brazil (20°46'19"S and 42°51'12"W; 707 m elevation). According to the Köppen classification, the climate type is Cwa (tropical, high-altitude), with rainy summers and dry winters. The annual average temperature is 18.5 ºC, ranging from 8.2 °C to 28.5 ºC. The average annual precipitation in this region is 1,203 mm with average relative air humidity of 80%.

Fifty-one multiparous Alpine goats were sampled from a herd of 250 dairy goats, for homogeneity purposes, and allocated in individual metabolic pens provided with troughs for supplying feed and water *ad libitum*.

After parturition, three goats (control group) were slaughtered to estimate the initial body composition of the animals that remained in the experiment. The other 48 goats were arranged in a completely randomized design where the treatments were the eight subsequent weeks of lactation. Six goats were slaughtered per week. All animals received only one experimental diet (Tables 1 and 2).

The diet was offered twice daily (07.00 h and 16:00 h), always after milking the animals, and adjusted daily to allow *ad libitum* intake. Before the morning offer of the diet, the orts of each experimental unit were collected, weighed, sampled and stored in a freezer (–10 ºC). Samples of corn silage and concentrate fed to each animal were collected on a weekly basis. At the end of the experimental period a total composite sample was formed individually per treatment for the chemical analysis according to AOAC (1990).

A digestion trial was conducted starting on the 23rd experimental day, using 6 goats in lactation. The trial was based on a completely randomized design with six replicates and an experimental diet. The animals were placed in metabolic cages, which allowed the separation of feces and urine. After an adaptation period of 21 days total fecal collection was performed during five consecutive days with feces being collected every 2 hours. Fecal samples were collected, identified and stored in a freezer at –20 ºC. Feces, corn silage, concentrate and orts samples of the assay period were pre-dried at 55 to 60 °C in a forced-ventilation over for 72 hours. These samples were processed in a Wiley mill with 1 mm mesh sieves and conditioned individually in glass vials, at room temperature.

All samples were analyzed for moisture, N, EE, ash, Ca, and P according to the procedures of the Association of the Official Analytical Chemists (1990). Neutral detergent fiber and ash-free neutral detergent fiber (aNDFom) were determined with sodium sulfite and heat-stable alpha amylase and expressed including residual ash and lignin, and analyzed according to Van Soest et al. (1991). Non-fibrous carbohydrates (NFC) were calculated as 100 – (% CP + % EE + % NDF + % ASH) (Hall, 2003). The TDN were calculated as: CP intake – fecal CP + NDF intake – fecal NDF + NFC intake – fecal NFC + 2.25 × (EE intake – fecal EE).

The digestible energy (DE) and metabolizable energy (ME) values were calculated using the equations suggested by NRC (2001) for dairy cattle:

$$DE\ (Mcal/kgDM) = (dNFC/100) \times 4.2 + (dDNF/100) \times 4.2 + (dCP/100) \times 5.6 + (dEE/100) \times 9.4 - 0.3;\ \text{and}$$

$$ME\ (Mcal/kg\ DM) = 1.01 \times DE\ (Mcal/kg) - 0.45$$

The TDN_{3x} was converted to NE using the equation of NRC (2001):

$$NE\ (Mcal/kg\ DM) = 0.0245 \times TDN\ (\%) - 0.12$$

The goats were milked twice daily (06.30 h and 15.30 h). The milk production of the animals was measured by the two weighing sessions. Milk samples were collected weekly from each animal at each daily milking. Milk samples were stored with 2-bromo-2-nitropropane-1,3-diol and had their milk composition (fat, protein and lactose) determined by an infrared analyzer (Minor MilkoScanTM; 255A/B-Foss Electric, Hillerød, Denmark) according to the International Dairy Federation (1996).

This experiment was approved by the Ethics Committee on Animal Use of the Department of Animal Science of Universidade Federal de Viçosa (protocol no. 61/2013).

A group of three goats was slaughtered right after parturition (control group) to estimate the mass of fat and protein and to determine the initial body energy of the animals that remained in the experiment. The other slaughters were carried out every seven days (Six goats per week) during the eight weeks of lactation (from the 7th to the 56th days in milk) to measure the mass of internal fat and to determine the body energy by chemical analysis of body tissues.

After slaughter, the goats were bled by sectioning the jugular and carotid arteries. All the blood was collected and weighed. Subsequently they were skinned and the carcass was fractioned into hot carcass and internal organs and viscera (liver with gallbladder, kidneys, heart, pancreas, spleen, tongue, lungs, diaphragm, esophagus, trachea, bladder, and uterus; the bladder and the gallbladder were weighed full and empty). Then the mammary gland was removed, weighed and dissected. The internal fat was divided into omental and visceral fat (mesenteric, perirenal and pericardial fat). The organs of the gastrointestinal tract (rumen-reticulum, omasum, abomasum, small intestine and large intestines were weighed empty and full). Head, legs and skin were weighed and placed in previously labeled plastic bags, and frozen at –15 °C.

The empty body weight was determined as the difference between body weight at slaughter and the gastrointestinal content.

Individual parts of the body, namely carcass, head members, viscera, organs, blood, and mammary gland were ground separately in a cutting mill (30 HP, 1775 rpm), whereas skins were ground using a ball mill for chemical analysis.

The samples were composed of four parts: a) viscera, organ, blood, internal fat; b) carcass; c) head, legs; and d) mammary gland. One hundred grams were lyophilized for a period between 48 and 72 hours to determine the fat dry matter (FDM).

Subsequently, the samples were washed successively with petroleum ether. The result was the pre-defatted dry matter (PDDM). Then the samples were ground in a ball mill for subsequent determinations of dry matter, total nitrogen, ether extract, according to AOAC (1990). The fat removed during pre-defatting was calculated as the difference between FDM and PDDM, whose result was added to those obtained for the residual ether extract in the PDDM to determine the total fat content.

In the evaluation of the digestibility coefficients, TDN, MEI and NEI, the values observed and calculated in the experiment were compared to those predicted by the SRNS. This evaluation was performed considering 6 goats in early lactation. The evaluations of DMI, MEI, ME_M, ME_{MILK}, ME balance, ΔBCS and ΔBW were compared with the values predicted by the SRNS; this evaluation was performed considering 51 goats in early lactation.

Average shrunk body weight, age, intake of dry matter and dietary nutrients intake, milk production, fat and protein content, and body condition score (BCS; 0-5 scale) were used as inputs in the SRNS (Table 3). Feed composition was based on the chemical composition in the experiment for each feed. The other values required by the

SRNS (mostly degradation rates and mineral values) were obtained from the feed library. The sub-model of the SRNS that corrects ruminal degradation in N deficient diets (Tedeschi et al., 2000) was always adopted. The standard reference weights required by the SRNS model to estimate the relative size of each animal were estimated by using mature weight reported by the Brazilian Association of Alpine Goat Breeders. The standard reference weight for Alpine Oberhasli goats was 50 kg for females.

The predictions of DMI by the SRNS, based on AFRC (1998), were compared with those actually measured in the experiment.

$$\text{DMI (kg/d)} = 0.42 \times \text{Yn} + 0.024 \times \text{FBW}^{0.75} + 0.4 \times \text{FBWc} + 0.7 \times \text{Fp};$$
$$\text{Yn} = (0.6340 + 0.1046 \times \text{PQ}) \times \text{Y},$$

in which: Y = measured milk yield (kg/d); PQ = measured milk fat for a particular day of lactation (%); Yn = measured milk yield corrected for 3.5% milk fat (kg/d); FBW = full body weight (kg); FBWc = full body weight change (kg/d); Fp = proportion of forage in the diet as a decimal.

The energy requirement and its efficiencies were described by the equations proposed by Moe et al. (1971):

$$\text{MEI, Mcal} = \beta_0 + \beta_1 \times \text{FBW}^{0.75} + \beta_2 \times \text{Milk} + \beta_3 \times \text{Tissue loss} + e_{ijk}$$

In this model β_1, β_2, and β_3 represent the amount of ME required for maintenance, milk production, and the amount of dietary MEI spared per unit of body tissue energy loss, respectively. The $1/\beta_2$ reciprocals represent the efficiency of milk production (k_L, expressed as %).

From this equation, the obtained metabolizable energy required for maintenance goats at the first 8 weeks of lactation was 0.190 Mcal/kg$^{0.75}$ of BW, and the use efficiency of the MEI for lactation was 93%.

Metabolizable energy for lactation was calculated using the equation:

$$\text{ME}_{\text{MILK}} = ((289.72 + 71.93 \times \text{PQ} + 48.28 \times (\text{PP}/0.92)) \times \text{Yn})/1000 \times k_L,$$

in which: Yn is actual milk yield at a particular day of lactation (kg/d); PQ is the measured milk fat for a particular day of lactation (%); PP is the measured true milk

protein for a particular day of lactation (%); and 0.92 was used to convert the milk true protein to CP for goats (Pulina et al., 1992).

Estimated energy balance was computed on a weekly basis using the equation: EB = MEI – (ME_M + ME_{MILK}).

The assessment of the adequacy of the models is only possible through the combination of several statistical and empirical analyses and proper investigation regarding the purposes of the model initially conceptualized (Tedeschi, 2006), and in the present study several techniques were used. The coefficient of determination (r^2) (Neter et al., 1996), confidence intervals for the parameters (Mitchell, 1997), and the simultaneous test for the intercept and slope (Dent and Blackie, 1979; Mayer et al., 1994) were used.

Additional techniques were also used as discussed by Tedeschi (2006), including evaluation for accuracy with the concordance correlation coefficient (CCC; Lin, 1989), mean bias (Cochran and Cox, 1957) and mean square error of prediction (MSEP; Bibby and Toutenburg, 1977). The MSEP values were expanded in three fractions to represent errors in central tendency, errors due to regression and errors due to disturbances (or random errors), i.e., unexplained variance that cannot be accounted for by the linear regression (Theil, 1961).

Results and Discussion

The Small Ruminant Nutrition System accurately predicted apparent DM digestibility, with a mean difference between predicted (77.53) and observed (78.64) digestibility of –1.39 units, which did not differ from zero (P>0.1), with a RMSEP of 2.6 units, and the regression bias accounted for 4.3% of MSEP (Table 4) (Figure 1A), corroborating the reports of Cannas et al. (2004).

The apparent digestibility of OM was accurately predicted by the SRNS, with a mean difference between predicted (81.01) and observed (79.52) digestibility of 1.49, with a RMSEP of 2.6 units and the regression bias accounted for 4.5% of MSEP (Table 4).

The fat apparent digestibility was underestimated by the SRNS, with a mean difference between predicted (75.42) and observed (93.46) values of –18.04 units. The root mean square error of prediction was much larger than 18.1 units, with the majority of the MSEP (99.6%) associated with the mean bias (Table 4; Figure 1D). The protein

apparent digestibility was also underestimated, with a mean difference between predicted (68.42) and observed (80.66) values of –12.24 units. The root mean square error of prediction was much larger than 12.4 units, with the majority of the MSEP (96.7%) being associated with mean bias (Table 4; Figure 1B).

Both of these underestimates are related to the endogenous component. The endogenous fraction is the regression intercept between digestible nutrient (protein and fat) and nutrient intake (protein and fat). However, the CNCPS considers the endogenous CP or CP as microbial fecal, leading to double counting of microbial CP, and this also happens with the fat, as described in the equations:

$$\text{Fecal CP} = \text{F-CP}_U + 30 \times \text{DMI; and}$$
$$\text{Fecal fat} = \text{F-FAT}_U + 11.9 \times \text{DMI,}$$

in which Fecal CP is the total CP in the feces (g/d); F-CP_U = feed undegraded crude protein (g/d); 30 = grams of microbial and endogenous crude protein; and DMI = dry matter intake (kg/d). Fecal fat is the total fat in the feces (g/d); F-FAT_U = feed undegraded fat as estimated by the CNCPS-C (g/d); 11.9 = grams of microbial and endogenous fat in the feces as originally estimated by Lucas and Smart (1959); and DMI = dry matter intake (kg/d).

Also, another limitation is the assumption that the indigestible fraction of the diet is constant. However, it is known that the indigestible fraction is not constant in plants; is influenced, for instance, by the stage of maturity of the forage. Tedeschi et al. (2010) suggested the alternative of a mechanistic approach that considers that only 15% of the values of the constants described above would be endogenous. According to Van Soest (1994), 85% of the endogenous components are of microbial origin. Therefore, they were adjusted and included in the equations, implying a reduction in the values of the constants:

$$\text{Fecal CP} = \text{F-CP}_U + \text{F-CP}_M + 4.5 \times \text{DMI; and}$$
$$\text{Fecal Fat} = \text{F-FAT}_U + \text{F-FAT}_M + 1.79 \times \text{DMI,}$$

in which Fecal CP is the total CP in the feces (g/d); F-CP_U = feed undegraded crude protein (g/d); F-CP_M = fecal microbial crude protein (g/d); 4.5 = grams of microbial CP/kg of DMI. Fecal Fat is the total fat in the feces (g/d); F-FAT_U = feed undegraded

fat as estimated by the CNCPS-C (g/d); F-FAT_M = fecal microbial fat (g/d); 1.79 = grams of microbial fat/kg of DMI.

Neutral detergent fiber digestibility was overestimated by the SRNS, with a mean difference between predicted (60.62) and observed (56.34) digestibility of 4.28 units, and the RMSEP was larger 5.9 units (Table 4; Figure 1C). The model may have been overestimated because of the adopted degradation rate that is based on feeds produced in temperate climates.

The neutral detergent fiber of the tropical grasses is higher in concentration and perhaps less degradable compared with temperate forage, because the incidence of solar radiation in the tropics is greater than in temperate regions. Moreover, the high radiation and temperature in the tropics can influence the greater complexity of the interactions between carbohydrates and phenolic compounds in plant cell walls of tropical grasses, which would be, in the first instance, a damaging factor to the quality of these ruminant feed. Besides, differences in anatomic characteristics between tropical and temperate grasses affect the fiber degradability (Wilson et al., 1976).

The total digestible nutrients were accurately predicted by the SRNS, with a mean difference between predicted (82.03) and observed (82.88) digestibility of –0.85 units, which did not differ from zero ($P>0.1$; $r^2 = 0.91$), with a RMSEP of 1.6 units. However, the regression bias accounted for 54.8% of MSEP (Table 4).

The Small Ruminant Nutrition System accurately predicted MEI and NEI, with a mean difference between predicted and observed digestibility of –0.67 and 0 units, which did not differ from zero ($P>0.1$; $r^2 = 0.99$ and 0.92), with a RMSEP of 0.7 and 0.03 units, and the regression bias accounted for 8.2 and 81.9% of MSEP, respectively (Table 4).

The dry matter intake (DMI) was estimated by the equation described by AFRC (1998) for lactating goats because the SRNS contains an equation for ewes. The equation did not accurately estimate DMI, with a mean difference between predicted (1.83) and observed (1.38) values of 0.45 kg/d, which differ from zero ($P<0.1$). The RMSEP was 0.57 units, and the regression bias accounted for 7.3% of the MSEP (Table 5; Figure 2A).

The reduction in the intake of these animals from the model may have been because these animals reached a good body condition at parturition because their diet was rich in energy peripartum. After kidding, great amount of body energy was mobilized; until the 5th week of lactation animals were at the limit (0.6 mmol/L) of the

amount of non-esterified fatty acid in the blood. In the first week these animals reached 0.9 mmol/L, possibly because of ketosis, which could explain the reduction in the dry matter intake of these animals, besides the physical compression caused by the fetus during pregnancy.

The prediction of MEI was underestimated by the SRNS, with a mean difference between predicted (4.15) and observed (4.80) MEI of –0.65 Mcal/d, differing from zero ($P<0.1$; $r^2 = 0.99$). The RMSEP was 0.7 units, and the regression bias accounted for 14.19% of MSEP (Table 5). This may be due to the high energy concentration of the diet, which showed 3.47 Mcal/kg of DM.

The prediction of ME_M by the SRNS was underestimated, with a mean difference between predicted (2.08) and observed (3.65) values of –1.56 Mcal/d, differing from zero ($P<0.1$; $r^2 = 0.76$). The RMSEP was 1.58 units, and the regression bias accounted for 1.2% of the MSEP (Table 5; Figure 2B).

This difference have been be because the equation was developed for ewes and adapted for goat milk. Moreover, the model was not developed with a database of animals in early lactation, because at this phase the energy requirement and efficiency for maintenance of these animals are higher in the later stages of lactation.

Another significant factor is that most of the committees measure the body energy by room calorimeter using non-lactating animals, which explains the lower requirement of metabolizable energy of the committees in relation to this study.

The Small Ruminant Nutrition System accurately predicted ME_{MILK}, with a mean difference between predicted (3.26) and observed (3.50) ME_{MILK} of –0.245 Mcal/d, differing from zero ($P<0.1$; $r^2 = 1.0$). The RMSEP as 0.26 units, and the regression bias accounted for 14.4% of the MSEP (Table 5). The equation used herein was that described by Pulina et al. (1992), the same used by the SRNS.

The prediction of the ME balance was underestimated by the SRNS, with a mean difference between predicted (–0.92) and observed (–2.77) values of –1.84 Mcal/d, differing from zero ($P<0.1$; $r^2 = 0.003$), with a RMSEP of 2.8 units. The regression bias accounted for 22.72% of the MSEP (Table 5; Figure 2C). This larger regression bias indicates inadequacies in the ability of the model to predict the variables in question, because of the high value of the observed ME_M data.

The Small Ruminant Nutrition System accurately predicted ΔBCS and ΔBW, with a mean difference between predicted and observed digestibility of 0.01 d and –0.01 kg/d, differing from zero ($P<0.1$; $r^2 = 0.24$ and 0.12), with a RMSEP of 0.02 and 0.14

units, and the regression bias accounted for 16 and 21.2% of MSEP, respectively (Table 5; Figure 2D).

Conclusions

The Small Ruminant Nutrition System does not provide a good estimate for protein and fat digestibility in sheep. The digestibility of neutral detergent fiber is overestimated by this system. Body reserves are estimated by the Small Ruminant Nutrition System with great accuracy. However, this model underestimates the energy requirement for maintenance of goats in early lactation, reflecting upon the energy balance.

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Table 1 - Ingredients of the diet supplied during the lactation period

Ingredients	Diet (g/kg, as fed)	DM diet (g/kg)
Corn silage	700	415
Ground corn	133	257.5
Soybean meal	80	156.1
Wheat bran	63	123.7
Oil	11	21.8
Calcitic limestone	6	11.5
Sodium bicarbonate	5	10.1
Salt	2	4.3

Table 2 - Chemical composition of the feeds supplied during the lactation period (g/kg DM)

Nutrients	Silage corn	Concentrate	Diet
Dry matter	263.3	867.5	617
Crude protein	78.4	184.1	140
aNDFom	431.5	181.6	285
ADF	279.4	45.2	142
Lignin	36.1	4.8	18
NDICP (g/kg CP)	29.4	99.8	71
ADICP (g/kg CP)	28.5	97.3	69
Fat	37.6	74.6	59
Ash	50.6	63.6	58
NFC	291.3	616.9	482
Calcium	2.84	4.05	3.5
Phosphorus	0.56	2.82	1.9

NDF - neutral detergent fiber; ADF - acid detergent fiber; NDICP - neutral detergent insoluble crude protein; ADICP - acid detergent insoluble crude protein; NFC - non-fibrous carbohydrates.

Table 3 - Mean, standard error (SE), and maximum and minimum values of variables used as inputs in the SRNS

Variable	Mean	SE	Maximum	Minimum
Feed supplied (kg/d)	1.84	0.14	2.29	1.37
Orts (kg/d)	0.27	0.07	0.52	0.10
Dry matter intake (kg/d)	1.57	0.16	2.03	0.95
Body weight (kg)	47.12	2.27	57.30	41.10
Shrunk body weight (kg)	41.24	2.18	55.01	39.46
Body condition score	2.66	0.11	3.00	2.50
Milk yield (kg/d)	2.79	0.28	3.43	1.48
Fat (%)	3.12	0.19	3.68	2.52
Protein (%)	2.73	0.10	3.03	2.51
Age (mo)	40	2.53	48	36

SRNS - Small Ruminant Nutrition System.

Table 4 - Evaluation of the diet digestibility of goats in the lactation predicted by the Small Ruminant Nutrition System (SRNS)

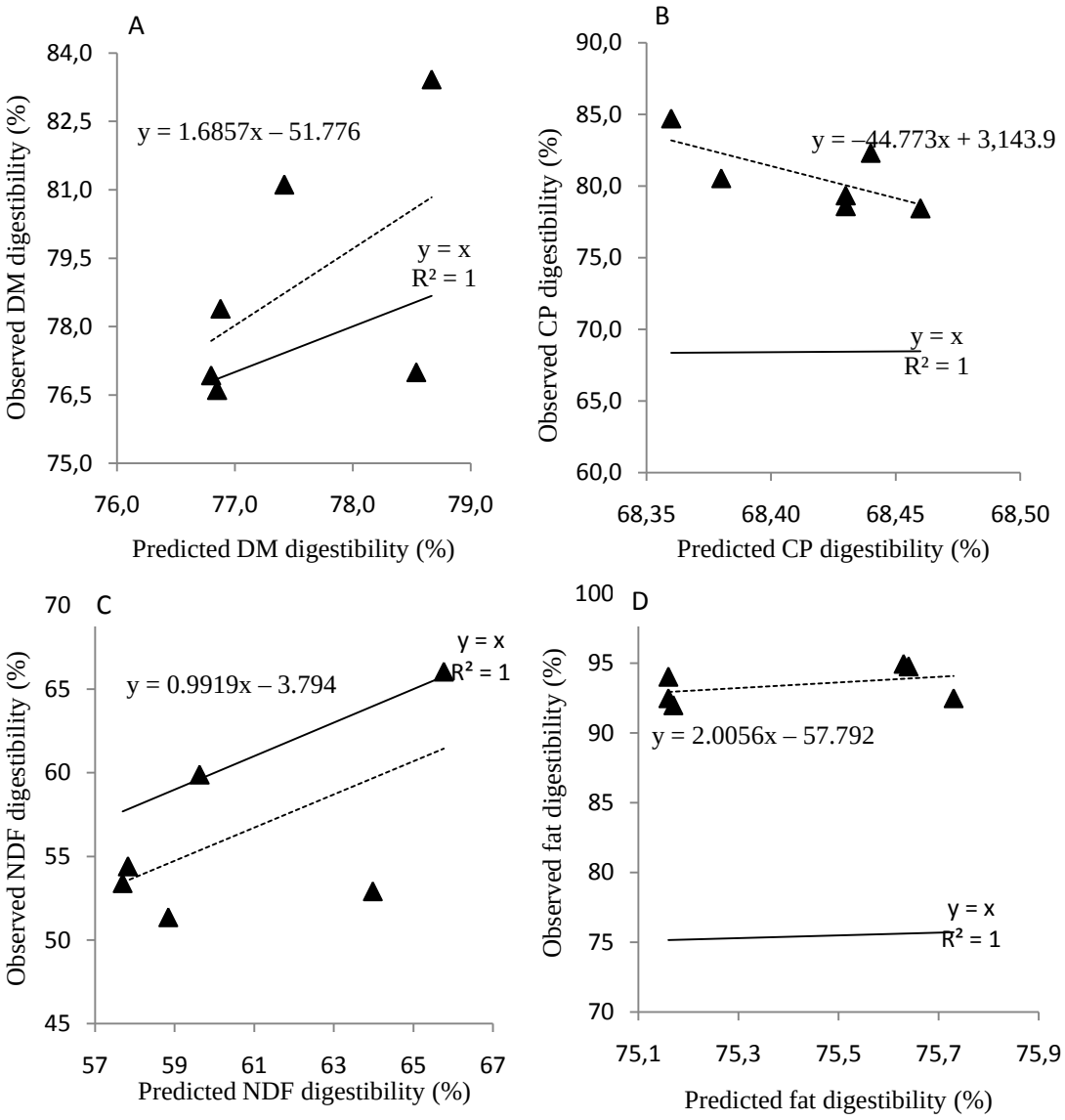
Variable	Predicted SRNS (P)	Observed SRNS (O)	P-O	Mean bias (% of O)	Components of MSEP (% of MSEP)			RMSEP	R^2	*P-value*	C_b	ρ_c
					Mean bias	Regression bias	Unexplained variation					
Dry matter digestibility coefficients (%)	77.53	78.91	–1.39	1.7	28.1	4.3	67.6	2.6	0.28	NS	0.46	0.24
Organic matter digestibility coefficients (%)	81.01	79.52	1.49	–1.9	31.6	4.5	63.9	2.6	0.31	NS	0.48	0.27
Crude protein digestibility coefficients (%)	68.42	80.66	–12.24	15.2	96.7	1.6	1.7	12.4	0.49	0.01	0.00	0.00
Neutral detergent fiber digestibility coefficients (%)	60.62	56.34	4.28	–7.6	52.7	0.0	47.3	5.9	0.37	NS	0.62	0.38
Fat digestibility coefficients (%)	75.42	93.46	–18.04	19.3	99.6	0.0	0.4	18.1	0.19	0.01	0.00	0.00
Non-fibrous carbohydrates digestibility coefficients (%)	97.09	94.26	2.83	–3.0	88.2	3.1	8.7	3.0	0.43	0.01	0.06	0.04
Total digestible nutrients (%)	82.03	82.88	–0.85	1.0	28.5	54.8	16.7	1.6	0.91	NS	0.62	0.59
Metabolizable energy intake (Mcal/day)	4.65	5.31	–0.67	12.6	91.4	8.2	0.4	0.7	0.99	0.01	0.86	0.86
Net energy intake (Mcal/day)	1.91	1.91	0.00	0.0	0.0	81.9	18.1	0.03	0.92	NS	0.65	0.63

MSEP - mean squared error of prediction; RMSEP - root mean squared error of prediction; R^2 - coefficient of determination of the best fit regression line not forced through the origin; *P* - probability associated with an F-test to reject the simultaneous hypothesis that the slope = 1 and the intercept = 0, when NS (P>0.1) in the hypothesis is not rejected (Dent and Blackie, 1979); C_b - accuracy of the model (Lin, 1989); ρ_c - concordance correlation coefficient (CCC) (Lin, 1989).

Table 5 - Evaluation of the energy requirements and energy mobilization of goats lactation predicted by using the Small Ruminant Nutrition System (SRNS)

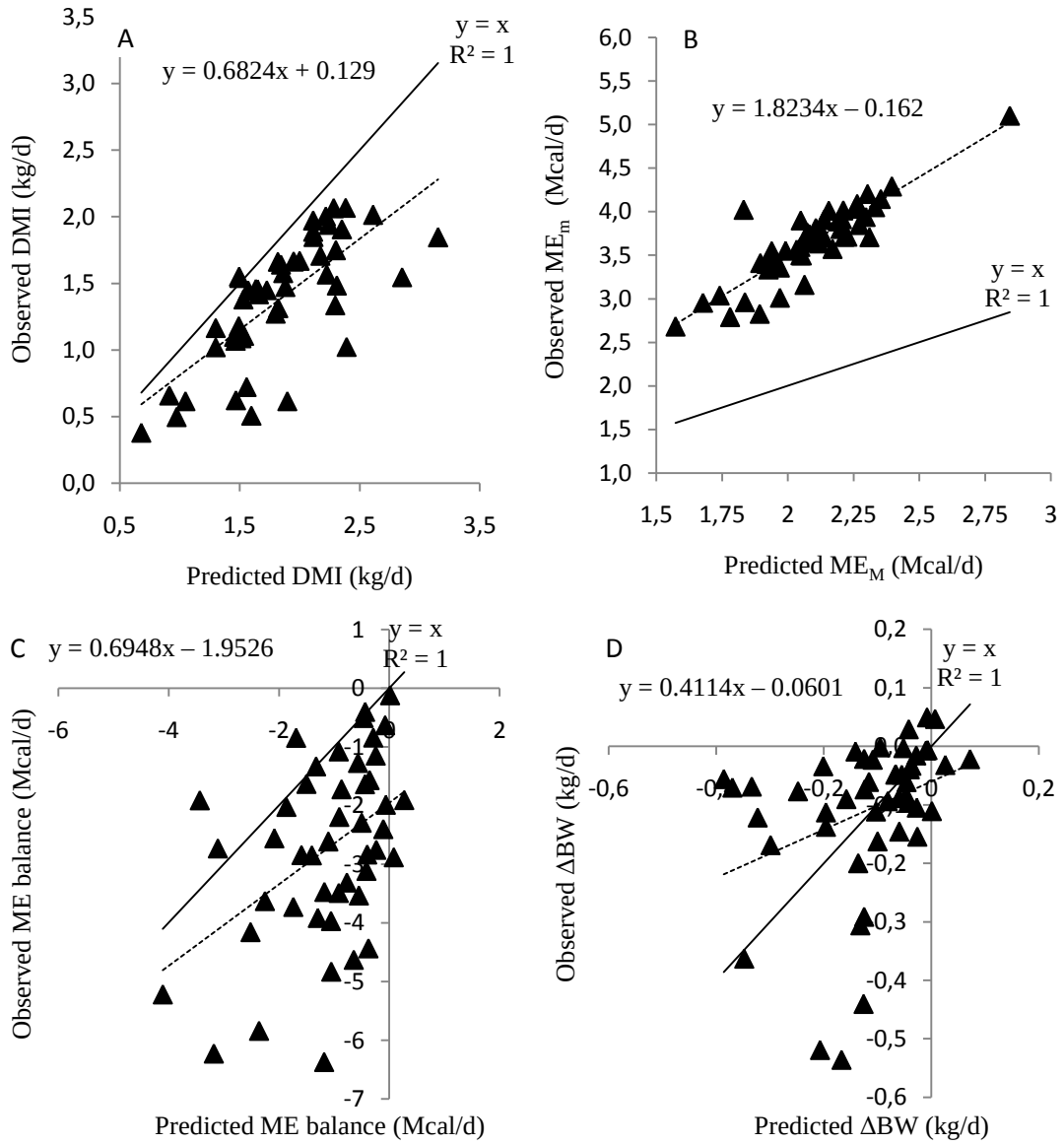
Variable	Predicted SRNS (P)	Observed SRNS (O)	P-O	Mean bias (% of O)	Components of MSEP (% of MSEP)			RMSEP	R^2	P-value	C_b	ρ_c
					Mean bias	Regression bias	Unexplained variation					
Dry matter intake (kg/d)	1.83	1.38	0.45	–32.84	62.7	7.3	30.0	0.57	0.53	0.01	0.69	0.50
Metabolizable energy intake (Mcal/d)	4.15	4.80	–0.65	13.5	84.6	14.19	1.21	0.70	0.99	0.01	0.90	0.90
Metabolizable energy for maintenance (Mcal/d)	2.08	3.65	–1.56	42.81	97	1.2	1.8	1.58	0.76	0.01	0.07	0.06
Metabolizable energy for lactation (Mcal/d)	3.26	3.50	–0.25	7.0	85.6	14.4	0	0.26	1.0	0.01	0.98	0.98
Metabolizable energy balance (Mcal/d)	–0.92	–2.77	1.84	0	43.48	22.72	33.8	2.8	0.03	0.01	0.58	0.03
Variation in BCS, d	–0.015	–0.027	0.01	0	35.6	16	48.4	0.02	0.24	0.01	0.78	0.38
Variation in body weight, kg/d	–0.116	–0.108	–0.01	0	0.33	21.2	78.47	0.14	0.12	0.03	0.98	0.33

MSEP - mean squared error of prediction; RMSEP - root mean squared error of prediction; R^2 - coefficient of determination of the best fit regression line not forced through the origin. P-value - probability associated with an F-test to reject the simultaneous hypothesis that the slope = 1 and the intercept = 0, when NS (P>0.1) in the hypothesis is not rejected (Dent and Blackie, 1979); C_b - accuracy of the model (Lin, 1989); ρ_c - concordance correlation coefficient (CCC) (Lin, 1989).



Solid line indicates unitary equivalence (X = Y).

Figure 1 - Relationship between digestibility coefficients of dry matter (DM; A), crude protein (CP; B), neutral detergent fiber (NDF; C) and fat (D) predicted by the Small Ruminant Nutrition System and observed in this study.



Solid line indicates unitary equivalence (X = Y).

Figure 2 - Relationship between dry matter intake (DMI; A), metabolizable energy for maintenance (ME_M; B), metabolizable energy (ME) balance (C) and body weight variation (ΔBW; D) predicted by the Small Ruminant Nutrition System and observed in this study, except for DMI, for which an equation of the AFRC (1998) was used.

CONCLUSÕES GERAIS

O experimento foi realizado no Departamento de Zootecnia da Universidade Federal de Viçosa, com o objetivo de mensurar a mobilização das reservas corporais e a eficiência energética de cabras no início da lactação. Adicionalmente, foi realizado uma avaliação da dieta e da exigência de energia destes animais pelo programa *Small Ruminant Nutrition System* (SRNS).

Assim, conclui-se que:

Ocorre uma intensa mobilização das reservas corporais durante as oito semanas pós-parto. Sendo que nas três primeiras semanas de lactação além da mobilização da gordura ocorre também mobilização da proteína.

As cabras mobilizam energia não somente das gorduras internas, mas também, da carcaça e dos componentes não-carcaça, em média de 6,48 MJ/d.

No perído que compreende o parto a oitava semana de lactação, as cabras tem uma variação da exigência de energia para mantença de 3,38 a 2,57 Mcal/$BW^{0,75}$ e uma exigência de energia para lactação de 1,30 a 0,83 Mcal/kg.

A eficiência de utilização da energia mobilizada é de 74% e a eficiência de utilização da energia dietética é de 93%.

O SRNS tem baixa acurácia para predição da qualidade da dieta e boa acurácia para predição das reservas corporais de cabras em início de lactação.

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Tabela 1 – Efeito das semanas de lactação sobre consumo da matéria seca (CMS), consumo de FDN (CFDN), consumo de proteína bruta (CPB) e o consumo de extrato etéreo (CEE)

Ordem de parto	Nº cabra	Baia	CMS, kg/d	CFDN, kg/d	CPB, kg/d	CEE, kg/d
	4097	REF2	0.551			
Parto	4127	REF 1	0.252			
	3787	REF3	0.826			
	3270	30	1.024	0.591	0.089	0.022
	3906	29	0.616	0.410	0.050	0.012
7º	2687	1	0.722	0.491	0.059	0.037
	4085	2	0.506	0.389	0.054	0.032
	3874	16	1.545	0.918	0.169	0.074
	3640	4	0.496	0.483	0.032	0.034
	4198	45	1.335	0.649	0.173	0.064
	3924	3	1.165	0.631	0.136	0.056
14º	3968	22	0.379	0.368	0.031	0.017
	4009	12	1.179	0.660	0.135	0.065
	3356	6	1.846	0.892	0.238	0.091
	4190	23	1.887	0.920	0.244	0.086
	4212	46	1.449	0.729	0.186	0.068
	4204	11	0.622	0.459	0.050	0.034
21º	4312	10	1.473	0.722	0.189	0.073
	4305	34	1.106	0.535	0.144	0.057
	4382	14	1.708	0.815	0.222	0.083
	4338	13	1.669	0.804	0.216	0.083
	4110	17	1.099	0.574	0.132	0.050
	4118	36	1.566	0.769	0.198	0.070
28º	4404	41	1.273	0.618	0.155	0.063
	3905	31	1.484	0.748	0.178	0.072
	4252	43	2.014	0.981	0.260	0.092
	4376	44	2.063	1.009	0.264	0.094
	4244	32	1.314	0.634	0.157	0.058
	4257	38	1.642	0.771	0.209	0.083
35º	4224	48	1.662	0.807	0.216	0.079
	4133	9	1.663	0.816	0.216	0.073
	4035	27	1.021	0.555	0.122	0.044
	4426	50	1.380	0.687	0.176	0.070
	4194	39	1.069	0.581	0.116	0.049
	4274	21	1.088	0.609	0.129	0.051
42º	4337	19	1.447	0.722	0.184	0.069
	4350	24	1.457	0.724	0.185	0.069
	4366	20	1.418	0.695	0.181	0.068
	4476	26	1.749	0.865	0.224	0.083
	4199	5	2.003	1.048	0.251	0.096
	4284	8	2.067	1.017	0.267	0.098
49º	4342	35	1.906	0.917	0.241	0.086

	4256	15	1.577	0.793	0.203	0.077
	4273	37	1.540	0.753	0.192	0.069
	4327	49	0.616	0.429	0.058	0.026
	4412	33	1.551	0.749	0.203	0.072
	4381	28	1.459	0.714	0.187	0.072
56º	4395	47	1.848	0.902	0.240	0.087
	4095	7	1.939	0.957	0.247	0.091
	4130	42	1.971	0.927	0.255	0.092
	4398	25	0.658	0.420	0.068	0.030

Tabela 2 – Efeito das semanas de lactação sobre a prdução de leite, porcentagens de gordura (%Gord), proteína (%Prot) e lactose (%Lac) do leite

Ordem de parto	Nº cabra	Baia	Produção de leite (kg/d)	%Gord	%Prot	%Lac
Parto	4097	REF2	1.83	12.50	4.12	2.48
	4127	REF 1	0.47	11.50	5.98	2.03
	3787	REF3	2.57	9.30	4.59	2.26
7º	3270	30	3.07	7.24	6.90	2.62
	3906	29	2.07	8.01	6.45	4.77
	2687	1	1.45	8.03	6.62	3.69
	4085	2	1.51	7.18	5.78	4.26
	3874	16	3.72	6.66	4.99	4.60
	3640	4	0.45	5.61	6.98	3.06
14º	4198	45	3.30	6.12	5.38	3.43
	3924	3	1.19	5.03	5.53	4.30
	3968	22	0.23	7.38	6.31	3.52
	4009	12	1.70	3.85	4.70	3.51
	3356	6	3.89	7.77	4.44	3.75
	4190	23	3.08	6.06	7.45	4.68
21º	4212	46	2.22	5.24	4.50	3.19
	4204	11	1.32	9.01	5.89	3.04
	4312	10	2.24	4.84	4.23	4.29
	4305	34	2.19	4.67	3.15	4.98
	4382	14	2.85	5.09	3.56	4.48
	4338	13	2.83	4.94	4.12	4.72
28º	4110	17	1.51	5.65	4.29	4.74
	4118	36	3.22	5.14	4.93	4.25
	4404	41	1.98	5.89	4.08	4.16
	3905	31	3.27	5.25	3.40	3.36
	4252	43	3.58	5.69	3.56	4.63
	4376	44	3.46	3.93	3.73	4.17
35º	4244	32	2.57	4.48	3.84	4.16
	4257	38	2.12	5.59	4.07	3.64
	4224	48	2.50	4.73	3.90	3.46
	4133	9	2.51	4.89	3.88	4.20
	4035	27	1.29	4.99	3.86	4.72
	4426	50	1.61	5.47	3.89	4.21
42º	4194	39	1.80	6.49	3.88	4.58
	4274	21	1.60	5.70	4.71	4.18
	4337	19	1.87	3.83	3.67	4.27
	4350	24	2.06	4.26	3.87	4.49
	4366	20	1.90	4.91	3.97	4.59
	4476	26	3.45	4.80	3.35	4.66
49º	4199	5	3.17	5.22	3.93	4.93
	4284	8	3.49	4.78	3.93	4.71
	4342	35	3.85	3.85	3.48	4.47

	4256	15	2.74	3.96	3.31	4.39
	4273	37	1.81	4.43	3.76	4.25
	4327	49	1.18	6.10	3.76	4.12
	4412	33	1.79	4.63	3.37	4.74
	4381	28	1.98	4.42	3.81	4.45
56º	4395	47	3.29	3.92	3.20	4.94
	4095	7	3.33	4.08	3.66	4.25
	4130	42	3.29	4.12	3.51	4.47
	4398	25	0.87	5.03	3.60	3.59

Tabela 3 – Efeito das semanas de lactação sobre peso corporal inicial e final, peso de corpo vazio e escore de condição corporal

Ordem de parto	Nº cabra	Baia	PCi (kg)	PCf (kg)	PCZ (kg)	ECCi	ECCf
Parto	4097	REF2	62.20	62.20	51.81	4	4
	4127	REF 1	72.40	72.40	62.12	3.5	3.5
	3787	REF3	66.30	66.30	56.39	3.5	3.5
7º	3270	30	61.60	52.70	43.83	2.5	2
	3906	29	73.10	63.80	53.43	3.5	3
	2687	1	63.05	58.55	51.49	3	3
	4085	2	59.00	56.70	54.43	3	3
	3874	16	84.90	80.40	58.35	3.5	3
	3640	4	56.70	56.20	50.15	2.5	2.5
14º	4198	45	53.10	49.60	39.76	2.5	2
	3924	3	62.15	59.80	47.66	3	2
	3968	22	50.30	38.95	35.63	2.5	1.5
	4009	12	67.60	62.10	55.14	3.5	2
	3356	6	65.45	58.35	45.48	4	3
	4190	23	51.60	49.90	37.20	2.5	2.5
21º	4212	46	42.25	40.30	29.42	3	3
	4204	11	49.00	35.95	30.63	2	2
	4312	10	62.40	61.00	47.73	2	3
	4305	34	37.90	34.10	26.41	2.5	2.5
	4382	14	56.60	56.50	43.09	3	3.5
	4338	13	62.75	59.15	42.38	3	3
28º	4110	17	51.90	47.45	39.23	3	2.5
	4118	36	56.15	50.45	41.49	3	3
	4404	41	58.35	54.35	41.61	3	3
	3905	31	59.95	52.70	42.87	4	3
	4252	43	59.65	58.40	45.47	3.5	3.5
	4376	44	50.85	53.50	41.17	3	3
35º	4244	32	65.30	48.85	38.51	4	2.5
	4257	38	56.70	56.10	44.52	3.5	3.5
	4224	48	52.70	45.65	34.10	3	2.5
	4133	9	60.70	56.00	45.18	3.5	3
	4035	27	49.25	47.00	38.08	2.5	2.5
	4426	50	52.00	51.20	40.29	2.5	2.5
42º	4194	39	65.20	43.45	34.84	3.5	2
	4274	21	63.05	52.55	44.10	3.5	2.5
	4337	19	51.95	54.50	43.86	2.5	3
	4350	24	62.45	56.95	45.57	3	2.5
	4366	20	51.60	53.15	39.05	3	3
	4476	26	57.40	52.65	37.88	3.5	2.5
49º	4199	5	49.70	49.55	35.13	2.5	2.5
	4284	8	55.05	52.50	37.42	2.5	2.5
	4342	35	61.15	52.60	37.02	3	2.5

	4256	15	48.25	46.70	32.15	3	3
	4273	37	50.15	48.60	38.49	2.5	2.5
	4327	49	55.60	36.60	29.61	3	2
	4412	33	39.65	38.80	29.19	2.5	2.5
	4381	28	47.10	46.80	35.26	3	3
56º	4395	47	53.75	48.65	34.69	3.5	3
	4095	7	62.40	58.80	45.06	3.5	3
	4130	42	51.15	46.05	36.72	2.5	2
	4398	25	57.40	39.85	32.40	2.5	2

Tabela 4 – Efeito das semanas de lactação sobre composição corporal das cabras

			Composição corporal		
Ordem de parto	Nº cabra	Baia	PB (kg)	Gord (kg)	Energia (Mcal)
Parto	4097	REF2	7.46	13.22	166.31
	4127	REF 1	8.85	14.17	183.02
	3787	REF3	7.83	13.56	171.56
7º	3270	30	6.16	7.33	103.65
	3906	29	7.64	11.37	149.88
	2687	1	6.90	13.26	163.43
	4085	2	6.20	14.28	169.08
	3874	16	8.72	13.57	176.64
	3640	4	6.84	13.78	168.04
14º	4198	45	6.31	5.85	90.60
	3924	3	6.22	12.09	148.68
	3968	22	5.48	5.30	80.71
	4009	12	7.52	14.90	182.39
	3356	6	6.17	10.37	132.20
	4190	23	5.37	5.81	84.90
21º	4212	46	4.28	2.85	50.90
	4204	11	4.62	2.76	51.97
	4312	10	6.11	11.10	138.75
	4305	34	4.09	2.95	50.79
	4382	14	5.96	8.69	115.24
	4338	13	6.20	8.25	112.43
28º	4110	17	6.17	8.37	113.43
	4118	36	6.01	10.51	132.64
	4404	41	6.16	9.01	119.41
	3905	31	6.51	10.64	136.68
	4252	43	6.27	9.51	124.65
	4376	44	6.78	7.57	109.35
35º	4244	32	6.78	8.00	113.38
	4257	38	6.39	9.41	124.46
	4224	48	5.08	3.95	65.74
	4133	9	6.85	9.22	125.20
	4035	27	5.01	8.01	103.48
	4426	50	6.18	6.53	96.20
42º	4194	39	5.33	3.75	65.25
	4274	21	6.48	11.10	140.84
	4337	19	6.21	11.09	139.22
	4350	24	6.53	9.44	125.47
	4366	20	5.93	6.74	96.74
	4476	26	5.57	5.38	81.98
49º	4199	5	5.14	3.20	59.01
	4284	8	5.75	4.97	79.15
	4342	35	5.71	4.92	78.45

	4256	15	4.97	3.31	59.16
	4273	37	5.68	4.25	71.92
	4327	49	4.59	2.74	51.67
	4412	33	4.38	2.80	51.02
	4381	28	4.84	5.21	76.26
56º	4395	47	5.39	4.12	69.09
	4095	7	6.34	7.92	110.17
	4130	42	5.75	4.54	75.06
	4398	25	4.70	4.83	71.84