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AUMENTO DE SÓLIDOS TOTAIS NA DIETA LÍQUIDA DE BEZERROS LEITEIROS

RAFAEL ALVES DE AZEVEDO

Belo Horizonte

Escola de Veterinária da UFMG

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Rafael Alves de Azevedo

Aumento de sólidos totais na dieta líquida de bezerros leiteiros

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Orientador: Prof.ª Sandra Gesteira Coelho
Coorientadores: Prof.ª Ângela Maria Quintão Lanna
Dr.ª Fernanda Samarini Machado

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Prof.ª Sandra Gesteira Coelho

(Orientadora)

Dr.ª Mariana Magalhães Campos

Dr. Luiz Gustavo Ribeiro Pereira

Prof. Ricardo Reis Silva

Prof. Antônio Último de Carvalho

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RESUMO

Embora os estudos apontem claramente para ganhos ao se aumentar o volume de leite oferecido às bezerras, muitos produtores relutam em adotar esse programa devido a redução do volume de leite a ser comercializado. Uma estratégia que pode contornar em parte esse problema seria a adição de sucedâneo em um volume fixo de dieta líquida, aumentando-se o teor de sólidos totais (ST) da dieta fornecida. Esse trabalho foi executado com o objetivo de determinar os efeitos desta estratégia sobre a osmolalidade do produto final, o consumo, o desempenho dos animais e a saúde das bezerras durante o aleitamento e pós-aleitamento, bem como a taxa de passagem, a digestibilidade aparente dos nutrientes, o desenvolvimento ruminal e de outros órgãos, e a composição corporal de bezerros leiteiros. Bezerras mestiças Holandês-Gir (n = 60) e bezerros mestiços Holandês-Gir (n = 32) foram aleatoriamente distribuídos em 4 tratamentos, mantendo o equilíbrio para o peso corporal ao nascimento, concentração de proteína total sérica e composição genética. O sucedâneo do leite foi adicionado ao leite integral para ajustar os ST em 12,5; 15,0; 17,5 e 20,0%. Todos os animais receberam 6 L/d de dieta liquida, dividida em duas refeições iguais (08:00 e 16:00 h), fornecida em baldes de 5 a 55 dias de idade. Para as bezerras, entre 56 a 59 dias, o volume foi reduzido pela metade (0800h) e aos 60 dias essas foram desaleitadas, sendo acompanhadas até os 90 dias de idade. Os bezerros foram desaleitados aos 56 dias de idade. O concentrado e a água foram fornecidos a vontade. Aos 70 dias de idade foi incluída na dieta das bezerras silagem de milho. O consumo e a saúde de todos os animais foram avaliados diariamente e os parâmetros de desempenho e desenvolvimento corporal semanalmente. Nas fêmeas o pH ruminal foi mensurado a partir dos 14 dias de idade. Nos machos, aos 43 dias de idade, a taxa de passagem pelo trato gastrointestinal foi avaliada utilizando-se óxido de cromo como marcador externo; entre 50 e 55 dias de idade os animais foram submetidos a ensaio de digestibilidade aparente dos nutrientes e aos 56 dias de idade foram eutanasiados para posterior avaliação dos órgãos e da composição da carcaça. Fragmentos do rúmen, omaso e intestinos foram coletados para a avaliação histológica e amostras do conteúdo ruminal e do ceco foram coletadas para a mensuração do pH e da concentração de AGV. Após análises dos tratamentos, foram verificados teores de 13,5; 16,1; 18,2 e 20,4% de ST. A osmolalidade variou entre 264,9 e 533,5 mOsm/L. As bezerras apresentaram consumo dos tratamentos (kg/d) similar entre os grupos a partir da quarta semana. Durante a fase de aleitamento ocorreu similar consumo de concentrado e foi verificado aumento linear do consumo de água com o aumento da % de ST. O pH ruminal durante a fase de aleitamento foi semelhante entre os tratamentos (6,2), bem como os dias em diarreia. O aumento da % de ST aumentou linearmente as medidas de desenvolvimento corporal e de desempenho, porém reduziu linearmente a eficiência alimentar. No pós-aleitamento o consumo de concentrado, de silagem de milho, de matéria seca total e água foram semelhantes entre os tratamentos, bem como o desempenho e a eficiência alimentar. Já as medidas de desenvolvimento corporal apresentaram aumento linear de acordo com o aumento da % de ST. Esses dados mostram que as concentrações de ST avaliadas não foram capazes de alcançar o ponto máximo de influência do consumo de ST sob o desempenho das bezerras, sugerindo que novas estratégias de aleitamento com o fornecimento de maiores % de ST devem ser avaliadas para se alcançar maiores desempenho durante o aleitamento. Nos machos, observou-se que o aumento da % de ST não alterou a taxa de passagem e a digestibilidade dos nutrientes, bem como os parâmetros de desenvolvimento dos pré-estômagos, intestino e a composição corporal dos bezerros.

Palavras-chave: bovinocultura de leite, consumo, desempenho, digestibilidade, novilhas, rúmen, sistemas de aleitamento

ABSTRACT

Although studies clearly point advantages for increasing the volume of milk provided to calves, many dairy farmers are reluctant to adopt this nutritional strategy due to the reduced volume of milk to be sold. One strategy that could partly work around this problem would be the addition of milk replacer in a fixed volume of liquid diet, increasing the total solids (TS) content of the diet provided. This research was carried out to determine the effects of this alternative on the osmolality of the final product, intake, performance and health of calves during pre and postweaning, as well as the rate of passage, apparent digestibility of nutrients, rumen and other organ development, and body composition of dairy calves. Crossbreed Holstein-Gir heifers (n = 60) and crossbred Holstein-Gir calves (n = 32) were randomly assigned to 4 treatments, maintaining a balance regarding body weight at birth, total serum protein concentration and genetic composition. Milk replacer was added to whole milk to adjust TS at 12.5; 15.0; 17.5 and 20.0%. All animals received 6 L/d of liquid diet, divided in two equal meals (0800 and 1600 h), supplied in buckets from 5 to 55 d of age. For heifers, between 56 and 59 days of age, the quantity was reduced by half (0800h) and at 60 d of age they were weaned, being monitored until 90 d of age. The calves were weaned at 56 d of age. Starter and water were provided *ad libitum*. At 70 d of age, corn silage was included in heifer's diet. Intake and health of all animals were evaluated daily whilst body performance and development parameters were performed weekly. From 14 d of age, the ruminal pH was measured in heifers. The rate of passage through the gastrointestinal tract was evaluated using chromium oxide as external marker in calves at 43 d of age; between 50 and 55 d of age, it was performed an evaluation of apparent digestibility of nutrients and at 56 d of age the calves were euthanized for further evaluation of the organs and carcass composition. Fragments of rumen, omasum and intestines were collected for histological evaluation, and samples of ruminal contents and cecum were collected for pH and VFA measurements. After analyzing the treatments, the TS levels of 13.5; 16.1; 18.2 and 20.4% were verified. The osmolality ranged from 264.9 to 533.5 mOsm/L. The heifers showed similar intake regardless (kg/d) of treatment from the fourth week. During the preweaning period, the starter intake was similar and there was a linear increased in water intake with the increase in TS%. The ruminal pH during the preweaning period was similar between the treatments (6.2) as well as the days of diarrhea. The increase in TS% linearly increased body development and performance measures, but linearly reduced feed efficiency. During the postweaning, the starter and water intake, corn silage and total dry matter were similar between treatments, as well as performance and feed efficiency. However, the body development measurements showed a linear increased according to the increase in TS%. These data show that the TS concentrations evaluated were not able to reach the peak of influence of TS intake under heifer’s performance, suggesting that new strategies with the provision of higher TS% should be evaluated to achieve greater performance during preweaning. In calves, it was observed that the increase in TS% did not alter the rate of passage and nutrient digestibility, as well as the development parameters of the pre-stomachs, intestine and calves' body composition.

Key-words: Dairy production, digestibility, heifers, intake, milk system, performance, rumen

INTRODUÇÃO

Durante a fase de aleitamento a recomendação adotada mundialmente consiste no fornecimento da dieta líquida de modo restrito, equivalente a aproximadamente 10% do peso corporal (PC) do bezerro (Jasper e Weary, 2002). Essa estratégia, junto com o desaleitamento precoce, é utilizada para reduzir os custos com a alimentação, além de incentivar o consumo precoce de concentrado pelos bezerros (Yavuz et al., 2015), sem comprometimento do desenvolvimento ruminal. Entretanto, a alimentação restrita durante a fase de aleitamento proporciona baixo ganho médio diário (GMD), além de maior risco de doenças e comportamentos indicativos de fome crônica, demonstrando que esse método de alimentação pode reduzir o bem-estar dos bezerros.

A adoção de aleitamento com 4 L/d é pratica convencional em fazendas leiteiras, quantidade inferior ao que é ingerido por bezerros aleitados à vontade (8 a 12 L/d), os quais consomem mais que o dobro de dieta líquida fornecida no sistema convencional, mantendo-os saudáveis e com maior GMD antes do desaleitamento. Mesmo que o maior volume de dieta líquida proporcione menor consumo de alimentos sólidos antes do desaleitamento, além de gerar um maior custo com alimentação líquida para o produtor, esse fato pode não permanecer após o mesmo, já que o GMD e a ingestão de alimentos sólidos após a fase de aleitamento geralmente são semelhantes entre bezerros alimentados convencionalmente ou com maiores quantidades de dieta líquida. Porém, a diferença de PC obtida pelos animais aleitados à vontade ou com maior volume de dieta líquida pode persistir durante várias semanas após a fase de aleitamento.

Os bezerros alimentados à vontade ou com maior quantidade de dieta líquida apresentam maior taxa de crescimento e menor morbidade. Assim, nas últimas duas décadas, novos programas de aleitamento denominados de acelerado, melhorado ou intensificado foram propostos (Drackley, 2004).

Além do aumento do volume fornecido, o aumento da concentração dos nutrientes pode ser uma opção para os programas artificiais de aleitamento, modificando a ingestão de nutrientes ao longo do dia. Objetiva-se com esse trabalho determinar os efeitos da inclusão de sucedâneo ao leite integral, com aumento no teor de ST, sobre o consumo de alimentos, desempenho e desenvolvimento, eficiência alimentar e a saúde de bezerras nas fases de pré e pós-aleitamento, bem como a ingestão de alimentos, desempenho, eficiência alimentar, taxa de passagem, digestibilidade aparente de nutrientes, desenvolvimento de rúmen e de outros órgãos e a composição corporal de bezerros machos durante o período de aleitamento.

CAPÍTULO I – REVISÃO DE LITERATURA

1. Aumento do volume da dieta líquida

No oferecimento de dieta líquida à vontade, os bezerros consomem em média 22,5 a 25% do PC por dia, o que é equivalente a, aproximadamente, 9 a 10 L/d de leite integral para bezerros da raça Holandês com PC de 40 kg (Jasper e Weary, 2002; Von Keyserlingk et al., 2006; Khan et al., 2007a,b; Borderas et al., 2009; Sweeney et al., 2010). Esta quantidade é consumida em 6 a 10 períodos de sucção ao longo do dia (Miller-Cushon et al., 2013), cada um com duração de aproximadamente de 10 minutos (de Passillé, 2001), em intervalos mínimos entre as refeições de 40 minutos (Von Keyserlingk et al., 2004). Já nos programas de aleitamento intensivo que preconizam o aumento do volume da dieta líquida, são fornecidas quantidades em volumes próximos a 20% do PC dos bezerros, variando entre 6 a 8 L/d, divididos em duas vezes ao dia.

1.1 Consumo e desempenho de bezerros aleitados com maiores volumes de dieta líquida

O aumento do volume da dieta líquida, mantendo-se as concentrações de ST entre as dietas testadas, pode provocar diferentes resultados sobre o consumo dos animais, sendo importante se atentar a qual o volume adotado em cada experimento, bem como as condições experimentais adotadas, podendo ser verificado redução no consumo de concentrado durante o aleitamento (Jasper e Weary, 2002; Cowles et al., 2006; Morrison et al., 2009; Hill et al., 2010; Bach et al., 2013; Miller-Cushon et al., 2013; Kiezebrink et al., 2015; Silva et al., 2015; Gelsinger et al., 2016; Hill et al., 2016a) ou similaridade (Azevedo et al., 2014; Silper et al., 2014; Rodrigues et al., 2016) de consumo em relação ao sistema convencional. Porém, animais em ambos os sistemas geralmente apresentam consumo de concentrado similar no pós-aleitamento (Bach et al., 2013; Yavuz et al., 2015), e dependendo da estratégia de aleitamento adotada com maior volume de dieta líquida, podem chegar a apresentar até maior consumo de concentrado (Khan et al., 2007a,b) do que os animais aleitados convencionalmente. O maior fornecimento de volume de dieta líquida também pode reduzir (Kiezebrink et al., 2015) ou não (de Passillé et al., 2011; Azevedo et al., 2014) o consumo de água pelos bezerros em relação aqueles aleitados convencionalmente, porém, poucos estudos avaliaram esse parâmetro.

Khan et al. (2007b) avaliaram o fornecimento de maior volume de leite, seguido por redução no volume de acordo com a idade dos animais, em um sistema denominado de *Step-Down*, e relataram maior consumo de dieta líquida (média de 9 kg/d no *Step-Down* contra 4,41 kg/d no sistema convencional) até os 28 dias de idade, com redução de 14% no consumo de concentrado em relação aos aleitados convencionalmente. Segundo os autores, os bezerros do sistema *Step-Down* apresentaram quadro hipofágico pela maior concentração plasmática de insulina e menor concentração plasmática de glucagon durante a fase de maior fornecimento de dieta líquida, em relação àqueles aleitados convencionalmente. Também foram observadas concentrações sanguíneas mais elevadas de glicose, bem como menores concentrações de ácidos graxos não esterificados (AGNE) nos bezerros do sistema *Step-Down* na fase de maior fornecimento de dieta líquida, o que, segundo os autores, pode refletir o início de lipólise nos bezerros aleitados convencionalmente, para satisfazer o menor fornecimento de energia nesse sistema. Esses resultados suportam a hipótese proposta e confirmam que a condição hipofágica foi causada por substâncias químicas (glicose e insulina) e por efeito mecânico (enchimento intestinal contínuo causado pela formação do coágulo no abomaso) que podem reduzir o consumo de concentrado e de feno em bezerros alimentados com maior volume de dieta líquida.

Porém, mesmo com o menor consumo de concentrado observado em animais recebendo maior volume de dieta líquida, melhores taxas de crescimento são observadas, com maior GMD (Jasper e Weary, 2002; Bartlett et al., 2006; Khan et al, 2007a,b; Borderas et al., 2009; Uys et al., 2011; Kmicikewycz et al., 2013; Geiger et al., 2016; Rodrigues et al., 2016) e maior desenvolvimento estrutural (Cowles et al., 2006; Kmicikewycz et al., 2013; Yavuz et al., 2015; Geiger et al., 2016). Bach et al. (2013) observaram que bezerros recebendo 8 L/d de sucedâneo apresentaram taxas superiores de crescimento quando comparados a animais alimentados com 6 L/d, porém, no período entre o aleitamento e o desaleitamento, quando o volume de 8 ou 6 L de sucedâneo foi reduzido para 4 L/d, aqueles que estavam recebendo menor volume apresentaram maior taxa de crescimento do que os que estavam recebendo maior volume de dieta líquida. Segundo os autores, nenhuma diferença foi observada no PC aos 228 dias de idade, porém, a ausência de diferença após o desaleitamento pode ter ocorrido pelo método de desaleitamento imposto de forma similar entre os grupos, o qual pode ter sido muito agressivo para os animais que foram aleitados com maior volume de dieta líquida. Já

Conneely et al. (2014), alimentaram bezerros com leite a 15% do PC e verificaram que o maior fornecimento de leite resultou em animais mais pesados no início e no final da fase de aleitamento, além de reduzir os dias necessários para atingir a meta de PC ao desaleitamento.

Yavuz et al. (2015) testaram três diferentes sistemas de aleitamento: baixo volume de leite pasteurizado (4 L/d até 35 dias de idade); moderado volume (6 L/d até 49 dias de idade) e alto volume (8 L/d até 49 dias de idade) e verificaram que o maior fornecimento de dieta líquida proporcionou maior taxa de crescimento dos bezerros, além de melhoria na eficiência alimentar, porém, o estresse durante o desaleitamento foi maior para o grupo com alto volume de dieta líquida quando comparado ao de baixo e médio volume de dieta líquida, os quais apresentaram menor consumo de concentrado durante a fase de aleitamento. Yunta et al. (2015) avaliaram o fornecimento de 4, 6 ou 8 L/d de sucedâneo até os 57 dias de idade e verificaram maior GMD para os animais aleitados com 8 L/d em relação aos demais tratamentos. Já no pós-aleitamento (até 300 dias de idade), mesmo que o maior PC tenha se mantido para os grupos aleitados com o maior volume de dieta líquida, os autores observaram que todos os grupos igualaram a taxa de GMD.

1.2 Trato digestório de bezerros aleitados com maiores volumes de dieta líquida

Segundo Baldwin et al. (2004), variações no tipo e na forma de nutrientes fornecidos, o uso total de nutrientes pelo intestino e os nutrientes disponíveis para suportar o crescimento dos bezerros podem alterar a proliferação celular do trato digestório. Após iniciar o consumo de dieta sólida e o subsequente estabelecimento da fermentação ruminal, o rúmen passa por desenvolvimento físico (aumento de massa e pelo crescimento das papilas ruminais) e metabólico (Baldwin et al., 2004). O desenvolvimento do rúmen envolve a aquisição e o estabelecimento do ecossistema microbiano, muscularização e vascularização da parede, desenvolvimento papilar e o início da ruminação e da motilidade do rúmen, não sendo impulsionado somente pela presença de ácidos graxos voláteis (AGV), mas também pelos nutrientes fornecidos a partir da dieta líquida, estando o desenvolvimento do rúmen e do intestino delgado vinculados (Khan et al., 2016).

Khan et al. (2007b) relataram que o aumento da ingestão de alimentos sólidos observado após a redução do volume de leite nos bezerros em sistema *Step-Down* resultou em início precoce da fermentação e de desenvolvimento ruminal, mesmo sendo observado maior consumo de concentrado e de feno nos primeiros 28 dias de idade nos animais aleitados convencionalmente. Segundo os autores, o maior desenvolvimento ruminal foi comprovado pelos maiores valores de peso dos pré-estômagos e maior desenvolvimento de papilas ruminais, bem como pela menor concentração sanguínea de glicose e maior concentração sanguínea de nitrogênio uréico, atribuído a maior concentração de amônia ruminal e de β-hidroxibutirato em bezerros alimentados em *Step-Down* quando comparados àqueles alimentados convencionalmente. Segundo os autores essas variáveis sanguíneas indicam claramente as mudanças fisiológicas na principal fonte de energia, a glicose, para AGV, em bezerros com rúmen metabolicamente mais funcional quando aleitados com maior volume de dieta líquida na forma *Step-Down* em relação aos animais aleitados convencionalmente.

Avaliando também um sistema *Step-Down* de aleitamento (6 L/d de 6 aos 25 dias de idade; 4 L/d de 26 a 45 dias de idade e 2 L/d de 46 a 59 dias de idade) contra sistema convencional (4 L/d de 6 aos 59 dias de idade), Azevedo et al. (2013) verificaram que mesmo que o sistema de aleitamento não tenha interferido no consumo de concentrado, de feno, de matéria seca (MS) total e no PC final vazio, foi observado que o aleitamento em *Step-Down* proporcionou maior PC final, maiores pesos absolutos do trato digestório, do rúmen-retículo, do omaso e dos intestinos e maiores pesos do omaso e dos intestinos em relação ao PC vazio, bem como maior índice mitótico das papilas ruminais, o que demonstra que esse sistema pode ser uma alternativa para melhorar o desenvolvimento ruminal e o desempenho de bezerros.

Kristensen et al. (2007) observaram que o peso do rúmen-retículo, do omaso e do estômago total (rúmen-retículo, omaso e abomaso) dos bezerros aos 35 dias de idade diminuiu linearmente com o aumento do fornecimento de sucedâneo (3,1; 4,8; 6,6 e 8,3 kg/d), porém, os pesos do abomaso e o comprimento de papilas no átrio ou na região ventral do saco ruminal não foram afetados pelo aumento da dieta líquida. Segundo os autores, a variação relativamente grande na ingestão de concentrado proporcionada pelas diferentes quantidades de sucedâneo teve pequeno efeito sobre o ambiente ruminal, porém, aqueles animais que receberam menor volume de dieta líquida apresentaram aumento das concentrações sanguíneas de AGV e de corpos cetônicos, bem como aumento na massa de conteúdo da digesta e pesos de rúmen-retículo e de omaso.

Já Silper et al. (2014) verificaram que diferentes estratégias de aleitamento (4 L/d por 60 d; 6 L/d até 29 d e 4 L/d de 30 a 60 d; 6 L/d até 60 d) com sucedâneo não influenciaram o peso vazio do rúmen-retículo de bezerros, com exceção do omaso, o qual foi mais pesado aos 90 d em bezerros aleitados com 6 L/d de dieta líquida, e para o abomaso, que foi mais pesado para os bezerros que receberam 6 L/d até 29 d e 4 L/d de 30 a 60 d. Também foi verificado que o tamanho das papilas ruminais presentes no saco ventral não foi afetado pela estratégia de fornecimento da dieta líquida, embora a concentração de propionato tenha sido diferente entre os grupos, com maior concentração para as estratégias com 4 L/d até 60 d e a de 6 L/d até 29 d e 4L/d de 30 a 60 d do que no grupo que recebeu 6 L/d até os 60 dias de idade, os quais apresentaram maior índice mitótico do que aqueles alimentados com 4 L/d durante o mesmo período. Segundo os autores, a semelhança entre a maioria dos parâmetros ruminais ocorreu devido a similaridade no consumo de concentrado entre os grupos avaliados. No entanto, segundo Baldwin et al., (2004) os mecanismos que controlam a diferenciação ruminal ainda não são suficientemente compreendidos.

1.3 Digestibilidade dos nutrientes de bezerros aleitados com maiores volumes de dieta líquida

O maior volume de dieta líquida para os bezerros disponibilizará maior concentração de nutrientes, o que pode elevar a secreção intestinal de alguns hormônios reguladores de consumo, como a colecistoquinina, a qual pode conduzir a maior tempo de retenção do alimento no trato gastrointestinal, aumentando assim a digestibilidade dos nutrientes (Stanley et al., 2005; Silva et al., 2015).

Hill et al. (2010) forneceram 440, 660 ou 1.090g de MS de sucedâneos para bezerros Holandês até os 49 dias de idade, sendo todos os tratamentos reconstituídos para 134 g em 1 L de água, com concentrado a vontade, e avaliaram os efeitos sobre a digestibilidade dos nutrientes. Segundo os autores, a digestibilidade da MS e da matéria orgânica (MO) foi menor nos animais aleitados com 1.090 g de MS, demonstrando que o adicional de nutrientes consumido não foi utilizado de forma eficiente, porém, não foram observadas diferenças para as digestibilidades da proteína bruta (PB) e da gordura das dietas entre os grupos. Nesse mesmo trabalho, em um segundo experimento, os autores demonstraram que bezerros alimentados com maior volume de dieta líquida tiveram menor digestibilidade da MS, MO, PB e gordura no pós-aleitamento, provavelmente associado com o menor consumo de concentrado na fase inicial.

Ao avaliar o fornecimento de três sistemas de aleitamento com sucedâneo reconstituído para 14% ST (convencional = 0,66 kg/d, durante 39 dias; 0,33 kg/d, durante 3 dias; moderado = 0,88 kg/d, durante 5 dias; 1,1 kg/d, durante 23 dias; 0,66 kg/d, durante 18 dias; 0,33 kg/d, durante 3 dias; intensivo = 0,88 kg/d, durante 5 dias; 1,1 kg/d, durante 37 dias, 0,56 kg/d, durante 7 dias) e a digestibilidade dos nutrientes na fase de pós-aleitamento (11 ou 16 semanas de idade), Hill et al. (2016) relataram que a digestibilidade da MS, da MO, da fibra em detergente neutro (FDN), da fibra em detergente ácido (FDA) em bezerros alimentados intensivamente foi menor do que nos bezerros alimentados moderadamente na 11ª semana, justificando a perda de ganho de peso e das medidas de largura de quadril nesses animais. No geral, a digestibilidade dos nutrientes foi menor para bezerros alimentados intensivamente em relação aos animais alimentados moderadamente, os quais foram similares aos aleitados convencionalmente, sendo que a digestibilidade da PB foi maior para bezerros alimentados moderadamente em relação aos alimentados convencionalmente, demonstrando que esse programa foi efetivo em manter o desenvolvimento digestivo dos bezerros. Também foi relatado que a digestibilidade de todos os nutrientes, com exceção do amido, foi maior na 16ª semana em relação à 11ª semana, em consequência da maior maturidade digestiva dos animais de acordo com o avanço da idade e do manejo alimentar, sendo mais indicada, segundo os autores, para avaliações de digestibilidade em bezerros.

Entretanto, não é possível determinar se a variação na digestibilidade dos nutrientes ocorre como resultado do consumo da dieta líquida ou do concentrado, sendo importante o entendimento e o efeito de cada variável para correto entendimento das possíveis interações entre eles e os reais efeitos da maior quantidade de dieta líquida nos sistemas de aleitamento para bezerros (Silva et al., 2015). Sendo assim, Silva et al. (2015) avaliaram o efeito de diferentes volumes de leite (2; 4 e 8 L/d), com ou sem fornecimento de concentrado, para bezerros mestiços (Holandês x Gir) até 64 dias de idade, e observaram maior digestibilidade do leite em relação ao concentrado para todos os grupos, como esperado, e não observaram nenhum efeito do oferecimento de concentrado e nenhuma interação entre o volume de dieta líquida e o oferecimento ou não de concentrado sobre a digestibilidade dos nutrientes. Segundo os autores, o baixo consumo de concentrado nesse período, em comparação a dieta líquida, pode causar efeito de diluição na digestibilidade total da dieta, o que pode ter justificado a semelhança entre os resultados. Porém, foi observado que a digestibilidade de todos os nutrientes aumentou de acordo com o aumento do fornecimento de leite, sendo atribuída a menor diluição da fração metabólica fecal dos bezerros que receberam menores quantidades de dieta líquida.

Liang et al. (2016) avaliaram a digestibilidade de nutrientes em bezerros Jersey em sistema de aleitamento intensivo (4 L/d) contra sistema convencional (2,4 L/d), com sucedâneo, sem fornecimento de água e concentrado, e verificaram que nas primeiras 72 h de idade a digestibilidade do nitrogênio, da MO e das cinzas foi maior para os bezerros em sistema intensivo de aleitamento, não sendo verificado diferenças em relação aos aleitados de forma convencional nas 72 h seguintes. Porém, a porcentagem de ingestão de energia que foi digerida ou disponível para o metabolismo não diferiu entre os sistemas. Segundo os autores, supondo a produção de quantidades constantes de fezes de mecônio e de nitrogênio não digerido na coleta total de fezes nas primeiras 72 h de coleta, em ambos os tratamentos, a digestibilidade aparente pode ter sido mais subestimada para os bezerros em aleitamento convencional, podendo explicar, parcialmente, a redução da digestibilidade aparente de nitrogênio e de cinzas observada para esses bezerros nesse período de avaliação em relação aos que receberam sistema intensivo de aleitamento.

1.4 Taxa de passagem de bezerros aleitados com maiores volumes de dieta líquida

A taxa de passagem refere-se ao fluxo de resíduos não digeridos ao longo do trato digestório (Burger et al., 2000) e a sua resposta é alcançada quando há controle na quantidade de ingestão pelo animal, sendo que animais com maior consumo de alimento apresentam maior fluxo de nutrientes e, ao contrário, aqueles submetidos à restrição alimentar irão apresentar menor taxa de passagem, estando a retenção intrinsecamente associada com a digestibilidade e aproveitamento dos alimentos (Van Soest, 1994), pois a retenção do alimento por mais tempo no trato gastrintestinal irá permitir que o mesmo seja mais digerido.

Alterações no tempo de retenção com variações na ingestão podem ser demonstradas quando esses dois parâmetros são estudados (Dias et al., 2011), sendo que a magnitude da resposta desses dois mecanismos provavelmente é dependente das características químicas e físicas da dieta (densidade, tamanho de partícula e constituição química e física dos alimentos) e o aumento da velocidade de passagem resultará em perda de matéria potencialmente digestível, requerendo dieta de melhor qualidade (Van Soest, 1994). Porém, nas duas últimas décadas, não são encontrados estudos que avaliaram o efeito do aumento do volume de dieta líquida sobre a taxa de passagem dos alimentos em bezerros leiteiros.

1.5 Composição corporal de bezerros aleitados com maiores volumes de dieta líquida

A composição corporal de bezerros pode ser modificada por diferentes maneiras, como por exemplo o aumento da taxa de alimentação ou a alteração da composição de nutrientes da dieta podem ser umas delas (Blome et al., 2003; Bascom et al., 2007). Trabalhos que avaliam a composição corporal de bezerros geralmente focam em diferenças na composição das dietas, principalmente com variações entre as proporções de proteína e energia (Tikofsky et al., 2001; Blome et al., 2003; Brown et al., 2005; Bascom et al., 2007), e poucos trabalhos avaliaram o efeito do volume de dieta líquida fornecida, sem alteração dos valores de reconstituição dos sólidos, e o seu efeito sobre a composição corporal dos bezerros (Bartlett et al., 2006; Silva et al., 2015; Rodrigues et al., 2016).

Bartlett et al. (2006) verificaram que a porcentagem de água e PB corporal foram menores e a porcentagem de gordura e de energia (Mcal/kg) foram maiores para bezerros alimentados com sucedâneo a 1,75% do PC em relação aos aleitados com 1,25% do PC, sendo também verificado efeito sobre a composição de acordo com o aumento da concentração de PB do sucedâneo (14 a 26%) em ambos os sistemas de avaliação. Já a porcentagem de cinzas não foi afetada pela taxa de PB do sucedâneo e nem pelo sistema de aleitamento avaliado. Segundo os autores, a concentração ideal de PB em sucedâneos para bezerros deve ser indicada em função da taxa de alimentação de dieta liquida que os mesmos irão receber no sistema proposto, sendo que a adoção de planos superiores de dieta líquida requer maior concentração de PB do sucedâneo como forma de maximizar a quantidade de tecido magro e o crescimento estrutural dos animais (Blome et al, 2003; Bartlett et al., 2006).

Silva et al. (2015) avaliaram o fornecimento diário de 2, 4 e 8 L/d de leite (com 25,6% de PB) para bezerros, com ou sem disponibilização de concentrado (com 19% de PB), e não verificaram efeito de interação entre o volume de leite e inclusão do concentrado inicial sobre a composição corporal final dos animais. Porém, a quantidade de dieta líquida oferecida reduziu linearmente a porcentagem de PB e de cinzas, e aumentou linearmente a porcentagem de gordura corporal de acordo com o aumento da quantidade oferecida. Segundo os autores o aumento na deposição de gordura corporal está ligado ao aumento do consumo de energia pelos animais, o que foi alcançado de acordo com o aumento da dieta líquida ou quando o concentrado foi incluído na dieta. Já a redução de PB corporal provavelmente ocorreu em detrimento ao aumento do conteúdo de gordura corporal, sugerindo efeito de diluição no teor da PB.

Rodrigues et al. (2016) avaliaram o fornecimento diário de 2, 4, 6 e 8 L/d de leite (com 23,9% de PB) para bezerros, com concentrado (com 19% de PB) durante o aleitamento e de concentrado e de feno de *Coast-cross* (com 12,5% de PB) no pós-aleitamento, verificaram aumento linear da quantidade de gordura e de proteína no PC final de bezerros Holandês, sem efeitos sobre a composição para a quantidade de cinzas. Porém, redução da quantidade de água na constituição corporal foi verificada.

De acordo com Tikofsky et al. (2001), a composição corporal dos bezerros pode ser diferente pela diferença entre a composição das dietas, mesmo quando eles são alimentados com dietas isocalóricas e isoprotéicas, independente do GMD, demonstrando que as avaliações dos animais baseadas apenas nas taxas de GMD não refletem o desenvolvimento real. Segundo Blome et al. (2003), o aumento do GMD reflete os aumentos nos tecidos estruturais e deposição de tecido magro e não a deposição de gordura adicional, a qual pode ser maior de acordo com o balanceamento da composição dos nutrientes (Ballou et al., 2013), podendo interferir na lactação futura dos animais (Tikofsky et al., 2001), demonstrando a importância de estudos que avaliem a composição corporal dos animais criados em diferentes sistemas de aleitamento.

1.6 Efeitos em longo prazo de bezerros aleitados com maiores volumes de dieta líquida

O efeito da nutrição das bezerras sob o crescimento e a lactação é fator chave para sustentabilidade ambiental e financeira dos sistemas de produção de leite (Margerison et al., 2013). Fatores e eventos precoces na vida dos bezerros podem apresentar efeitos em longo prazo sobre o desempenho e pela quantidade de variação contabilizada na primeira e subsequente produção de leite, existem oportunidades para melhorar a resposta, uma vez que são conhecidos e entendidos esses fatores (Van Amburgh e Soberon, 2016).

Nos últimos anos, o interesse em estudar os efeitos de estratégias de aleitamento na lactação subsequente vem ganhando cada vez mais atenção, porém os resultados ainda são controversos (Gelsinger et al., 2016). Eventos epigenéticos durante o aleitamento (Soberon et al., 2012; Overton, 2016), juntamente com o maior desempenho e consumo de nutrientes, bem como a redução de doenças, podem (Soberon et al., 2012; Soberon e Van Amburgh, 2013; Gelsinger et al., 2016) ou não (Morrison et al., 2009; Kiezebrink et al., 2015) serem responsáveis por alterar o potencial de produção e a composição futura de leite dos animais. Morrison et al. (2009) avaliaram o fornecimento de 5 ou 10 L/d de sucedâneo até os 56 dias de idade e não verificaram diferenças entre o PC ao parto, bem como para a produção e a composição do leite na primeira e segunda lactação. O mesmo foi observado por Kiezebrink et al. (2015), os quais avaliaram o fornecimento de 4 ou 8 L/d de leite até os 56 dias de idade e também não verificaram efeitos sobre a idade ao parto, PC no pós-parto, bem como para a produção e composição de leite na primeira lactação dos animais.

Em meta-análise realizada por Gelsinger et al. (2016), a partir de um modelo baseado em nove estudos relacionados a nutrição durante o aleitamento e o acompanhamento dos animais na lactação, os autores indicaram que a taxa de crescimento na pré-desmama e a ingestão de leite ou sucedâneo de leite pode aumentar os efeitos positivos no pós-desmame. Segundo os autores, os consumos de ST da dieta líquida e da MS na dieta sólida, sinergicamente, podem aumentar o desempenho na primeira lactação. A suplementação de 100 g/d de ST gerou aumento de 66 kg de produção de leite na primeira lactação, que se combinado com o consumo de concentrado (g MS/d), proporcionou aumento de 138 kg na produção de leite futura para cada 100 g/d ingerido.

2. Aumento do volume e da concentração de sólidos totais da dieta líquida

Além de serem fornecidas quantidades de dieta líquida em maior volume, em alguns programas intensivos de aleitamento com sucedâneo como dieta líquida, preconiza-se também o aumento da concentração dos ST, tentando se aproximar ao máximo dos valores totais de nutrientes disponibilizados em maior volume de leite.

2.1 Consumo e desempenho de bezerros aleitados com maiores volumes e concentrações de sólidos totais na dieta líquida

Nesse sistema, da mesma forma ao observado para o sistema intensivo com o aumento de volume de dieta líquida, sem alterar a % de ST, também são observadas reduções no consumo de concentrado pelos bezerros durante o aleitamento (Terré et al., 2006; Terré et al., 2007; Raeth-Knight et al., 2009; Terré et al., 2009; Hengst et al. 2012; Ballou et al., 2013; Obeidat et al., 2013; Guindon et al., 2015; Chapman et al., 2016; Hill et al., 2016b) quando comparados a animais aleitados de forma convencional. No trabalho de Raeth-Knight et al. (2009) foram avaliados diferentes programas de aleitamento, não sendo verificadas diferenças entre os consumos de concentrado pelos bezerros nos primeiros 14 d de avaliação. Porém, segundo os autores, bezerros aleitados convencionalmente, com sucedâneo (13,9% de ST) diluído em 3,5 kg/d de água até os 42 dias de idade, apresentaram maior consumo de concentrado do que aqueles aleitados de forma intensiva, recebendo sucedâneo (16,7% de ST) diluído em 3,4 (1 a 10 dias de idade) e 5,1 kg/d (11 a 42 dias de idade) de água.

Guindon et al. (2015) observaram que os bezerros aleitados com sucedâneo (12% de ST) diluído em 3,8 L/d de água apresentaram 52% a mais de consumo de concentrado do que aqueles aleitados com sucedâneo (17% de ST) diluído em 4,8 L/d de água do 2º ao 8º dias de idade e 6,7 L/d de água entre 9 e 41 dias de idade, demonstrando que o maior adensamento nutricional da dieta dos bezerros aleitados com maior volume de dieta líquida, bem como maior % de ST, atendeu as exigências dos bezerros e não gerou estímulo de busca por outros alimentos, como o concentrado. Os autores também observaram maior consumo de água para os bezerros em sistema intensivo, sendo justificado pela maior densidade de nutrientes, provavelmente causando aumento da pressão osmótica e que, combinado a maior deposição de tecido, pode ter levado os bezerros a ingerirem mais água.

Chapman et al. (2016) avaliaram três sistemas de aleitamento com o fornecimento de sucedâneos: convencional (0,44 kg de MS por 39 dias e 0,22 kg de MS até 42 dias), moderado (0,66 kg de MS por 39 dias e 0,33 kg de MS até 42 dias) e intensivo (0,66 kg de MS por 5 dias; 0,87 kg de MS até 42 dias e 0,43 kg de MS até 49 dias), sendo o tratamento convencional e o moderado reconstituídos para 13% ST e o intensivo reconstituído para 15% ST. Segundo os autores, os animais aleitados de forma intensiva apresentaram os menores consumos de concentrado durante os 56 dias de experimento.

Melhores taxas de crescimento dos bezerros também são observadas quando recebem maior volume de dieta líquida com maior concentração de ST, sendo observado maior GMD (Terré et al., 2007; Raeth-Knight et al., 2009; Terré et al., 2009; Ballou, 2012; Hengst et al., 2012; Ballou et al., 2013; Obeidat et al., 2013; Ballou et al., 2015; Guindon et al., 2015; Chapman et al., 2016) e de desenvolvimento estrutural (Raeth-Knight et al., 2009; Hengst et al., 2012; Ballou et al., 2013; Guindon et al., 2015) em relação aos animais aleitados de forma convencional durante a fase de aleitamento.

Após a fase de aleitamento, as diferenças de consumo de concentrado entre os sistemas intensivos com maior volume de dieta líquida, com maior concentração de ST, e os sistemas convencionais, geralmente desaparecem (Raeth-Knight et al., 2009; Obeidat et al., 2013; Guindon et al., 2015, Hill et al., 2016b). Porém, mesmo que ocorra semelhança entre o GMD nessa fase (Terré et al., 2009; Ballou, 2012; Ballou et al., 2013; Obeidat et al., 2013; Ballou et al., 2015; Guindon et al., 2015), os animais que receberam aleitamento intensivo podem conseguir manter a diferença obtida de maior PC durante a fase de aleitamento em relação aos animais aleitados convencionalmente (Raeth-Knight et al., 2009), demonstrando a importância de manejo correto de aleitamento como forma de acelerar a fase de crescimento dos bezerros.

2.2 Trato digestório de bezerros aleitados com maiores volumes e concentrações de sólidos totais na dieta líquida

Como os parâmetros de desenvolvimento do trato digestório geralmente seguem os padrões de ingestão de alimentos sólidos durante a fase de aleitamento (Khan et al., 2016), é possível que os resultados de desenvolvimento do trato digestório nesse sistema de aleitamento tendem a seguir os resultados observados para o sistema intensivo de aleitamento com aumento apenas do volume da dieta líquida, porém, são necessários estudos que avaliem o aumento concomitante do volume e da densidade dos ST e os seus efeitos sobre as variáveis de desenvolvimento do trato digestório dos bezerros.

2.3 Digestibilidade dos nutrientes de bezerros aleitados com maiores volumes e concentrações de sólidos totais na dieta líquida

Terré et al. (2007) avaliaram a digestibilidade de nutrientes em bezerros aleitados com maior volume de dieta líquida e maior concentração de ST (18% de ST diluídos em 4 L/dia por sete dias; 6 L/dia por mais sete dias; 8 L/dia por mais sete dias; 6 L/dia por mais sete dias e 3 L/dia até os 54 dias de idade) comparados a bezerros aleitados convencionalmente (12,5% de ST em 4 L/dia de água até os 47 dias de idade e em 2 L/dia até os 54 dias de idade). Os autores relataram redução da digestibilidade de MS, MO, PB e energia bruta (EB) nos animais aleitados de forma intensiva. Chapman et al. (2016) verificaram que a digestibilidade aparente da MS, MO, FDN, FDA, PB, açúcar e gordura, com exceção do amido, foram menores para bezerros aleitados em sistema intensivo de aleitamento (reconstituído para 15%ST) quando comparados ao sistema convencional e moderado, ambos com dietas reconstituídas para 13%ST.

Já Hill et al. (2016b) realizaram ensaios de digestibilidade em diferentes períodos e verificaram que a digestibilidade aparente da MS, MO e PB foi maior para bezerros aleitados em sistema intensivo de aleitamento (0,66 kg MS/dia nos 4 dias iniciais; 0,96 kg de MS/dia por quatro dias; 1,31 kg MS/dia por 34 dias; 0,66 kg MS/dia por sete dias, reconstituído para 15%ST, com exceção dos últimos 7 dias de aleitamento, os quais foram reconstituídos para 13%ST) quando comparados ao sistema convencional (0,66 kg de MS/dia, por 49 dias, reconstituída para 13%ST) dos 19 a 23 dias experimentais. Porém, neste mesmo período, animais aleitados em sistema intensivo apresentam menores digestibilidades de amido, FDN e FDA quando comparados aos bezerros aleitados convencionalmente. Entre 40 a 44 dias experimentais, a digestibilidade aparente da MS, gordura e MO foi maior para os bezerros aleitados em sistema intensivo de aleitamento e maior digestibilidade aparente de amido, FDN e FDA foram observados para os bezerros em sistema convencional. Já no pós-aleitamento (52 a 56 dias experimentais), a digestibilidade aparente da MS, gordura e MO foram maiores para os animais do sistema convencional de aleitamento quando comparados aos animais em aleitamento intensivo.

São necessários mais estudos para o entendimento do efeito do aumento do volume e da concentração de ST sobre a digestibilidade dos nutrientes, buscando-se encontrar melhor relação entre os resultados de desempenho e de melhor aproveitamento dos nutrientes presentes na dieta.

2.4 Taxa de passagem

Não foram encontrados estudos que avaliaram o efeito do aumento do volume e da concentração de ST da dieta líquida sobre a taxa de passagem dos alimentos em bezerros leiteiros nas duas últimas décadas. Como esse parâmetro infere sobre o fluxo dos alimentos pelo trato digestório, estando associado, por exemplo, à ingestão voluntária de alimentos e a extensão da digestão da dieta (Okine et al., 1998), estudos que avaliem esse parâmetro são importantes e podem auxiliar na compreensão do desempenho e eficiência alimentar dos animais.

2.5 Composição corporal de bezerros aleitados com maiores volumes e concentrações de sólidos totais na dieta líquida

No trabalho de Diaz et al. (2001) foi avaliada a composição corporal de bezerros aleitados com maior volume e com maior concentração de ST na dieta líquida, sem o fornecimento de concentrado, sendo verificado que bezerros aleitados com sucedâneo (15% de ST) a 1% do PC tiveram menor deposição de gordura e maior deposição de água e de PB do que bezerros aleitados com sucedâneo (15% de ST) a 3 % do PC, do que bezerros aleitados com sucedâneo (18% de ST) a 4% do PC. Já a deposição de cinzas foi menor para os bezerros aleitados com sucedâneo (15% de ST) a 3 % do PC do que os aleitados com sucedâneo (15% de ST) a 1% do PC, e do que os aleitados com sucedâneo (18% de ST) a 4% do PC. Segundo os autores, a maior deposição de gordura nos animais aleitados com maior quantidade de sucedâneo em relação ao PC dos animais, quando comparados aos aleitados com 1% do PC (com 15% de ST), demonstrou que o aumento do GMD nos mesmos ocorreu com maior deposição de gordura corporal, porém, não ocorreu aumento linear de acordo com o aumento do PC e não seguiu padrão consistente entre os tratamentos, concluindo-se que a alteração da composição da dieta líquida pode alterar a composição do crescimento dos bezerros.

Chapman et al. (2016) indicaram que bezerros aleitados em sistema intensivo de aleitamento (reconstituído para 15%ST) apresentam aumento no acúmulo de gordura corporal e maiores escores de condição corporal quando comparados ao sistema convencional e moderado, ambos com dietas reconstituídas para 13%ST, nos dois primeiros meses de vida.

2.6 Efeitos em longo prazo de bezerros aleitados com maiores volumes e concentrações de sólidos totais na dieta líquida

Terré et al. (2009), Raeth-Knight et al. (2009) e Davis Rincker et al. (2011) não observaram aumento da produção de leite na primeira lactação de animais alimentados com maior volume e/ou concentração de ST na dieta líquida.

Mesmo que sejam observados valores percentuais de aumento na produção de leite em 2,9% (Davis Rincker et al., 2009), 5,2% (Raeth-Knight et al., 2009) ou 5,9% (Terré et al., 2009) em animais aleitados com maior volume e concentração de ST na dieta líquida, esses autores não verificaram diferenças significativas em relação aos animais aleitados convencionalmente.

No estudo de Terré et al. (2009) a ausência de diferença (P = 0,21) na produção de leite foi atribuída ao pequeno número de animais (n = 14 por tratamento). Já no estudo de Raeth-Knight et al. (2009), segundo Soberon et al. (2012), houve confundimento na determinação de diferenças de produção de leite, pois as bezerras após o experimento foram devolvidas para diferentes fazendas, onde foram avaliadas as respectivas produções de leite, sendo difícil separar os efeitos de rebanho, estação, dias em lactação, dias de gestação, e outros fatores ambientais, entre as fazendas.

3. Aumento da concentração de sólidos totais na dieta líquida

Por várias razões, produtores e técnicos relutam em aumentar o volume de leite fornecido para os bezerros, entre elas refere-se a redução no consumo de concentrado e o possível atraso no desenvolvimento do rúmen, com consequente perda de peso após o desaleitamento, além da recusa de grandes volumes de leite ou de sucedâneo por animais que nasceram com menor PC.

Os valores relatados para o PC inicial de bezerros da raça Holandês em trabalhos americanos variam entre 44 e 48 kg para machos (Diaz et al., 2001; Bartlett et al., 2006; Quigley et al., 2006; Hill et al., 2010) e 37 a 44 kg para fêmeas (Brown et al., 2005; Obeidat et al., 2013), sendo superiores aos relatados em trabalhos brasileiros para bezerros da raça Holandês, com médias de 37 a 43 kg para machos (Schalch et al., 2001; Jorge et al., 2002; Medina et al., 2002; Carvalho et al., 2003; França et al., 2005; Bittar et al., 2009; Azevedo et al., 2013; Silper et al., 2014) e 39 para fêmeas aos dois dias de idade (Batista et al., 2008), bem como para bezerros mestiços, os quais variam entre 32 a 36 kg para machos (Mancio et al., 2005; Oliveira e Nogueira, 2006; Lima et al., 2012; Silva et al., 2015) e 29 kg para fêmeas (Oliveira e Nogueira, 2006).

Outro motivo pelo qual os produtores são relutantes em adotar programas com maior volume de dieta líquida é devido à redução do volume de leite a ser comercializado, reduzindo-se assim a receita da propriedade. Mesmo que o leite seja uma excelente opção para fornecimento de nutrientes de alta qualidade para os bezerros, esse produto pode apresentar variação na sua constituição nutricional ao longo do ano, em função do estádio de lactação, da nutrição, da flutuação de ST no uso do leite de descarte, entre outros fatores. Uma estratégia que pode contornar em parte esses problemas seria a adição de determinada quantidade de sucedâneo em pó, aumentando os ST da dieta líquida, sem aumentar o volume oferecido aos bezerros. Porém, apenas dois artigos foram publicados nas duas últimas décadas com esse sistema de aleitamento.

Raeth-Knight et al. (2009) testaram cinco dietas líquidas diferentes, e dentre elas, em uma fixou-se o volume de 3,5 kg de dieta líquida, composta de sucedâneo enriquecido para 13,9 % de ST (convencional), em outra o volume foi mantido próximo (3,4 kg), com16,7% de ST (intensivo). Ambos os tratamentos foram fornecidos duas vezes ao dia, com 50% do volume final sendo oferecido em cada refeição, até os 35 d. Dos 36 aos 42 d as dietas líquidas foram reduzidas pela metade, sendo os animais desaleitados em seguida. Durante a fase de aleitamento os autores relataram que no sistema convencional as bezerras apresentaram menor consumo de MS total, de GMD, de PC e de eficiência alimentar do que as bezerras em aleitamento intensivo, não sendo observadas diferenças entre o consumo de concentrado, desenvolvimento corporal e escore de fezes entre os animais. No pós-aleitamento os animais apresentaram similaridade de consumo, de desempenho e de eficiência alimentar, bem como para a idade ao parto e os parâmetros de produção e de composição do leite, demonstrando que as bezerras que receberam maior % de ST na dieta líquida, em baixo volume, foram mais pesadas durante a fase de aleitamento e no pós-aleitamento imediato (56 d) em comparação aos animais aleitados convencionalmente. No entanto, essa vantagem não foi mantida durante a fase de recria das novilhas.

Mais recentemente, Glosson et al. (2015) avaliaram sistemas de aleitamento intensivos com leite adicionado com produto em pó *Milk plus balancer* (o qual possui 25% de PB e 10% de gordura, sendo composto com ingredientes de soro de leite em pó, concentrado de proteína de soro de leite, produto de soro de leite, leite em pó desnatado, leite em pó, proteína e gordura animal) em três tratamentos intensivos [T1-3,8 L de leite mais *Milk plus balancer* para 17,6% de ST; T2-sistema *Step-Down* (3,8 L/d até 14 d; 5,7 L/d até 49 d e 2,8 até 56 d) com leite a 12,5% de ST; T3- mesmo sistema Step-Down do T2, com *Milk plus balancer* para 17,6% de ST], contra um sistema convencional T4 (3,8 L de leite com 12,5 % de ST) de aleitamento, até os 56 dias de idade. Foi observado que o consumo de concentrado dos animais aleitados convencionalmente foi superior aos demais sistemas avaliados, os quais não diferiram entre si, o GMD dos animais aleitados convencionalmente foi menor do que o T2 e o T3, sendo verificado maior valor no T3 do que nos demais. Já a eficiência alimentar foi superior nos animais do T3 e T4 do que os animais aleitados convencionalmente ou no T2, os quais foram semelhantes entre si, demonstrando que a mesma está mais interligada ao consumo de leite integral do que ao consumo de ST, possivelmente devido à diferença constitucional dos nutrientes entre ambos e ao melhor aproveitamento do leite pelas bezerras em relação aos sucedâneos. Para as medidas de desenvolvimento corporal nenhuma diferença foi observada entre os tratamentos e ao final da fase de aleitamento, os bezerros do T3 apresentaram maior PC em relação aos demais sistemas, os quais não diferiram entre si. O escore fecal foi maior nos animais do T3, sem diferenças para o escore respiratório entre os tratamentos. Os autores concluíram que uma opção para os produtores aumentarem o GMD, PC e a eficiência alimentar na fase de aleitamento seria a utilização de leite enriquecido com produto em pó balanceador. Os autores chamam atenção que o investimento no período pré-desaleitamento para bezerras deve ser benéfico para o desempenho futuro como vacas, ressaltando a importância de observações de longo prazo para determinar os efeitos desses sistemas na produção e na composição posterior do leite.

4. Ocorrência de diarreia em bezerros leiteiros criados em diferentes sistemas de aleitamento

A diarreia é a mais importante causa de mortalidade em bezerros, ocorrendo geralmente nas primeiras semanas de vida (McGuirk, 2008; Liang et al., 2016), e muitos produtores continuam a fornecer quantidades restritas de leite para bezerros com a percepção de que o aumento da ingestão de leite leva a maior incidência dessa enfermidade gastrointestinal (Jasper e Weary, 2002; Silper et al., 2014).

A ocorrência de diarreia pode estar mais relacionada a baixa qualidade sanitária, ao manejo e/ou a condições de instalações do que ao volume de leite fornecido, podendo ser causada por vários fatores, incluindo patógenos entéricos, que podem afetar diferentes segmentos do trato gastrointestinal (Araujo et al., 2015), indicando que quando a microbiota fecal não é avaliada, influências nutricionais e microbianas sobre a consistência fecal possuem difícil diferenciação entre si (Ballou, 2012).

A maioria dos dados relacionados com a saúde de bezerros alimentados com diferentes estratégias de aleitamento são limitados a avaliações de escores fecais durante as primeiras semanas de vida (Liang et al., 2016) e não levam em consideração outros fatores de risco para a diarreia.

Desta forma, os resultados para escores fecais são ambíguos, sendo que alguns estudos mostram que bezerros alimentados com maior volume de dieta líquida, quando comparados a animais em sistema convencional, não apresentam diferenças para essa variável (Jasper e Weary, 2002; Bartlett et al., 2006; Khan et al., 2007a,b; Bach et al., 2013; Yavuz et al., 2015) e alguns relatam presença de fezes mais pastosas (Nonnecke et al., 2003; Hill et al., 2006; Geiger et al., 2016; Hill et al., 2016; Liang et al., 2016). Esta discrepância de resultados pode ser atribuída, em parte, a diferenças entre as avaliações das pontuações dos escores fecais, variações entre práticas de colostragem e aleitamento (como a quantidade, método de fornecimento e qualidade dos alimentos fornecidos) e as diferenças de clima e situações de manejo entre os estudos (Khan et al., 2011).

Já bezerros alimentados com maior volume e maior concentração de ST na dieta líquida, quando comparados a animais em sistema convencional, não apresentaram diferenças entre os escores de fezes (Ballou, 2012; Obeidat et al., 2013; Chapman et al., 2016). Outros estudos relataram presença de fezes mais pastosas (Diaz et al., 2001; Brown et al., 2005; Quigley et al., 2006; Raeth-Knight et al., 2009; Davis Rincker al., 2011; Hengst et al., 2012; Ballou et al., 2015, Hill et al., 2016b), as quais nem sempre resultaram em diferenças na saúde dos bezerros (Diaz et al., 2001; Bartlett et al., 2006; Brown et al., 2005; Raeth-Knight et al., 2009; Davis Rincker al., 2011, Hill et al., 2016b).

Porém, é importante relatar que nenhum estudo publicado nas últimas décadas relatou maior escore fecal de bezerros em sistema convencional do que bezerros em sistema intensivo de aleitamento (Liang et al., 2016).

Segundo Ballou et al. (2015) e Liang et al. (2016), pesquisas futuras devem determinar se bezerros alimentados com planos de aleitamento intensivo apresentam redução do percentual de MS fecal e se o maior escore de fezes nas primeiras semanas de vida poderia ser atribuído a redução da digestibilidade de ST da dieta líquida ou se são resultados de aumento do consumo de água, tal como sugerido por Nonnecke et al. (2003). Se a digestibilidade dos sólidos for reduzida, bezerros alimentados com maior volume de dieta líquida teriam aumento de substrato para o crescimento microbiano no trato gastrointestinal inferior, sendo um risco para o desenvolvimento de patógenos causadores de diarreia. Mas caso isso não aconteça, o aumento do escore fecal pode ser uma resposta de proteção contra doença gastrointestinal devido ao maior volume de sólidos que se movem através do trato gastrointestinal, ajudando a reduzir a colonização de patógenos ou diluindo qualquer potencial de enterotoxinas (Ballou et al., 2015).

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CAPÍTULO II

The effects of increasing amounts of milk replacer powder added to whole milk on feed intake and performance of dairy heifers

ABSTRACT

The aim of this study was to evaluate the effects of increasing total solids (**TS**) content of liquid feed, composed of whole milk (**WM**), by adding increasing amounts of milk replacer powder (**MRP**) on feed intake, heifer performance and health during the pre- and postweaning periods. Crossbred Holstein-Gyr heifers (n = 60) were assigned to 1 of 4 treatments (n = 15 per group), which consisted of four different TS concentrations: 12.5, 15.0, 17.5, and 20.0% in liquid feed. Heifers received 6 L of liquid feed daily divided in two equal meals (0800 and 1600 h), which were provided in buckets, from 5 to 55 d of age. From 56 to 59 d of age, the total amount fed was reduced by half and only morning feedings were maintained. Heifers were weaned at 60 d of age and monitored until 90 d of age. Water and starter were provided ad libitum during the entire experiment. Corn silage was included in the diet during the postweaning period (70 d of age). Feed intake and health scores were evaluated daily. Body weight (**BW**) and body frame development were recorded weekly. Starting at d 14, ruminal pH was measured every other week. Laboratory analysis determined that the actual TS contents in liquid feed were 13.5, 16.1, 18.2, and 20.4%, for treatments 12.5, 15.0, 17.5, and 20.0% TS, respectively. The osmolality of liquid feed treatments was in a range of 265 to 533 mOsm/L. Intake of liquid feed was similar among treatments from the 4 wk of age. During the preweaning period, starter intake, fecal score and days with diarrhea were similar among treatments. Ruminal pH at weaning averaged 6.2 and was similar among treatments. The increasing concentrations of TS in the liquid feed linearly increased average daily gain (**ADG**), final BW and grow performance, but linearly decreased feed efficiency. During the postweaning, intake of starter, corn silage, and water were similar among treatments, as well as ADG and feed efficiency. Final BW and grow performance during the postweaning period also increased linearly with increased concentration of TS in liquid feed during the preweaning period. Results show that increasing concentration of TS in liquid feed up to 20.4% increases

performance and body frame development of dairy heifers during the pre- and postweaning periods and have no effects on solid feed intake and health.

Key words: calf, osmolality, performance, total solid

INTRODUCTION

Restricted milk feeding during the preweaning period is a widely used strategy to reduce costs in calf rearing system. This practice is also known to stimulate starter intake and promote early rumen development. However, limiting milk consumption, especially during the first month of life, has been challenged by recent research. Kiezebrink et al. (2015) and Yunta et al. (2015) demonstrated that calves fed restricted amounts of liquid feed are not able to ingest sufficient nutrients to ensure satisfactory ADG. In addition, adequate nutrient intake during the preweaning period is essential for calf well-being, health and future productivity.

Compared with calves fed lower amounts of milk or milk replacer (**MR**), improved growth rates are obtained when heifers are fed milk ad libitum (Jasper and Weary, 2002), higher volumes of milk (Borderas et al., 2009) or MR (Kmicikewycz et al., 2013; Silper et al., 2014) during the preweaning period, with no negative effects on rumen development (Khan et al., 2007; Silper et al., 2014) and health (Borderas et al., 2009; Hengst et al., 2012; Bach et al., 2013). Recent studies also observed that heifers fed higher volumes of liquid feed improved immune response postweaning period compared with those fed lower volumes (Ballou, 2012; Ballou et al., 2015). However, in spite of the aforementioned advantages, farmers and technicians are reluctant to increase the volume of milk fed to heifers because of the increase costs with milk or MR, and possible reduction in the amount of milk available for sale (Moore et al., 2009).

Milk is an excellent option to provide high quality nutrients to heifers, even though it may imply higher costs when compared with MR. However, different factors, such as lactational stage, nutrition of cows, and total TS fluctuation of waste milk (Moore et al., 2009), may alter the nutrient content in milk. A strategy that can help to partially overcome this problem is the addition of products commonly sold as “balancers”, which increase the TS content in the liquid feed without increasing the amount of milk feed (Glosson et al., 2015). Jenny et al. (1982) recommended calves be fed MR once a day, with a concentration of 10 to 13% of TS in the liquid feed offered at 8% of BW, and free access to starter. However, Glosson et al. (2015), however, observed that higher volumes of pasteurized milk enriched with milk balancer (17.6% TS) increased ADG, BW, and feed efficiency of heifers compared with calves fed with 3.8 L/d of pasteurized milk without milk balancer (12.5% TS) during preweaning period.

Moreover, the final osmolality of a liquid feed is a factor that must be considered when TS is increased. According to McGuirk (2003), the normal serum osmolality is about 280-290 mOsm/kg, and milk is an isosmotic food. As the liquid feed osmolality increases, gastric emptying becomes progressively faster and complete, which can potentially reduce diet digestibility (McGuirk, 2003). On the other hand, a delay in gastric emptying may increase absorption and nutrient utilization. Although reference values are not well established, according to McGuirk (2003), cautions should be taken when offering fluids with osmolality greater than 600 mOsm/L, and they should never be provided when water is not available. According to Glosson et al. (2015), an increase in osmolality due to the addition of milk balancer to the whole milk (**WM**) can affect water absorption by intestines, leading to an increase in incidence of diarrhea.

Recommendations regarding maximal concentration of TS in liquid feed are still not well stablished and further research on the effects of feeding different concentrations of liquid feed TS on calf performance is needed. The objective of this study was to evaluate the effect of increasing the concentration of TS in WM through the addition of milk replacer power (**MRP**) on feed intake, performance, body frame development, feed efficiency, and health of heifers during the pre- and postweaning periods.

MATERIAL AND METHODS

Protocols for this study were approved by Ethics Committee of Embrapa Dairy Cattle, under protocol n. 06/2014. The experiment was conducted at the Embrapa Dairy Cattle Experimental Farm, located in Coronel Pacheco, Minas Gerais, Brazil.

Animals, Housing and Treatments

Holstein x Gyr crossbred heifers (n = 60) were used, and the genetic composition was 5/8 or more of Holstein breed and 3/8 or less of Gyr breed. Heifers were born between

April and June 2014 (brazilian autumn). Dams were vaccinated against clostridial diseases (Excell 10, Vencofarma, Londrina, Paraná, Brazil) at 25 d prepartum.

At birth, heifers were removed from their dams, weighted and the umbilical cord was immersed in iodine solution (7%). Colostrum (3L; >50 g/L of IgG) was fed within 6-8 h after birth. Blood samples were collected via jugular venipuncture within 48 h after birth and centrifuged at 800.6 X g for 10 min to measure total serum protein (**TSP**) using a refractometer (Serum protein REF-301, Biocotek, Beilun, Ningbo, China). The TSP was used to assess the quality of the passive transfer of immunity, which was attained through colostrum feeding. The value of 5.5 g/dL was adopted as a limit to consider animals with a good transfer of immunity by the colostrum (McGuirk, 2003). All heifers were housed in individual shelters over tropical grass pasture (*Cynodon sp*) during the entire study.

At 2 to 4 d of age, heifers were fed 6 L/d of transition milk divided into two equal meals offered at 0800 and 1600 h. At 5 d of age, heifers were assigned to 1 of 4 treatments (n = 15 per group), maintaining a balance of birth month, birth BW, TSP and genetic composition. There was no difference in birth weight, TSP, genetic composition, and month or birth among treatments. Treatments consisted of increasing amounts of MRP (Sprayfo Violet SSP, Deventer, the Netherlands, Table 1) added to 6 L/d of WM (12.6 ± 0.7% TS, mean ± SD; Table 1) to adjust TS to expected concentrations of 12.5; 15.0; 17.5, and 20.0% in liquid feed. The initial TS content in WM was measured daily, immediately after milking and before each feeding, using a Brix refractometer (Misco DD-3 Palm Abbe Digital, Solon, Ohio, EUA). The Brix grade values were converted to TS content using the equation proposed by Moore et al. (2009) [TS = 0.9984 x (Brix refractometer reading) + 2.077] and adjust the amount of MRP to be added to WM was adjusted according to the TS content aimed in each treatment. MRP was added to WM and immediately supplied to heifers. The time between milking and providing the treatment to heifers was not more than 30 min.

The total volume of treatment (6 L/d) was divided into two equal meals (0800 and 1600 h) and provided to heifers in buckets, from 5 to 55 of age. At 56 d of age, total volume of liquid feed was reduced by half (3 L/d provided at 0800 h) and heifers were weaned at 60 d of age. Starter (Soylac Rumen 20% Flocculated, Total Alimentos, Três Corações, Minas Gerais, Brazil; Table 1) and water were offered ad libitum throughout the whole experimental period. During the postweaning period, at 70 d of age, corn silage was included in the diet (Table 1). The amount of starter and corn silage provided was sufficient to result in 10% orts.

Intake, Performance and Growth

Performance, body frame development and feed intake were monitored until 90 d of age. Intakes of WM and MRP mixture, starter, and water were calculated daily by subtracting refusals from the amounts provided. The total intakes of DM, CP, and gross energy (**GE**) of starter and WM+MRP were calculated during the preweaning period. During postweaning period, the intake of nutrients, starter, and corn silage was evaluated. Water intake was measured using a portable balance (WH-A04, WeiHeng, China) and no bucket reference was used to evaluate evaporation.

Starting at 5 d of age, BW, withers height (Teletape, Ketchum, Ottawa, Canada), heart girth, and rump width (tape measuring) were measured once a week before morning feeding. Feed efficiency was calculated using the ratio between ADG and total DM intake (Khan et al., 2007). During the preweaning period, rumen fluid samples were collected through an esophageal tube 5 h after morning feeding at 14, 28, 42, and 56 d of age and pH was assessed using a portable potentiometer (DM-2-Digimed, São Paulo, São Paulo, Brazil). During the postweaning period, samples were collected using the same procedure at 70 and 84 d of age, at the same time preweaning period samples were collected.

Handling and Health Measurements

At 8 d of age, preventive oral treatment against coccidiosis (Baycox Ruminants, Bayer, Leverkursen, Germany) was performed, at the dose of 3 mL per 10 kg of BW. Health and fecal scores were monitored daily by trained farm staff. Fecal score were graded according to Larson et al. (1977), as follow: 1- normal (firm but not hard); 2 - soft (does not hold form, piles but spread slightly); 3 - runny (spreads readily to about 6 mm depth); and 4 - watery (liquid consistency, splatters). A heifer was considered to have diarrhea if fecal score was 3 or 4.

All heifers were dehorned in the first week after weaning. One heifer (treatment 17.5% TS) was removed from the study, in the last week of the postweaning period due to an accident that leaded to the fracture of the anterior right limb.

Nutritional Composition Analysis

Milk samples were collected twice a day (morning and afternoon) and then analyzed for TS, CP and fat content using an infrared analyzer (Bentley model 2000; Bentley Instrument Inc., Chaska, Minnesota, USA; Table 1). Samples from liquid feed treatments were collected daily, composed by month, lyophilized and analyzed for nutritional composition (AOAC international, 1990, Table 1). Osmolality of the liquid feed was measured using an osmometer (Micro-Osmette, Natick, Massachussets, USA).

Samples of the starter, MRP, and corn silage were collected weekly, and composed by month to determine DM, CP, ether extract (**EE**), Ash, Ca, P, and Mg according to the International AOAC (1990). The NDF and ADF were analyzed in sequence for the starter and corn silage samples using the method describe in Van Soest et al. (1991). GE was determined by an adiabatic bomb calorimeter (Parr Instrument Company, Moline, IL, USA).

Statistical Analysis

Data were analyzed using SAS 9.0 (SAS Institute Inc., Cary, NC). All data collected were summarized and analyzed by period [preweaning (5-59 of age) and postweaning (60-90 d of age) periods] and by week within period. Weekly averages of feed intake, performance, body frame development, ruminal pH, and days with diarrhea were analyzed using a repeat-measures mixed model (PROC MIXED), including calf as the random component of the model and treatment, week, and their interaction as fixed components. Differences among treatments were assessed using orthogonal polynomial contrasts used to estimate the linear, quadratic, and cubic effects of increasing concentrations of TS in the liquid feed. Fecal score was first pooled by period (5 and 59 of age) and it was tested as nonparametric variables, with the Kruskal-Wallis test, with 95% confidence for treatment comparisons (PROC NPAR1WAY). BW at birth and TSP were analyzed with ANOVA including treatment as a fixed effect, using a Tukey adjustment for *P*. Least squares means for each treatment are reported. The variables BW at birth and TSP were considered as covariates. Significance was declared at $P \leq 0.05$.

RESULTS AND DISCUSSION

The actual concentrations of TS in the WM+MRP were 13.5, 16.1, 18.2, and 20.4% TS (Table 1) for the proposed diets of 12.5, 15.0, 17.5, and 20.0% TS, respectively. The difference between the TS content initially proposed for treatments ant the values found by laboratory analysis may have occurred because the equation used to convert the Brix grade values to TS content was designed based on waste milk samples (Moore et al., 2009), which is different from WM, used in this experiment.

Birth weight (34.5 ± 4.6 kg; mean ± SD, Table 2) and passive immune transfer were similar among treatments. The passive transfer of immunity was evaluated based on the TSP value at 24 h after colostrum feeding, which averaged 6.8 ± 1.1, 6.9 ± 1.0, 6.1 ± 0.9, and 6.8 ± 1.0 g/dL (mean ± SD), for the liquid feed with 13.5, 16.1, 18.2, and 20.4% TS, respectively. Eighty-five percent of the heifers had TSP values above 5.5 g/dL. Nine heifers had TSP values below 5.5 g/dL, but above 5.2 g/dL (two, one, four, and two heifers belonged, respectively, to the liquid feed with 13.5, 16.1, 18.2, and 20.4% TS). However, these heifers didn't show any signs of illness or changes in feed intake and ADG that could justify the removal of their data.

Preweaning Period

There was an interaction ($P = 0.01$; Table 2) between treatment and weeks for intake of WM+MRP (kg/d). During wk 2 and 3, a decreased (linearly, $P = 0.01$) in intake of WM+MRP (kg/d) was detected as the concentration of TS increasing in the liquid feed. After wk 4, a similar intake of WM+MRP (kg/d) was observed among treatments (Figure 1a). However, intake of WM+MRP (g DM/d) increased (linearly, $P = 0.01$) with increasing concentration of TS in the liquid feed, as initially proposed for the experimental design.

It was observed that, regardless of the concentration of TS in the liquid feed, heifers were able to ingest all liquid feed provided only after wk 7 (Figure 1a). This fact indicates a physical limitation in intake capacity in all groups. The reduction in feed liquid intake (wk 2 and 3) observed, with the concentrations of TS increasing in the liquid feed, indicates a chemostatic limitation in the groups with greater amounts of TS (Figure 1a).

Silper et al. (2014) also reported that calves were not able to ingest a total volume of 4 or 6 L/d of MR (12.5% TS) during the first month of age.

The TS intakes in the liquid feed, measured as % of birth weight, were 2.1, 2.5, 2.5, and 2.8% in the wk 2 and 2.2, 2.6, 2.7, and 3.0% in the wk 3, respectively, for the liquid feed with 13.5, 16.1, 18.2, and 20.4% TS. Kiezebrink et al. (2015) verified an intake of 71% of the liquid feed during the wk 1, and 92% from wk 2 to 8, when 8 L/d of milk was provided. These values represent a TS intake of 1.8 and 2.3% TS of the birth weight, respectively. Our results show that increasing the TS content of WM is an effective strategy to increase the amount of nutrients provided to heifers in the first weeks of life. This is also important when considering that the majority of farms provide milk to heifers only twice daily (Jasper and Weary, 2002).

Starter intake (Table 2) was similar among treatments, indicating that a higher intake of TS in liquid feed did not discourage heifers to seek solid feed. Previous studies showed that increasing TS supplied through higher volumes of the liquid feed reduced starter intake (Bach et al., 2013; Kiezebrink et al., 2015; Silva et al., 2015). Glosson et al. (2015) demonstrated that providing 3.8 L/d of pasteurized milk enriched with milk balancer (17.6% TS) reduced starter intake in the same proportion as the supply of greater volumes of liquid feed. In the present study, all heifers consumed an insignificant amount of starter during the first weeks of life and began to increase starter consumption during wk 7. A substantial increase in starter intake was observed after the total volume of liquid feed was reduced by half (3 L/d) in the week before weaning (Figure 1b).

Analysis of total DM intake (liquid feed DM + starter DM) expressed as percentage of BW/d showed an interaction (P = 0.01) between treatments and weeks (Table 2). Between wk 2 and 8, total DM intake (%BW/d) increased (linearly, P = 0.01) as the concentration of TS increased. However, in the last week of preweaning period, total DM intake (% of BW/d) was similar among treatments (Figure 1c). These results show that after the volume of WM offered was reduced by half, animals from the treatments with greater amounts of TS in liquid feed were not able to compensate for the reduction in TS by increasing starter intake (Figure 1b) compared with heifers fed 13.5% TS in liquid feed. As predicted, the total intake of CP (g/d) and GE (Mcal kg/d) increased (linearly, P = 0.01) as the concentration of TS increased (Table 2).

Heifers fed a higher concentrations of TS intakes more water (linear increased, P = 0.01; Table 2). These results corroborate the positive relationship normally observed between total DM intake and water intake (Kertz et al., 1984). Conversely, when a greater volume of milk is offered (and indirectly greater amount of TS), there is a negative relationship between DM intake and voluntary water intake (Kiezebrink et al., 2015), since part of the needs for water have been obtained from the liquid feed. The linear increased of both variables, according to the increased amounts of TS in liquid feed, showed that the plateau of this relation is higher than 20.4% TS.

Ruminal pH during the preweaning period averaged 6.2 and was similar among treatments. A linear decreased (P = 0.01) in ruminal pH was observed in response the increased in starter intake. The low starter intake (mean of 165 g DM/d) and the presence of fresh forage in the hutches, even though in small amounts, may have helped in the control of ruminal pH. At d 42 and 56, heifers presented an average ruminal pH of 5.9, which is a value near to those described by Duffield et al. (2004) as an indicator of subacute ruminal acidosis in lactating cows. However, in the present study, heifers did not present any signs of this disorder, such as tympanism, diarrhea, presence of non-digested food in the feces, gas bubbles, and abdominal discomfort (Kleen et al., 2003; Suarez-Mena et al., 2016). According to Suarez-Mena et al. (2015), calves are apparently able to tolerate lower rumen pH values in comparison to adult animals, what might explain the potential adaptation of ruminal epithelium to starter fermentation (Laarman et al., 2012). However, subacute ruminal acidosis in young calf has received scant attention and the severity of rumen acidosis caused by different factors is not yet clear in dairy calves (Khan et al., 2016).

The increased in amounts of TS led to an increased (linearly, P = 0.01) in ADG and BW at 60 d of age (Table 2), similarly to the results reported by Glosson et al. (2015). The increasing in concentrations of TS in the liquid feed increased (linearly, P = 0.01) withers height of heifers (Table 2). Interactions (P = 0.01) between treatments and weeks (Table 2) were detected for measurements of heart girth and hip width. Except for wk 3, heifer's heart girth increased (linearly, P = 0.01) as the concentration of TS increased (Figure 1d). During wk 3, the heifers (95%) presented diarrhea and signs of dehydration, what could have interfered with girth measurements. For the hip width, differences were observed only for the sixth, seventh and last week, when an increased (linearly, P = 0.01) was verified with the increasing amounts of TS in the liquid feed (Figure 1e).

Body frame development, ADG, and BW at d 60 showed that the increasing in concentrations of TS favored the development of skeletal and tissue structure of heifers during the preweaning period. These results are explained by the increased in total CP and GE intake (*P* = 0.01) as the concentration of TS increased in the liquid feed (Table 2). According to Blome et al. (2003) and Bartlett et al. (2006), the increase in calf growth rate, as well as the increase in body protein and water associated to lean tissue, occurs when protein is provided in synchrony with energy in the liquid feed. Glosson et al. (2015) did not observe differences for measurements in body development as the TS content increased up to 17.6% of the liquid feed. However, according to those authors, the similarities of these measurements in combination with the higher BW that was verified in the calves fed a greater volume of enriched milk, suggest a potential addition of muscle and fat tissues. Pettyjohn et al. (1963) suggested that feeding 15% TS in liquid feed improve performance, body frame development, and more efficient use of nutrients. Jenny et al. (1978) verified a linear increased on ADG when calves were fed with liquid feed containing up to 20% TS, and no starter was provided. In a following study, Jenny et al. (1982) reported similar results when 10-13% TS in liquid feed was used, and starter was available to calves. However, these studies, increased TS content in liquid feed exclusively composed of MR and adopted different feed handling procedures compared with those taken in the present study.

The increased in amounts of TS decreased (linearly, *P* = 0.01) feed efficiency (Table 2). In order to increase the TS content in the liquid feed, MRP was included and the proportion of WM was reduced, such that a fixed volume of liquid feed was provided for all treatments (6 L/d). Thus, the replacement of nutrients from a dairy source with a non-dairy source may justify the decrease in feed efficiency. However, even with lower efficiency in performance, heifers that received higher amounts of TS were more efficient regarding body frame development. Other studies also reported a greater feed efficiency of calves fed greater volumes of milk (Ballou et al., 2015; Glosson et al., 2015; Silva et al., 2015).

Fecal scores (Table 2) and days with diarrhea (fecal score ≥ 3) were similar among treatments. The days with diarrhea showed an average of 1 d during the preweaning period, and reduction with quadratic effect across weeks evaluated (Figure 1f). The incidence of diarrhea in the first three weeks of the study, regardless treatments, was 95, 95, and 55%, respectively, for wk 2, 3, and 4. According to Jenny et al. (1978), only one meal provided with higher TS content of MR increased the incidence of diarrhea in calves. Calves fed a greater volume of milk, divided in two meals, also presented more days of diarrhea during the preweaning period as the content of TS increased in the diets (Ballou et al., 2015; Glosson et al., 2015). The increased in fecal score of calves fed pasteurized milk containing milk balancer can be explained by the higher osmolality of those liquid feed (280-483 mOsm/L), which may affect the water absorption in the intestines (Glosson et al., 2015). In the present study, the osmolality of the treatments were 265, 351, 439, and 533 mOsm/L for the diets with 13.5, 16.1, 18.2, and 20.4% TS, respectively. However, no differences were observed among the treatments for fecal score and days with diarrhea, indicating that the increase in osmolality (up to 533 mOsm/L) didn't affect incidence of diarrhea in calves.

Additionally, it is important to point out that the MRP used in the present study has probiotics in its composition (Table 1), so the heifers fed higher TS amounts also received higher amounts of probiotics in liquid feed. Therefore, even though there was no difference in fecal score among treatments (Table 2), the variation in the amount of probiotics provided may represent a confounding factor, indicating that further studies are needed for a better understanding this effect. Signorini et al. (2012) did a meta-analysis evaluating the incidence of health issues in young calves, and showed that the addition of probiotics to the calves' diet reduced the incidence of diarrhea. Additionally, this study found that feeding WM containing probiotics further improved the positive effects on fecal score. However, a consensus has not been reached as to whether probiotics may be effective in reducing the prevalence of gastrointestinal diseases in young calves (Signorini et al., 2012). While some studies have reported improvements in growth performance of calves supplemented with probiotics (Timmerman et al., 2005; Frizzo et al., 2010), others have found no beneficial effects (Jenny et al., 1991; Abu-Tarboush et al., 1996; Cruywagen et al., 1996). Moreover, Agarwal et al. (2002) found no effect of feeding probiotics on the rumen microbial ecosystem of preweaning calves.

Postweaning Period

Intake of starter, corn silage, total DM (%BW/d), total CP (g/d), total GE (Mcal kg/d), water, and ruminal pH were similar among treatments during the postweaning period (Table 3).Ruminal pH increased (P = 0.01) with age; in the first pH measurement postweaning period (70 d of age), the mean pH was 5.8 and all heifers presented watery feces containing gas bubbles, which is considered as an indicative of subacute acidosis

(Duffield et al., 2004). After corn silage was provided to the heifers, at 84 d of age, the average of ruminal pH increased to 6, demonstrating the importance of forage in controlling ruminal pH (Castells et al., 2013; Terré et al., 2013; Terré et al., 2015).

During the postweaning period, ADG and feed efficiency were similar among treatments (Table 3). However, the difference in BW among treatment group observed by the end of the preweaning period was maintained after weaning (Table 3). Ballou et al. (2015) verified that supplying higher volumes of liquid feed to calves promoted greater ADG during preweaning calves, although two weeks after weaning, these animals presented lower ADG compared with those fed lower liquid feed volume.

Even though withers height were similar across treatments during the postweaning period, heart girth and hip width increased (linearly, $P = 0.01$) as the concentration of TS in the liquid feed increased (Table 3), indicating that the differences in body frame development observed during the preweaning period were maintained postweaning period up to 90 d of age. Morrison et al. (2009) and Kiezebrink et al. (2015) reported that even when calves presented greater body frame development during the preweaning period, this effect was not maintained after 90 d of age. These findings show the need for long term evaluations of heifers fed greater concentrations of TS in the liquid feed.

Based on the linear effect of the increasing amounts of TS in the liquid feed on ADG during the preweaning period, we can speculated that a greater performance could be achieve if heifers were fed liquid feed containing TS concentrations greater than 20.4%. However, the total intake of liquid feeds was only after wk 7, indicating a plateau for total DM intake. Thus, new strategies of milk feeding with supply of greater amounts of TS need to be evaluated in order to achieve greater ADG and feed efficiency during the pre- and postweaning periods. Furthermore, the economic analysis and cost section of different feeding practices should be considered when devising feeding recommendation for sustainable dairy calf production.

CONCLUSIONS

The increase of total solids in whole milk by the addition of milk replacer powder up to 20.4% TS is an option to increase performance and body frame development of dairy heifers in the pre- and postweaning periods, with no effects on solid feed intake, fecal score and days with diarrhea.

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Table 1. Nutrient composition (DM basis) of whole milk (WM), milk replacer powder (MRP), starter, corn silage, and treatments

Item	WM	MRP[3]	Starter	Corn silage	Treatment, % TSWM			
					13.5	16.1	18.2	20.4
DM[1], %	12.6	94.7	89.3	31.7	13.5	16.1	18.2	20.4
CP, %	25.6	20.0	21.2	6.7	25.2	23.8	23.2	22.9
Ether extract, %	33.0	13.4	2.1	3.6	33.0	28.6	26.0	23.7
Ash, %	–	7.3	11.9	5.8	5.8	5.6	5.5	5.3
NDF, %	–	–	23.5	56.7	–	–	–	–
ADF, %	–	–	10.1	28.6	–	–	–	–
GE, Mcal/kg	–	4.5	3.7	4.1	5.8	5.7	5.6	5.6
Lactose[2], %	33.9	47.0	–	–	31.5	39.6	42.5	44.8
Calcium, %	–	1.1	1.5	0.2	1.1	1.0	1.0	1.0
Phosphorus, %	–	0.5	0.5	0.2	0.8	0.8	0.7	0.7
Magnesium, %	–	0.1	0.3	0.2	0.1	0.1	0.1	0.1

[1] As fed basis.

[2]Lactose % of treatments = 100 – CP% - EE% - Ash% - 2 (Drackley, 2008).

[3]Basic composition: whey, whey lactose free, lipids of plant origin, wheat gluten hydrolyzate, folic acid, nicotinic acid, pantothenic acid, betaine, biotin, iron oxide, magnesium oxide, zinc oxide, sodium selenite, copper sulphate, manganese sulfate, vitamin A, vitamin $B_{1,}$ vitamin $B_{12,}$ vitamin $B_{2,}$ vitamin $B_{6,}$ vitamin C, vitamin $D_{3,}$ vitamin $E_{,}$ vitamin K, and probiotic additive (*Enterococcus faecium* and *Lactobacillus rhamnosus*).

Table 2. Feed and water intake, performance, feed efficiency, body frame development structural body measures, and fecal score of heifers (n = 60) fed different total solid contents in whole milk (**TSWM**) during the preweaning period

Item	Treatment, % TSWM				SEM	*P*-value[1]		
	13.5	16.1	18.2	20.4		T	W	TxW
Intake								
WM+MRP, as fed, kg/d	5.4	5.4	5.2	5.2	0.05	0.08	0.01	0.01
WM+MRP, g of DM/d	732	876	959	1073	9.9	0.01	0.01	0.01
Starter, g of DM/d	189	181	162	127	11.6	0.13	0.01	0.59
Total DM, % of BW/d	1.7	1.9	2.0	2.0	0.01	0.01	0.01	0.01
Total CP, g/d	225	247	259	273	2.1	0.01	0.01	0.60
Total GE, Mcal/kg	4.9	5.5	5.8	6.2	0.04	0.01	0.01	0.08
Water, kg/d	1.4	1.5	2.1	2.2	0.05	0.01	0.01	0.71
Performance								
Birth BW, kg	34.4	34.6	33.4	35.6	0.6	0.62	–	–
Final BW, kg	70.8	75.2	77.2	80.4	1.1	0.01	–	–
ADG, g/d	658.2	690.7	747.6	780.7	12.8	0.01	0.01	0.07
Feed efficiency	0.72	0.66	0.64	0.64	0.01	0.01	0.01	0.63
Body frame development, cm								
Withers height	81.7	82.6	83.4	83.7	0.2	0.03	0.01	0.16
Heart girth	85.4	86.5	87.7	88.7	0.3	0.01	0.01	0.02
Hip width	20.1	20.5	20.7	21.0	0.1	0.13	0.01	0.01
Fecal Score	1.4	1.4	1.5	1.5	0.03	0.74	–	–

[1] T = treatment effect; W = week effect; T x W = treatment by week interaction.

Table 3. Postweaning period feed and water intake, performance, feed efficiency, and body frame development structural body measures of heifers (n = 60) fed different total solid contents in whole milk (**TSWM**) during the preweaning period

Item	Treatment, % TSWM				SEM	*P*-value[1]		
	13.5	16.1	18.2	20.4		T	W	TxW
Intake								
Starter, g of DM/d	2060	2033	2059	2197	39.9	0.64	0.01	0.10
Corn silage, g of DM/d	204	176	195	246	11.3	0.34	0.01	0.71
Total DM, % of BW/d	2.5	2.3	2.3	2.4	0.03	0.32	0.01	0.26
Total CP, g/d	447	437	445	478	8.88	0.57	0.01	0.12
Total GE, Mcal/kg	8.2	8.0	8.2	8.9	0.17	0.46	0.01	0.12
Water, kg/d	8.3	8.0	8.7	8.7	0.1	0.42	0.01	0.56
Performance								
Initial BW, kg	70.8	75.2	77.2	80.4	1.1	0.01	–	–
Final BW, kg	101.5	104.9	106.9	110.9	1.6	0.02	–	–
ADG, g/d	1036.5	961.3	981.5	1022.6	22.8	0.69	0.01	0.83
Feed efficiency	0.32	0.31	0.30	0.29	0.01	0.52	0.01	0.99
Body frame development, cm								
Withers height	91.9	92.4	93.6	94.0	0.2	0.06	0.01	0.53
Heart girth	100.5	101.5	103.0	104.3	0.3	0.01	0.01	0.29
Hip width	23.7	24.3	24.6	24.6	0.1	0.03	0.01	0.89

[1] T = treatment effect; W = week effect; T x W = treatment by week interaction.

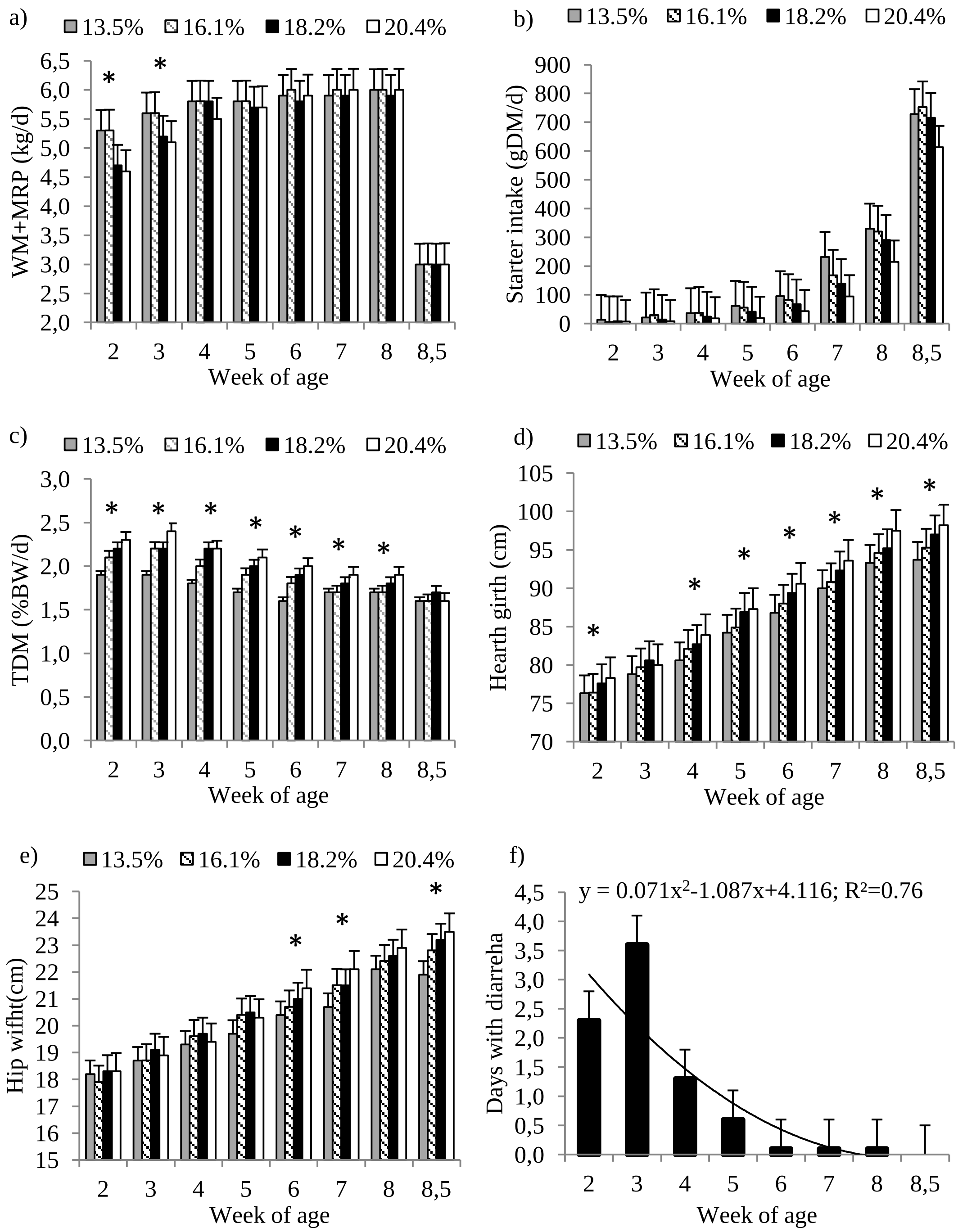

Figure 1. (a) Liquid feed (WM+MRP, kg/d) intake, (b) starter intake (g DM/d), (c) TDMI (total dry mater intake, %BW/d), (d) heart girth (cm), (e) hip width (cm), and (f) days with diarrhea of heifers (n = 60) fed different total solid contents in whole milk (**TSWM**) during the preweaning period. *Treatment effect ($P \leq 0.05$). Error bars represent SE.

CAPÍTULO III

The effects of increasing amounts of milk replacer powder added to whole milk on passage rate, nutrient digestibility, ruminal development, and body composition in dairy calves

ABSTRACT

The aim of this study was to evaluate the effects on feed intake, calf performance, feed efficiency, fecal score, passage rate, apparent nutrient digestibility, development of rumen and other organs, and body composition of increasing the total solids (**TS**) content of liquid feed (whole milk) by adding increasing amounts of milk replacer powder during the preweaning period. Crossbred Holstein-Gyr calves (n = 32) were assigned to 1 of 4 treatments (n = 8 per group), which consisted of different TS concentrations: 12.5, 15.0, 17.5, and 20.0% of liquid feed. Calves received 6 L of liquid per day, divided into 2 equal meals (0800 and 1600 h) and provided in buckets, from 5 to 55 d of age. Starter and water were provided ad libitum during the entire experiment. At 56 d of age, animals were submitted to euthanasia. Laboratory analysis determined that the actual TS contents of the liquid feed were 13.5, 16.1, 18.2, and 20.4%, for the proposed 12.5, 15.0, 17.5, and 20.0% TS treatments, respectively. The osmolality of liquid feed treatments was 265 to 533 mOsm/L. Fecal score was similar among treatments, except for wk 2 and 7. Intake of liquid feed was similar among treatments from the 6 wk of age. During wk 4, 5, and 6, we detected a linear decrease in starter intake. After wk 7, greater starter intake was observed for calves fed approximately 16.1% TS. Water intake, feed efficiency, and withers height were similar among treatments. Increasing concentrations of TS in liquid feed affected quadratically the average daily gain (ADG), final BW, and empty BW. We observed the greater ADG for calves fed approximately 20.4% TS. The passage rate, nutrient digestibility, development of pre-stomachs and intestine, and body composition were similar among treatments. Increasing the concentration of TS in liquid feed up to 20.4% reduces the starter intake between 4 and 6 week of live, but increased the ADG in dairy calves. However, did not affect the passage rate, nutrient digestibility, ruminal and organs development, and body composition of calves during preweaning period, indicating that

this may be a viable alternative for feeding without increasing the total volume of liquid feed provided to a dairy calf.

Key words: calf performance, feed intake, preweaning, total solid

INTRODUCTION

Restricting liquid feed intake to approximately 10% of calf BW during the preweaning period is a common practice in calf rearing systems (Jasper and Weary, 2002; Terré et al., 2009; Sweeney et al., 2010) and, when associated with early weaning, can reduce feed costs and stimulate the early onset of starter intake (Eckert et al., 2015; Yavuz et al., 2015; Chapman et al., 2016). However, solid feed intake in the first month of life may be low (Sweeney et al., 2010) and, when combined to a liquid feed restriction regimen can limit calf performance (Khan et al., 2007a). This condition can explain the hunger behavioral characteristics demonstrated by dairy calves (De Paula Vieira et al., 2008; Miller-Cushon et al., 2013).

Controversial results are found in literature regarding the performance of calves fed a greater volume of liquid feed versus calves fed conventionally (Omidi-Mirzaei et al., 2015). The greater supply of liquid feed may (Kristensen et al., 2007) or may not result in negative effects on rumen development (Khan et al., 2007b; Silper et al., 2014), and reduce (Terré et al., 2007; Hill et al., 2010; Chapman et al., 2016) or not reduce (Silva et al., 2015) apparent nutrient digestibility. One way to partially overcome the negative effects of providing greater volumes of liquid feed is to add products commonly sold as “balancers” or milk replacer power (MRP), which increase the TS content in the liquid without increasing the amount of milk feed (Glosson et al., 2015). Terré et al. (2006) reported that calves fed a greater volume of enriched liquid feed (18% TS) showed higher BW. However, with a lower starter intake and an apparent delay in rumen development when compared to conventionally fed calves (12.5% TS). Glosson et al. (2015) reported that 17.6% TS, in greater volume of liquid feed, increased ADG, BW, and calves feed efficiency.

Recommendations for the maximal concentration of TS in liquid feed are still not well established, and further research on the effects of different concentrations of liquid feed TS on calf performance and development are needed. However, Tikofsky et al. (2001)

determined the effect of varying concentrations of dietary fat and carbohydrate on changes in body composition of Holstein calves fed under isocaloric and isonitrogenous intake conditions. Although dietary fat varied among treatments without compromising ADG and final BW, the body composition was altered by diet, demonstrating that the evaluation of animals based only on the ADG does not reflect the efficacy of the feeding regimen for dairy calves. Therefore, there is a need to evaluate the effects of this strategy on the apparent digestibility of the diets, on rumen development, and on body composition of calves. We are unaware of data showing the effects of increasing TS concentration in liquid feed by adding MRP in whole milk on the passage rate of preweaned calves.

Moreover, the final osmolality of a liquid feed must be considered. When the osmolality increased, it can lead to a degree of digestive problems (Kertz and Loften, 2013). According to Glosson et al. (2015), an increase in osmolality resulting from the addition of milk balancer to the whole milk can affect water absorption by intestines, leading to an increase in incidence of diarrhea. According to McGuirk (2003), the normal serum osmolality is about 280-290 mOsm/kg, and milk is an isosmotic food. Although reference values are not well established, fluids with an osmolality greater than 600 mOsm/L should be offered with caution (McGuirk, 2003), because the gradient is no longer as effective and absorption in the small intestine is inhibited, which could lead to as osmotic diarrhea (Floren et al., 2016). This suggests that feeding concentrations may be as important to calf health as total nutrients offered, and care should be taken to not concentrate replacers to a point where they might be harmful (Floren et al., 2016).

The objective of this study was to evaluate the effects of increasing the concentration of TS in whole milk on feed intake, performance, feed efficiency, body frame development, fecal score, passage rate, apparent nutrient digestibility, development of the rumen and other organs, and body composition of dairy calves during the preweaning period by adding MRP. Our hypothesis was that increasing TS concentrations in whole milk would alter the feed intake and performance, indirectly affecting the fecal score, passage rate, apparent nutrient digestibility, development of the rumen, and body composition of dairy calves during the preweaning period by adding MRP.

MATERIAL AND METHODS

The study was approved by the Ethics Committee of Embrapa Dairy Cattle, Brazil (protocol n. 06/2014). The experiment was conducted at the Embrapa Dairy Cattle Experimental Farm, located in Coronel Pacheco, Minas Gerais, Brazil.

Animals, Housing, and Treatments

Holstein x Gyr crossbred male calves (n = 32) were used; their genetic composition was 5/8 or more Holstein and 3/8 or less of Gyr. Calves were born during Brazilian fall (April to May, 2014), removed from their dam, fed 3L of colostrum (>50 g/L of IgG) within 6-8 h of birth, and transferred to individual shelters over tropical grass pasture (*Cynodon sp*) during the entire study. Blood samples were collected via jugular venipuncture within 48 h after birth, Samples were centrifuged at 800.6 X g for 10 min to measure total serum protein using a refractometer (Serum protein REF-301, Biocotek, Beilun, Ningbo, China).

Between 2 and 4 d of age, calves were fed 6 L/d of transition milk divided into 2 equal meals offered at 0800 and 1600 h. At 5, the calves were assigned to 1 of 4 treatments groups (n = 8 per group), maintaining a balance of birth BW and genetic composition in each group. Treatments consisted of increasing amounts of MRP (Sprayfo Violet SSP, Deventer, Netherlands; Table 1) added to 6 L/d of whole milk (12.6 ± 0.7% TS; mean ± SD; Table 1) to adjust the TS to expected concentrations of 12.5; 15.0; 17.5, and 20.0% of liquid feed. The initial TS content in the whole milk was measured daily, immediately after milking and before each feeding, using a Brix refractometer (*Misco DD-3* Palm Abbe Digital, Solon, Ohio, USA). Brix grade values were converted to TS content using the equation proposed by Moore et al. (2009) [TS = 0.9984 x (Brix refractometer reading) + 2.077] and the amount of MRP to be added to the whole milk was adjusted to achieve the desired TS content for each treatment. The MRP was added to the whole milk immediately before it was supplied to the calves. The time between milking and the feeding the calves was not more than 30 min.

The total volume of treatment (6 L/d) was divided into 2 equal meals (0800 and 1600 h) and provided to calves in buckets from 5 to 55 d of age. Starter (Soylac Rumen 20% CP, flaked corn and the rest of ingredients pelleted, Total Alimentos, Três Corações, Minas

Gerais, Brazil; Table 1) and water were offered ad libitum throughout the experimental period. The amount of starter provided was sufficient to result in 10% orts.

Handling and Health Measurements

At 8 d of age, preventive oral treatment against coccidiosis (Baycox Ruminants, Bayer, Leverkursen, Germany) was performed, at a 3 mL/10 kg of BW. Health and fecal scores were monitored daily by trained farm staff. Fecal score were graded according to Larson et al. (1977), as follow: 1-normal (firm but not hard); 2-soft (does not hold form, piles but spread slightly); 3-runny (spreads readily to about 6 mm depth); and 4-watery (liquid consistency, splatters). A calf was considered to have diarrhea if fecal score was 3 or 4.

Intake, Performance and Growth

Calves' performance, body frame development, and feed intake were monitored between 5 and 55 d of age. Intake of whole milk and MRP mixture, starter, and water were calculated daily by subtracting refusals from the amounts provided. The total intake of DM, CP, and gross energy from starter and whole milk + MRP were calculated. Water intake was measured using a portable balance (WH-A04, WeiHeng, China); no bucket reference was used to evaluate evaporation.

Starting at 5 d of age, BW and the body frame development (withers height and heart girth) were measured once a week before morning feeding. Feed efficiency was calculated using the ratio between ADG and total DM intake (Khan et al., 2007a).

Gastrointestinal Passage Rate and Nutrient Apparent Digestibility

Between 43 at 47 d of age, the total gastrointestinal tract (**GIT**) passage rate was estimated using a chromic oxide (Cr_2O_3) external marker (Castells et al., 2013). All calves received before the morning liquid feeding, a single oral dose of 2 g of chromic oxide, in gelatin capsule. Fecal samples were taken manually from the rectum at 0, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 48, 56, 64, 72, 84, and 96 h after receiving the marker. The samples were stored at -20ºC immediately after collection for subsequent chromium determination (atomic emission spectrum). Fractional passage rate in the rumen (***K_r***) and cecum (***K_c***), transit time (**TT**) in the tubular compartment of the GIT, the total mean retention time in rumen (**TRTR**), the total mean retention time post rumen (**TRTPR**), and the total mean marker retention time in the GIT (**TMRT**) were calculated according to the multi compartmental model proposed by Dhanoa et al. (1985).

Between 50 at 55 d of age, all animals were submitted to an apparent nutrient digestibility trial with the 5 d total feces collection. Plastic bags were attached to each animal to collect feces according to Terré et al. (2007). Bags were changed six times per day and feces weighed during the day, every day, for each calf, and stored at -20°C for further analysis. During the digestibility trial, few animals had diarrhea, thus, in these cases, the fecal samples were not taken into consideration. For each day of fecal collection, total feces per calf were weighed, homogenized, and sampled. During the digestibility trial, samples of liquid feed, starter and refusals for each calf were also sampled, pooled for the 5 d period, and stored in plastic containers until analysis.

Slaughter, Gastrointestinal Tract, Internal Organs and Viscera Weight

At 56 d of age, all calves were transported (135 km) in a livestock trailer to the Federal University of Viçosa (Minas Gerais, Brazil), and were slaughtered after being deprived from solid food for 14 h. Calves were euthanized by captive-bolt, which was followed by a jugular venipuncture for exsanguination (Silva et al., 2015). After slaughter, the abdominal cavity was immediately opened and each region of GIT (reticulo-rumen, omasum, abomasum, and small and large intestines) was isolated, tied off, and weighed. After collected samples in TGI, it was emptied, washed with running water (to remove TGI content), and weighed. Internal organs and viscera were also weighed. All variables were evaluated as a proportion of the empty body weight (**EBW**).

Ruminal and Cecum pH, Ruminal Ammonia Nitrogen, and Ruminal and Cecum Organics Acids

The rumen and cecum were immediately isolated after slaughter, preventing reflux and contamination of samples. Ruminal and cecum pH were measured immediately after separation of the components of the GIT from carcass using a portable potentiometer with puncture electrode (DM-2-Digimed, São Paulo, Brazil). Rumen and cecum content were collected separately and ruminal content were filtered through four layers of cheese cloth to separate the liquid and solid fractions. All samples were stored in plastic tubes at -20°C for further analysis. Ammonia nitrogen in the ruminal content was determined according to the colorimetric assay proposed by Chaney and Marbach (1962). Absorbance was measured at 630 nm in a spectrophotometer Spectronic 20D (Thermo Fisher Scientific, Madison, WI, USA) and ammonium chloride (NH_4Cl) was used as a standard.

Organic acids were determined by High Performance Liquid Chromatography (HPLC) in a Dionex Ultimate 3000 Dual Detector HPLC (Dionex Corporation, Sunnyvale, CA, USA) coupled to a Shodex RI-101 refractive index (RI) detector maintained at 40ºC using a Phenomenex Rezex ROA ion exchange column, 300 x 7.8 mm, maintained at 45ºC. The mobile phase was prepared with 5 mmol/L sulfuric acid (H_2SO_4) and the flow was 0.7 mL/min. All samples (2 mL) were defrosted at room temperature (25ºC), centrifuged (12,000 x *g*, 10 min) and the cell-free supernatants were treated as described by Siegfried et al. (1984). The following organic acids were used for the calibration of the standard curve: acetic, succinic, formic, lactic, propionic, valeric, isovaleric, isobutyric and butyric acid. The organic acids were prepared with a final concentration of 10 mmol/L, except isovaleric acid (5 mmol/L) and acetic acid (20 mmol/L).

Gastrointestinal Tract Development

An area of 5 cm^2 from the ventral ruminal sac, omasum laminae and different regions of the small intestine (duodenum, jejunum, and ileum) were fixed in formalin and routinely processed for paraffin embedding. The paraffin blocks were sectioned using an Olympus CUT 4055 manual microtome into 5 μm-thick serial sections. For morphometric analysis, the slides were stained with Hematoxylin-Eosin (HE) as described by Luna (1968). The images were captured using a light microscope (Olympus CX31), attached to a camera (Olympus OSIS SC30), using the software Cell-B (Olympus). The morphometric analyses were performed using the software AxioVision 4.8.2 -06/2010 (Carl Zeiss Images Systems®, Jena, Germany). The measurements taken were: 1- the area and height of ruminal and omasal papillae and the intestinal villi in different regions of the small intestine; and 2- depth of the intestinal glands. For the determination of the mitotic index (MI), 2,000 cells from the basal layer of the rumen and omasum epithelium were counted, including those with nuclei presenting mitotic figures (using a light microscope, 400X magnification). The MI was calculated as a ratio between the number of nuclei in division and the total number of nuclei counted (Costa et al., 2008; Azevedo et al., 2013). The cell proliferation in different regions of the small intestine was determined by counting the mitotic figures in the intestinal gland epithelium, in 10 fields, using a 40X objective and 10X eyepiece (400X magnification).

Body Composition

After the slaughter, reticulo-rumen, omasum, abomasum, small and large intestines, internal fat, mesentery, liver, heart, kidneys, lung, tongue, spleen, diaphragm, esophagus, trachea, reproductive tract, members, head, blood, and half carcass were grinded for approximately 20 min in an industrial grinder to make a composite and homogeneous sample, and samples were stored and frozen at -20°C for further analysis.

Nutritional Composition Analysis

Milk samples were collected twice a day (morning and afternoon) and analyzed for TS using an infrared analyzer (Bentley model 2000; Bentley Instrument Inc., Chaska, Minnesota, USA). Samples from liquid feed treatments were collected daily, composed by month, and lyophilized for nutritional composition (AOAC International, 1990; Table 1). The osmolality of the liquid feed was measured using an osmometer (Micro-Osmette, Natick, Massachussets, USA).

Samples of the starter and MRP were collected weekly and composed by month. Feces samples were pre-dried in a forced-ventilation oven (55°C) for 72 h and subsequently grinded in a1 mm sieve. Body components samples (‘non-carcass” + “carcass components”) were pre-dried by lyophilization and grinded in a 1 mm sieve in a knife mill (Detmann et al., 2012). All samples were analyzed for DM (method 934.01), CP (method 988.05), ether extract (method 920.39), and ash (method 942.05) according to the International AOAC (1990). The GE was determined by an adiabatic bomb calorimeter (Parr Instrument Company, Moline, IL, USA).

Statistical Analysis

Data were analyzed using SAS 9.0 (SAS Institute Inc., Cary, NC). Weekly averages of feed intake, performance, and body frame development were analyzed using a repeat-measures mixed model (PROC MIXED), including calf as the random component and treatment, week, and their interaction as fixed components. Differences among treatments were assessed using orthogonal polynomial contrasts to estimate the linear, quadratic, and cubic effects of increasing concentrations of TS in the liquid feed. Fecal score by period was tested as nonparametric variables using the Kruskal-Wallis test and with 95% confidence intervals for treatment comparisons (PROC NPAR1WAY). The mean per period and variables with a single measurement during the study, such as final BW, were analyzed by using the GLM procedure with orthogonal polynomial contrasts to estimate the linear, quadratic, and cubic effects of increased TS concentration in the liquid feed. We analyzed BW at birth and total serum protein using ANOVA, including treatment as a fixed effect and using a Tukey adjustment for *P*-values. Least squares means for each treatment are reported. The variables BW at birth and total serum protein were considered as covariates. Significance was declared at $P \leq 0.05$.

RESULTS AND DISCUSSION

The actual concentrations of TS in the whole milk + MRP were 13.5 ± 0.53%; 16.1 ± 0.03%; 18.2 ± 0.14%, and 20.4% ± 0.24%, for the proposed diets of 12.5, 15.0, 17.5 and 20.0 TS, respectively. The composition of treatments is in the table 1. The difference between the TS content initially proposed and the values found by laboratory analysis may have occurred because the equation used to convert Brix grade values to TS content was designed based on waste milk samples (Moore et al., 2009), which are different from the whole milk used in this experiment.

Birth weight (36.8 ± 4.46 kg; Table 2) and passive transfer of immunity were similar among treatments. We evaluated the passive transfer of immunity based on total serum protein value at 24 h after colostrum feeding, which averaged 7.2 ± 1.10 g/dL for all animals. The calves (97%) presented values above 5.5 g/dL. All calves remained healthy and presented no signs of illness during the experiment.

Fecal score (Figure 1a), except for wk 2 and 7, were similar among treatments. The increased in fecal score of calves fed pasteurized milk containing milk balancer can be explained by the higher osmolality of those liquid feed (280-483 mOsm/L), which may affect water absorption in the intestines (Glosson et al., 2015). In the present study, osmolality was 265, 351, 439, and 533 mOsm/L for the treatments with 13.5, 16.1, 18.2, and 20.4% TS, respectively. However, fecal score increased (linearly, P = 0.01; Figure 1a) with the concentration of TS only in the wk 2 and 7, indicating that the increase in osmolality (up to 533 mOsm/L) didn't affect the fecal score of calves, as reported by Floren et al. (2016). Moreover, in wk 2, probably the highest fecal score have occurred together with diarrhea caused by pathogens that affect the calves at this age, regardless of treatment; in wk 7, one possible explanation is the stress caused by the study of passage rate, as well as indicators used to measure the passing rate in calves.

Intake, Performance and Growth

We observed an interaction (P = 0.01; Table 2) between treatment and weeks for intake of whole milk + MRP (kg/d). During wk 2, 3, and 5, we detected a decrease (linearly, P = 0.01) in intake of whole milk + MRP (kg/d) as the concentration of TS increasing in the liquid feed. After wk 6, we observed a similar intake of whole milk + MRP (kg/d) among treatments (Figure 1b). However, intake of whole milk + MRP (g DM/d) increased (linearly, P = 0.01) with concentration of TS in the liquid feed, as initially proposed in the experimental design. Even with the reduction in liquid feed intake (kg/d) before wk 6, the increase in TS concentration, by the addition of MRP to whole milk, was an effective strategy to provide greater amount of nutrients (g DM/d) during the preweaning period.

Regardless of the concentration of TS in the liquid feed, calves were able to ingest all liquid feed provided only after wk 7 (Figure 1b). This indicates a physical limitation to intake capacity in all groups. The observed reduction in feed liquid intake (wk 2, 3, and 5) with the increasing concentrations of TS in the liquid feed indicates a chemostatic limitation in the groups with greater amounts of TS (Figure 1b). Silper et al. (2014) also reported that calves were not able to ingest a total volume of 4 or 6 L/d of MR (12.5% TS) in their first month.

We observed an interaction (*P* = 0.01; Table 2) between treatment and weeks for starter intake. During wk 2 and 3, starter intake was similar among treatments. During wk 4, 5, and 6, we detected a decrease (linearly, *P* = 0.01) in starter intake as the concentration of TS increasing in the liquid feed (Figure 1c). Previous studies showed that increasing TS supplied through higher volumes of liquid feed reduced starter intake (Bach et al., 2013; Kiezebrink et al., 2015; Silva et al., 2015). After wk 7, we observed a quadratic effect (*P* = 0.01) with the increase of TS concentration in the liquid feed (Table 2) and greater starter intake was observed for calves fed approximately 16.1% TS (Figure 1c). This may be also related to the chemostatic limitation caused by the increase of nutrient intake in the treatments with greater concentration of TS in the liquid feed, up to 16.1%. However, low starter intake (121 ± 67 g of DM/d) was observed regardless of treatment, possibly due to a hypophagic condition caused by the total volume (6L/d) of liquid feed offered in all treatments. Low starter intake during the preweaning period in intensive calf rearing programs have been reported in other studies (Jasper and Weary, 2002; Overvest et al., 2016).

Analysis of total DM intake (liquid feed DM + starter DM; g of DM/d) showed an interaction (*P* = 0.01) between treatments and weeks (Table 2). Between wk 3 and 6, total DM intake increased (linearly, *P* = 0.01) with the concentration of TS. However, in the two last weeks of preweaning period, we observed a quadratic effect (*P* = 0.01) with the increase of TS concentration in the liquid feed and greater DM intake was observed for calves fed approximately 18.2% TS (Figure 1d). We observed an interaction (*P* = 0.01; Table 2) between treatment and weeks for gross energy (Mcal kg/d) and CP (g/d) intake (Table 2). Between wk 2 and 6, gross energy intake increased (linearly, *P* = 0.01) with the concentration of TS (data not shown). During wk 2, 5 and 6, CP intake was similar among treatments (data not shown). Between wk 3 and 4, CP intake increased (linearly, *P* = 0.01) with the concentration of TS (data not shown). However, in the two last weeks of preweaning period, we observed a quadratic effect (*P* = 0.01) for gross energy and CP intake with the increase of TS concentration in the liquid feed and greater starter intake was observed for calves fed approximately 18.2% TS (data not shown).

Water intake was similar among treatments (2.0 ± 1.03 kg/d; Table 2). Ternouth et al. (1985) did not observe any differences in water intake as TS concentration increased (17 to 26%) in the liquid feed in calves up to 6 wk of age. Pettyjohn et al. (1963) reported a linearly increase in water intake as TS concentration increased in the liquid feed. There are a positive relationship between total DM intake and water intake (Kertz et al., 1984). In the present study, calves fed 16.1% TS presented a larger starter intake in the final weeks of preweaning period (Figure 1c). The greater osmolality observed in 20.4% TS (533 mOsm/L) may have resulted in more water intake to mitigate the concentration of TS in high osmolality, which may explain the similarity in water intake between the groups 16.1 and 20.4% TS (Table 2).

Feed efficiency and withers height were similar among treatments (Table 2). However, the increase in TS concentration in liquid feed affected quadratically (P = 0.01) ADG, final BW at 55 d of age, and EBW (Table 2). We observed the greater ADG for calves fed 19.5% TS, approximately the highest TS concentration evaluated in the present study. Interactions (P = 0.01) between treatments and weeks (Table 2) for measurements of heart girth showed, except for wk 4, 7 and 8, similar hearth girth among treatments. During wk 4 and after wk 7, we detected a quadratically effect (P = 0.01) in heart girth as the concentration of TS increasing in the liquid feed, and the greater heart girth was observed for calves fed approximately 18.2 % TS (Figure 1e).

These results can be explained by an increase in nutrient intake in calves fed liquid feed containing higher amounts of TS (Table 2). The optimum protein:energy ratio to maximize ADG of calves fed only milk replacer (**MR**) is estimated at 48 to 50 g CP/Mcal of metabolizable energy (**ME**) (Blome et al., 2003; Bartlett et al., 2006), or 51 g of CP/Mcal of ME (low ME intake) at 55 g CP/Mcal of ME (high ME intake) for calves fed MR and pelleted starter (Hill et al., 2009). In the current experiment, the protein:energy ratio was 54, 49, 49, and 48 g CP/Mcal of ME (ME calculated as 0.9 x intake of total gross energy; Davis and Drackley, 1998; Bartlett et al., 2006), for 13.5, 16.1, 18.2, and 20.4% TS, respectively. The optimum protein:energy ratio to maximize ADG in calves fed whole milk + MRP and starter was estimated to be between 48 and 49 g CP/Mcal of ME. According to Blome et al. (2003) and Bartlett et al. (2006), the increase in calves' growth efficiency is attributed to the increase of body protein and water associated to lean mass that occurs when protein is provided in synchrony with energy.

Gastrointestinal Passage Rate and Nutrient Apparent Digestibility

No differences in fractional passage rate in the rumen (K_r) and cecum (K_c), TT, TRTR, TRTPR, and in TMRT were observed among treatments (Table 3). These results may be explained by the low starter intake observed for all treatments. It is important to acknowledge that higher DM intake should result in greater passage rate (Huhtanen and Kukkonen, 1995; Castells et al., 2013). We are unaware of other studies showing the effects of increasing TS concentration in liquid feed, by the addition of MRP in whole milk, on the passage rate of preweaned calves. However, our objective was to assess the solids passage rate, as an indirect assessment of the feeding system in the development of the digestive tract of calves. We encourage integrated research efforts the separate passage rate only whole milk + MRP, with a liquid marker, and further studies must be performed to better understand the impact of TS in liquid feed and starter intake on these parameters.

The DM, OM, CP, and gross energy apparent digestibility were similar among treatments (Table 4), what may be due to the fact that all calves were feed the same amount of liquid feed (6 L/d) composed mainly by whole milk, which presents high digestibility, and they all had a low starter intake. The increase in nutrient digestibility in calves receiving greater amounts of whole milk (Silva et al., 2015), the reduction in nutrient digestibility in calves receiving greater amounts of MR (Hill et al., 2010; Chapman et al., 2016), and the results in the present study showed that increased TS concentration in the liquid feed, composed by whole milk + MRP, could be an option to avoid the decrease in nutrient digestibility, as observed when greater amounts of a liquid feed based on MR is provided to the calves. However, less digestion in postweaning of calves fed with greater amounts of liquid are reported (Terré et al., 2007; Hill et al., 2010; Chapman et al., 2016), and additional studies are needed to better explain the increasing total solids in whole milk by the addition of milk replacer powder and their effects on digestibility of calves during the postweaning period.

Gastrointestinal Tract, Internal Organs, and Viscera Weight

Reticulo-rumen, omasum, abomasum, small and large intestines mass were similar among treatments (Table 5). The lack of difference could be explained by the low starter intake observed in all treatments. The increase in total nutrient intake with the increase in TS concentration was not sufficient to determine an effect on GIT size. As reported by Baldwin et al. (2004), the rumen development has a remarkable impact in the capacity and provision of digestive substrates for the pre ruminant growth. The onset of solid feed intake and the establishment of anaerobic microbial ecosystem and ruminal fermentation promote a ruminal physical and metabolic development (Baldwin et al., 2004; Khan et al., 2011). Silper et al. (2014) did not observe any differences in ground starter intake and in reticulo-rumen mass of calves fed 6 L/d of liquid feed during the preweaning period. However, Kristensen et al. (2007) observed that the total weight of reticulo-rumen, omasum, and stomach of calves at 35 d of age decreased linearly when increasing amounts of MR (3.1; 4.8; 6.6, and 8.3 kg; 12.3% TS).

The weight of all internal organs and viscera were similar among treatments (Table 5). According to Ferrel and Jenkins (1998), internal organs present a higher metabolic rate, and the liver responds to alterations in feeding patterns. However, this was not observed in the current study, even with the increase in TS concentration in the liquid feed.

Ruminal and Cecum pH, Ruminal Ammonia Nitrogen, Ruminal and Cecum Organics Acids, and Gastrointestinal Tract Development

Ruminal and cecum pH, the concentration of ruminal ammonia nitrogen and the proportion of VFA (%) in the rumen and cecum, as well as the relationship between acetate and propionate and the total concentration of VFA (mmol/L), were similar among treatments (Table 6). The results may confirm the importance of starter intake on GIT development. According Khan et al. (2007b), the volume and method of liquid feed delivery can influence the intake of solid feed before weaning what can interfere the onset of ruminal fermentation and development.

The increase in TS concentration in the liquid feed had a quadratic effect (P = 0.01) on the duodenum villi height (mm) and a linear negative effect (P = 0.01) on height (mm) and area (mm^2) of ileum villi (Table 7). Variations in type and on how the nutrients are provided to the GIT may modify cellular proliferation, total use of nutrients by the intestine and the nutrients available to support growth. The regulation of intestine growth is complex, and it is affected by trophic and metabolic hormones, as well as chemical and physical dietary factors (Baldwin et al., 2004; Xiao et al., 2016). According to Górka et al. (2011) there are negative effects related to adding MR to liquid feeds on small intestine development. The authors pointed out that the maturation of the intestine epithelium, as indicated by a mitosis/apoptosis index, is decreased, which indicates a lower crypts depth and a tendency to a lower mitotic index of the small intestine epithelium as well. These findings may help explain the effects of MRP on height (mm) and area (mm^2) of ileum villi in the current experiment.

All other histological variables were not affected by treatments (Table 7) which may indicate an adaptive response of the GIT for digestion and absorption of different concentrations of solids presented in the liquid feed (Ternouth et al., 1985). It has been postulated that ruminal physical and chemical development depends on the intake of solid feed, such as starter (Baldwin et al., 2004; Khan et al., 2007b; Khan et al., 2016), and the lack of differences among treatments for other histological variables could also be explained by the low starter intake.

Body Composition

The body composition of protein, fat, ash, energy, and water were not affected by treatment (Table 8). The results show that the protein:energy ratio in the liquid feed (54, 49, 49, and 48 g CP/Mcal ME, respectively, for treatments with 13.5, 16.1, 18.2, and 20.4% TS) were adequate, regardless the amount of nutrient provided on each treatment. Similarly, Brown et al. (2005) did not find any effects of intensive high protein and energy intake MR fed on a DM basis of 2% BW and milk reconstituted to 14.1% TS on body composition when compared to moderate protein and energy intake of calves at 8 wk of age. However, Bartlett et al. (2006) reported an increase in fat percentage of body gain, ADG and feeding efficiency when an increase in liquid feed from 1.25% BW to 1.75% BW (MR reconstituted to 12.5% TS) occurred; Tikofsky et al. (2001) reported under conditions of isocaloric and isonitrogenous intake, body composition was altered by diet composition, independent of rate of gain in dairy calves.

CONCLUSIONS

Increasing total solids in whole milk by the addition of milk replacer powder up to 20.4% TS may be an interesting option to increase the amount of nutrients provided for dairy calves during the preweaning period. However, alter the starter intake, without alter the passage rate, nutrient digestibility, physical and morphological parameters of pre-stomachs, and intestine, as well as body composition. Furthermore, the economic analyses and the cost-effectiveness of different feeding practices should be considered when devising feeding recommendation for sustainable dairy calf production.

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Table 1. Nutrient composition (DM basis, % unless otherwise noted) of whole milk, milk replacer powder (MRP), starter, and treatments

Item	Whole milk	MRP[1]	Starter	Treatment (% TS in whole milk)			
				13.5	16.1	18.2	20.4
DM[2]	12.6	94.7	89.3	13.5	16.1	18.2	20.4
CP	25.6	20.0	21.2	25.2	23.8	23.2	22.9
Ether extract	33.0	13.4	2.1	33.0	28.6	26.0	23.7
Ash	–	7.3	11.9	5.8	5.6	5.5	5.3
Lactose[3]	33.9	47.0	–	31.5	39.6	42.5	44.8
Gross energy (Mcal/kg)	–	4.5	3.7	5.8	5.7	5.6	5.6

[1]Basic composition: whey, whey lactose free, lipids of plant origin, wheat gluten hydrolyzate, folic acid, nicotinic acid, pantothenic acid, betaine, biotin, iron oxide, magnesium oxide, zinc oxide, sodium selenite, copper sulphate, manganese sulfate, vitamin A, vitamin B_1, vitamin B_{12}, vitamin B_2, vitamin B_6, vitamin C, vitamin D_3, vitamin E, vitamin K, and probiotic additive (*Enterococcus faecium* and *Lactobacillus rhamnosus*).

[2]As fed basis.

[3]Lactose % of treatments = 100 – CP% - EE% - Ash% - 2 (Drackley, 2008).

Table 2. Feed and water intake, performance, feed efficiency, and body frame development of calves (n = 8 per group) fed different TS contents in whole milk (WM) during the preweaning period (5 to 55 d of age)

	Treatment (% TS in whole milk)					*P*-value[1]		
Item	13.5	16.1	18.2	20.4	SEM	T	W	T x W
Intake								
WM + milk replacer powder (as fed, kg/d)	6.0	5.9	5.9	5.6	0.03	0.01	0.01	0.01
WM + MRP (g of DM/d)	810	958	1,064	1,142	22.9	0.01	0.01	0.01
Starter (g of DM/d)	106	190	111	76	12.0	0.01	0.01	0.01
Total DM (g of DM/d)	948	1,150	1,178	1,220	22.8	0.01	0.01	0.01
Total CP (g/d)	253	267	271	278	3.2	0.09	0.01	0.02
Total gross energy (Mcal kg/d)	5.2	6.0	6.2	6.4	0.1	0.01	0.01	0.03
Water (kg/d)	1.6	2.4	1.8	2.3	0.2	0.37	0.01	0.95
Performance								
Birth BW (kg)	37.7	37.1	36.1	36.1	0.79	0.88	–	–
Final BW (kg)	70.4	82.7	82.2	80.8	1.37	0.01	–	–
ADG (g/d)	694	876	852	903	21.2	0.01	0.01	0.57
Feed efficiency	0.73	0.76	0.73	0.74	0.01	0.33	0.01	0.36
Body frame development (cm)								
Withers height (cm)	83.4	83.7	84.1	83.6	0.51	0.94	0.01	0.16
Hearth girth (cm)	85.1	88.8	87.7	87.9	0.44	0.02	0.01	0.01

[1]T = treatment effect; W = week effect; T x W = treatment by week interaction

Table 3. Fractional passage rates of the external marker in the gastrointestinal tract of calves (n = 8 per group) fed different TS contents in whole milk during the preweaning period (5 to 55 d of age)

	Treatment (% TS in whole milk)					Contrast, *P*-value[2]	
Item[1]	13.5	16.1	18.2	20.4	SEM	L	Q
K_r (h^{-1})	0.06	0.05	0.05	0.07	0.005	0.48	0.22
K_c (h^{-1})	0.33	0.24	0.38	0.37	0.029	0.30	0.43
TT (h)	1.81	2.37	1.54	1.56	0.175	0.35	0.48
TRT (h)	15.44	20.48	22.12	17.02	1.583	0.68	0.14
TRTPR (h)	3.23	4.01	3.37	2.75	0.295	0.47	0.27
TMRT (h)	20.55	26.86	27.59	23.10	1.707	0.61	0.15

[1]K_r = fractional passage rate in the rumen; K_c = fractional passage rate in the cecum; TT = transit time in the tubular compartment of the GIT; TRT = total mean retention time in rumen; TRTPR = total mean retention time in post rumen; TMRT = total mean retention time of the marker in the GIT.

[2]L = linear effect of treatment; Q = quadratic effect of treatment.

Table 4. Nutrient apparent digestibility of calves (n = 8 per group) fed different TS contents in whole milk during the preweaning period (5 to 55 d of age)

	Treatment (% TS in whole milk)					Contrast, *P*-value[1]	
Item	13.5	16.1	18.2	20.4	SEM	L	Q
Dry matter (%)	84.9	86.3	87.0	88.0	0.52	0.07	0.85
Organic matter (%)	87.7	87.9	88.5	89.7	0.43	0.17	0.60
Crude protein (%)	85.5	88.4	88.4	88.3	0.45	0.07	0.15
Gross energy (%)	88.1	88.1	88.5	89.5	0.46	0.31	0.60

[1]L = linear effect of treatment; Q = quadratic effect of treatment.

Table 5. Weight (%EBW) of internal organs and viscera of calves (n = 8 per group) fed different TS contents in whole milk during the preweaning period (5 to 55 d of age)

	Treatment (% TS in whole milk)					Contrast, *P*-value[1]	
Item	13.5	16.1	18.2	20.4	SEM	L	Q
EBW (kg)	69.8	80.5	79.0	80.1	1.43	0.01	0.04
% EBW							
Reticulo-rumen	1.09	1.20	1.14	1.06	0.043	0.67	0.25
Omasum	0.24	0.27	0.22	0.24	0.008	0.60	0.73
Abomasum	0.55	0.55	0.55	0.58	0.013	0.33	0.51
Small intestine	3.03	2.96	3.12	2.97	0.068	0.96	0.70
Large intestine	1.26	1.29	1.09	1.15	0.053	0.25	0.89
Liver	2.38	2.23	2.20	2.37	0.055	0.89	0.22
Lungs	1.32	1.40	1.24	1.42	0.035	0.71	0.46
Spleen	0.72	0.54	0.43	0.58	0.043	0.20	0.08
Kidneys	0.42	0.44	0.43	0.48	0.011	0.08	0.31
Pancreas	0.09	0.08	0.07	0.08	0.004	0.24	0.32
Heart	0.64	0.56	0.64	0.66	0.017	0.38	0.09
Omental fat	0.40	0.38	0.38	0.40	0.015	0.94	0.59
Perirenal fat	0.73	0.71	0.71	0.84	0.039	0.35	0.33

[1]L = linear effect of treatment; Q = quadratic effect of treatment.

Table 6. Ruminal and cecum pH, ruminal ammonia nitrogen (**NH_3**), and organic acids in rumen and cecum of calves (n = 8 per group) fed different TS contents in whole milk during the preweaning period (5 to 55 d of age)

	Treatment (% TS in whole milk)					Contrast, *P*-value[1]	
Item	13.5	16.1	18.2	20.4	SEM	L	Q
Rumen							
pH	7.2	7.1	7.0	7.0	0.08	0.27	0.99
NH_3 (mmol/L)	7.4	5.2	10.8	6.8	0.99	0.63	0.60
Acetate (%)	45.6	47.5	44.2	43.1	0.71	0.06	0.27
Propionate (%)	23.6	22.1	22.5	22.1	0.82	0.56	0.75
Isobutyrate (%)	16.9	17.8	18.0	10.1	0.83	0.16	0.71
Butyrate (%)	5.2	5.2	5.5	5.5	0.14	0.24	0.97
Isovalerate (%)	4.8	4.3	5.9	4.9	0.25	0.48	0.62
Valerate (%)	2.2	1.8	2.7	3.0	0.20	0.06	0.33
Succinate (%)	1.4	1.1	1.0	1.2	0.10	0.45	0.35
Acetate- to-propionate ratio	2.0	2.1	2.1	2.0	0.09	0.92	0.90
Total (mmol/L)	53.5	50.4	53.4	44.8	3.28	0.38	0.64
Cecum							
pH	7.0	7.0	6.8	6.9	0.07	0.56	0.57
Acetate (%)	53.6	52.5	49.2	49.7	1.33	0.23	0.75
Propionate (%)	17.7	20.5	16.3	19.5	0.66	0.85	0.90
Isobutyrate (%)	17.7	16.6	19.6	18.1	0.88	0.60	0.90
Butyrate (%)	5.4	5.3	4.9	6.5	0.29	0.34	0.20
Isovalerate (%)	2.2	1.8	1.8	2.3	0.18	0.99	0.30
Valerate (%)	1.6	1.6	1.9	2.5	0.16	0.04	0.33
Succinate (%)	0.5	0.3	0.6	0.7	0.09	0.31	0.34
L-Lactate (%)	1.3	1.1	1.0	1.2	0.19	0.56	0.70
Acetate- to-propionate ratio	2.6	2.7	3.0	3.1	0.11	0.11	0.81
Total (mmol/L)	109.0	87.1	80.0	97.4	4.89	0.33	0.05

[1] L = linear effect of treatment; Q = quadratic effect of treatment.

Table 7. Gastrointestinal tract development of calves (n = 8 per group) fed different TS contents in whole milk during the preweaning period (5 to 55 d of age)

	Treatment (% TS in whole milk)					Contrast, *P*-value[1]	
Item	13.5	16.1	18.2	20.4	SEM	L	Q
Height, mm							
Ruminal papillae	2.06	2.27	1.67	2.05	0.202	0.75	0.85
Omasum papillae	0.58	0.57	0.56	0.67	0.026	0.30	0.23
Duodenum villi	0.51	0.57	0.64	0.54	0.018	0.25	0.01
Jejunum villi	0.79	0.71	0.89	0.75	0.042	0.89	0.67
Ileum villi	0.87	0.74	0.75	0.71	0.019	0.01	0.24
Area (mm)							
Ruminal papillae	2.41	4.13	2.69	4.09	0.417	0.37	0.85
Omasum papillae	0.61	0.56	0.55	0.74	0.047	0.40	0.22
Duodenum villi	0.15	0.19	0.19	0.19	0.008	0.18	0.26
Jejunum villi	0.21	0.19	0.25	0.20	0.012	0.70	0.42
Ileum villi[2]	0.29	0.22	0.23	0.21	0.009	0.01	0.15
Profundity intestinal gland (mm)							
Duodenum	0.37	0.42	0.39	0.40	0.010	0.58	0.53
Jejunum	0.39	0.40	0.39	0.41	0.011	0.81	0.82
Ileum	0.49	0.46	0.48	0.48	0.010	0.94	0.34
Mitotic index							
Rumen	0.56	1.13	0.60	0.74	0.092	0.98	0.15
Omasum	1.18	1.31	1.06	1.06	0.131	0.53	0.75
Duodenum	13.05	18.00	17.50	18.50	1.129	0.16	0.42
Jejunum	18.02	29.75	21.62	23.12	2.325	0.69	0.20
Ileum	20.25	23.25	25.37	20.00	1.843	0.93	0.26

[1] L = linear effect of treatment; Q = quadratic effect of treatment.

Table 8. Body composition of calves (n = 8 per group) fed different TS contents in whole milk during the preweaning period (5 to 55 d of age)

	Treatment (% TS in whole milk)					Contrast, *P*-value[1]	
Item	13.5	16.1	18.2	20.4	SEM	L	Q
Protein (%DM)	56.1	58.1	54.4	55.3	0.42	0.10	0.45
Fat (%DM)	24.1	23.7	24.7	24.8	0.43	0.48	0.78
Ash (%DM)	13.9	12.4	14.4	13.7	0.31	0.62	0.53
Energy (Mcal/kg)	5.4	5.4	5.3	5.3	0.02	0.34	0.89
Water	68.6	68.9	68.3	67.5	0.41	0.29	0.44

[1] L = linear effect of treatment; Q = quadratic effect of treatment.

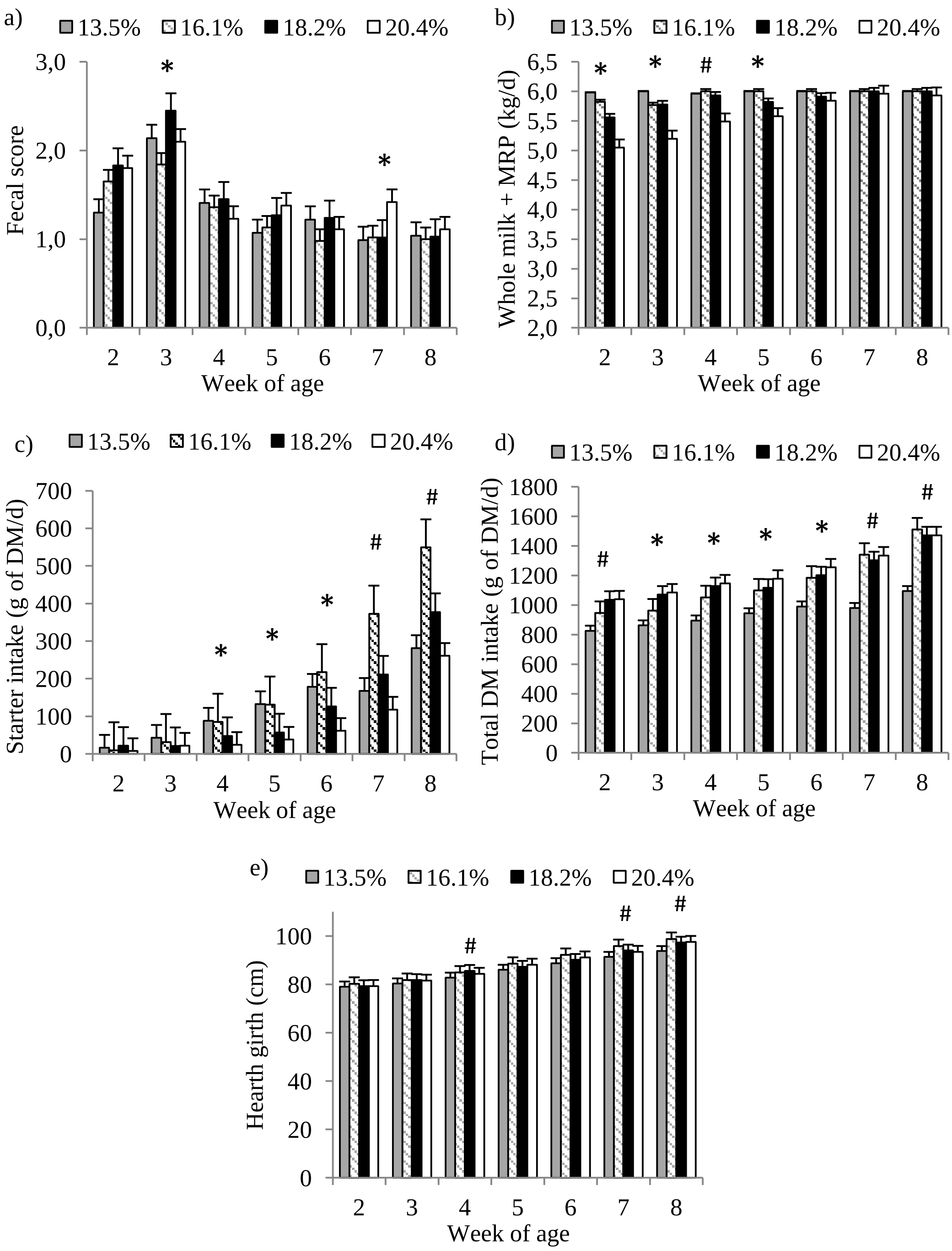

Figure 1. (a) fecal score (b) Liquid feed (Whole milk + MRP, kg/d) intake, (c) starter intake (g of DM/d), (d) Total DM intake (g of DM/d), and (e) heart girth (cm) of calves (n = 8 per group) fed different TS contents (13.5, 16.1, 18.2, and 20.4%) in whole milk during the preweaning period. *Linear effect ($P \leq 0.05$) and # Quadratic effect. Error bars represent SE.

CAPÍTULO IV

Considerações finais

Melhores taxas de crescimento são observadas em programas de aleitamento com maior volume de dieta líquida e/ou com aumento da concentração de ST, porém, o sucesso desses programas tem sido questionado devido à redução no consumo de concentrado durante o aleitamento e de GMD na fase de pós-aleitamento, além de aumento nos custos de criação, redução do volume de leite a ser comercializado para a indústria e menor capacidade de ingestão de grandes volumes de leite ou de sucedâneo por animais que nascem com menor PC.

Os resultados obtidos nesse trabalho demonstram que aumentar o fornecimento de nutrientes por enriquecimento da dieta líquida, até 20,4 % de sólidos totais, aumentando-se a concentração e não o volume da mesma pode ser uma alternativa interessante de aleitamento. O fornecimento de maiores quantidades de sólidos totais na dieta líquida aumenta o desempenho e o desenvolvimento corporal de bezerras leiteiras durante o pré e pós-aleitamento, sem alterar os dias em diarreia e a ingestão de alimentos sólidos e sem alterar a taxa de passagem, a digestibilidade dos nutrientes, os parâmetros físicos e morfológicos dos pré-estômagos e do intestino, bem como a composição corporal. Porém, análises de comportamento e bem estar animal, desenvolvimento da glândula mamária, produção e reprodução futura, bem como análises econômicas e a relação custo-efetividade de diferentes práticas alimentares devem ser consideradas na elaboração das recomendações de alimentação para a produção sustentável de bezerros leiteiros.