UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL

FACULDADE DE VETERINÁRIA

PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS VETERINÁRIAS

ESTRATÉGIAS NUTRICIONAIS E HORMONAIS PARA O AUMENTO DA PRODUTIVIDADE DE FÊMEAS SUÍNAS DESMAMADAS

RAFAEL DAL FORNO GIANLUPPI

PORTO ALEGRE

2020

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Tese apresentada como requisito parcial para obtenção do grau de Doutor em Ciências Veterinárias na área de Fisiopatologia da Reprodução de Suínos.

Orientador: Prof. Dr. Fernando Pandolfo Bortolozzo

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ESTRATÉGIAS NUTRICIONAIS E HORMONAIS PARA O AUMENTO DA PRODUTIVIDADE DE FÊMEAS SUÍNAS DESMAMADAS

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RESUMO

ESTRATÉGIAS NUTRICIONAIS E HORMONAIS PARA O AUMENTO DA PRODUTIVIDADE DE FÊMEAS SUÍNAS DESMAMADAS

Autor: Rafael Dal Forno Gianluppi
Orientador: Prof. Dr. Fernando Pandolfo Bortolozzo
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O objetivo do presente estudo foi avaliar diferentes quantidades e tipos de ração durante o intervalo desmame-estro (IDE) e o uso de altrenogest durante a última semana de lactação para melhorar a produtividade de fêmeas suínas desmamadas. O primeiro estudo avaliou duas quantidades (2,7 kg/d e 4,3 kg/d) e dois tipos de ração (gestação e lactação) durante o IDE para primíparas e multíparas. Houve interação ($P < 0,05$) no consumo de ração. Dentre as fêmeas que receberam 4,3 kg/d, as multíparas consumiram mais ração durante o IDE quando comparadas às primíparas contudo, no grupo que recebeu 2,7 kg/d não houve diferença entre as ordens de parto ($P > 0,05$). A variação de peso relativa (%) durante o IDE apresentou uma interação tripla onde primíparas recebendo 4,3 kg/d de ração gestação apresentaram menor variação do peso que os demais tratamentos ($P < 0,05$). A quantidade e o tipo de ração não afetaram nenhuma das variáveis reprodutivas ($P > 0,05$). Além disso, não houve interação da quantidade e das classes de perda de condição durante a lactação sobre o IDE, taxa de parto e nascidos totais ($P > 0,05$). Dessa forma, não há necessidade de alimentar fêmeas durante o IDE com 4,3 kg/d, sendo possível utilizar 2,7 kg/d. Devido à alta variabilidade no consumo de ração durante o IDE, um segundo estudo foi realizado com o objetivo de identificar fatores que influenciam este consumo. Para isso, foram utilizadas 600 fêmeas que receberam 4,3 kg/dia durante o primeiro estudo. O consumo de ração foi menor no dia da expressão do estro quando comparado com dois ou três dias antes do estro ($P < 0,05$). Em primíparas, o consumo no IDE foi negativamente afetado por alta espessura de toucinho (ET) aos 112 dias de gestação e alto ET, caliper ou peso corporal ao desmame, lactações curtas e poucos leitões desmamados ($P < 0,05$). Em multíparas, o consumo foi negativamente afetado por alto ET, caliper e escore corporal visual (ECV) aos 112 dias de gestação, alto ET no momento do desmame e alta perda de reservas corporais durante a lactação ($P < 0, 05$). Contudo, não houve diferença na taxa de anestro, parto e número de nascidos ($P > 0,05$). Assim, vários fatores parecem afetar o consumo da fêmea durante o IDE, contudo, no presente experimento, não foram suficientes para afetar o desempenho reprodutivo. O terceiro estudo avaliou o uso de altrenogest durante os últimos sete dias de uma lactação de três semanas sobre o tamanho folicular, tamanho de corpo lúteo e desempenho reprodutivo subsequente. Durante a última semana de lactação, fêmeas tratadas com altrenogest apresentaram menor diâmetro folicular quando comparadas com fêmeas controle ($P < 0,05$). Após o desmame, ocorreu uma inversão no tamanho folicular quando fêmeas tratadas com altrenogest apresentaram um maior tamanho folicular até 24 h antes da ovulação comparada as fêmeas controles ($P < 0,05$). Esse maior tamanho folicular resultou em maior tamanho e menor coeficiente de variação dos corpos lúteos das fêmeas tratadas com altrenogest ($P < 0,05$). Houve menos fêmeas tratadas com altrenogest entrando em estro nos dias três e quatro após o desmame quando comparada ao grupo controle ($P < 0,05$). Contudo, não houve diferença entre os tratamentos no IDE, progesterona sérica, desempenho reprodutivo e peso ao nascer dos leitões ($P > 0,05$). Dessa forma, o uso de altrenogest durante os últimos sete dias de lactação foi eficaz para melhorar as características ovarianas e reduzir a expressão de estro até o quarto dia, porém não melhorou o desempenho reprodutivo e peso ao nascer. Como conclusão geral da tese, durante o IDE pode ser fornecido 2,7 kg/dia de ração gestação para as fêmeas sem prejuízo no desempenho reprodutivo subsequente. Contudo, o uso de altrenogest durante a última semana de lactação não resultou em melhora do desempenho reprodutivo, mas reduziu o número de fêmeas expressando estro do dia dois e três após o desmame.

Palavras chave: Alimentação; progestágeno, Intervalo desmame-estro, nascidos totais, peso ao nascer.

ABSTRACT

NUTRITIONAL AND HORMONAL STRATEGIES TO INCREASE THE PERFORMANCE OF WEANED SOWS

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Co-advisor: Prof[a]. Dr[a]. Ana Paula Gonçalves Mellagi

This study aimed to evaluate diet types and amounts during weaning-to-estrus (WEI) and altrenogest treatment during the last week of lactation to improve the reproductive performance of weaned sows. The first trial evaluated two feed levels (2.7 and 4.3 kg/d) and two diets (gestation and lactation) during the WEI of primiparous and multiparous sows. There was an interaction (P < 0.05). In 4.3 kg/d group, multiparous had a greater feed intake than primiparous sows; however, in 2.7 kg/d group, there was no difference between parities (P > 0.05). There was a triple interaction on relative body weight change (%) during WEI, which primiparous fed with 4.3 kg/d of gestation diet lost less weight during WEI than those in the other treatments (P < 0.05). Multiparous had shorter WEI, larger follicle size, and higher total born and born alive than multiparous sows (P < 0.05). However, there was no difference in anestrous and farrowing rate (P > 0.05). The level and diet type did not affect any of the reproductive parameters (P > 0.05). Furthermore, there was no interaction between feeding level and body condition loss during lactation on WEI, farrowing rate, and litter size (P > 0.05). Thus, it is not necessary to fed sows with 4.3 kg/d during WEI, being possible to feed sows with 2.7 kg/d. Due to the high variability in feed intake during WEI, a second study was performed the analysis to evaluate factors that influence this feed intake. For this, 600 sows that received 4.3 kg/day during the first trial were used. The feed intake was lower on the estrus expression day than two- or three-days prior to the estrus expression (P <0.05). In primiparous sows, the feed intake during WEI was negatively affected by the high backfat thickness (BFT) at 112 d of gestation, and high BFT, caliper, and body weight at weaning, short lactation length and fewer weaned piglets (P < 0.05). In multiparous sows, the feed intake was negatively affected by high BFT, caliper, and body condition score (BCS) at 112 d of gestation, high BFT at weaning, and high body reserves loss during lactation (P < 0.05). However, there was no difference in anestrus and farrowing rate and total piglets born (P > 0.05). Thus, several factors could affect the feed intake during WEI; however, the reduction in feed intake was not enough to impair reproductive performance. The third study evaluated the altrenogest treatment during the last seven days of a 3-week lactation on follicular and corpora lutea size and reproductive performance. During the last week of lactation, altrenogest treated sows had smaller follicles than control sows (P < 0.05). After weaning, control sows had smaller follicles than altrenogest sows until 24 h before ovulation (P < 0.05). This larger follicle size resulted in a larger size and, a lower coefficient of variation of corpora lutea of altrenogest treated sows than control sows (P < 0.05). There was less altrenogest treated sows expressing estrus on day three and four after weaning than control sows (P < 0.05). However, there was no difference between treatments on WEI, serum progesterone, reproductive performance, and piglet birth weight (P > 0.05). Thus, the altrenogest treatment during the last seven days of a 3-week lactation period improved the ovarian traits and reduced the estrus expression until the fourth day after weaning, however it did not improve the reproductive performance and piglet birth weight. As general conclusions of this thesis, during WEI the sows can be fed with 2.7 kg/day of gestation diet with no negative impact on reproductive performance.

However, the altrenogest treatment during last week of Lactation does not improve the reproductive performance, but decrease the estrus expression on day two and three after weaning.

Keywords: *Feeding, progestogen, weaning-to-estrus interval, total born, piglet birth weight.*

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SUMÁRIO

1. INTRODUÇÃO

A rentabilidade de um sistema de produção está diretamente ligada a eficiência reprodutiva do plantel, sendo medida por meio de indicadores como taxa de parto, número de nascidos e número de partos por fêmea por ano. As fêmeas modernas possuem como características principais alto número de leitões nascidos, elevada produção de leite, elevada capacidade de ganho de tecido magro, baixa quantidade de gordura e consumo voluntário (CLOSE; COLE, 2001; TOKACH *et al.*, 2019). Dessa forma, a fêmea suína moderna tem altas necessidades nutricionais, mas com baixas reservas e capacidade de ingestão. Durante a lactação, essas características se tornam mais evidentes, quando as fêmeas, apesar de serem alimentadas à vontade, geralmente não conseguem ingerir a quantidade de nutrientes necessária para manter a condição corporal, resultando em catabolismo (QUESNEL, 2009).

Fêmeas que foram submetidas a um elevado grau de catabolismo durante a lactação, podem apresentar redução no tamanho folicular e no desempenho reprodutivo subsequente, como maior intervalo desmame-estro, aumento da taxa de anestro e redução no número de nascidos (BAIDOO *et al.*, 1992; ZAK *et al.*, 1997a; SCHENKEL *et al.*, 2010). O catabolismo lactacional, resultado de um consumo alimentar insuficiente, pode influenciar a reprodução por meio da redução da secreção das gonadotrofinas (hormônio luteinizante; LH e hormônio folículo-estimulante; FSH) o que compromete o desenvolvimento folicular (VAN DEN BRAND *et al.*, 2000). Além disso, a nível de ovário, ocorre a redução da concentração de mediadores metabólicos, como *Insulin-like Growth Factor* – I (IGF-I; QUESNEL, 2009). Dessa forma, períodos de restrição alimentar podem resultar em um *"imprinting"* folicular e, dessa forma, os folículos selecionados para o *pool* ovulatório podem ser maturados sob um ambiente metabólico adverso que pode resultar em pior desenvolvimento embrionário (ZAK *et al.*, 1997b).

Como forma de assegurar uma melhor qualidade dos folículos e aumentar a taxa ovulatória, uma prática comum nos sistemas de produção é o aumento do nível alimentar durante o intervalo desmame-estro (IDE). Em alguns sistemas, além do uso de alto nível de ração, é também utilizada a ração lactação, com o objetivo de aumentar ainda mais o aporte nutricional para as fêmeas. No passado, havia a sugestão de que o aumento dos níveis nutricionais, poderia melhorar, pelo menos parcialmente, o desempenho subsequente de fêmeas, principalmente as que sofreram restrição durante a lactação (BAIDOO *et al.*, 1992). Contudo, como resultado da seleção genética, buscando fêmeas cada vez mais produtivas, o IDE foi gradualmente reduzido ao longo dos anos e atualmente, um IDE de quatro a cinco dias é considerado adequado. Dessa forma, o período em que esse manejo é utilizado pode ser insuficiente para obter um efeito significativo.

Além de estratégias nutricionais, estratégias hormonais podem ser utilizadas para melhorar o desempenho subsequente de matrizes desmamadas. Durante a última semana de lactação, ocorre o desenvolvimento de ondas foliculares, as quais se estiverem crescendo no momento do desmame, irão atingir o tamanho pré-ovulatório (LUCY *et al.*, 2001), ovulando oócitos maturados em folículos selecionados durante a lactação, mais sujeitos a sofrer com um ambiente metabólico adverso. Dessa forma, o uso de progestágenos durante a última semana de lactação pode assegurar que os folículos sejam selecionados apenas após o desmame, resultando em folículos com melhor desenvolvimento (LOPES *et al.*, 2017) e consequentemente em embriões mais viáveis e maior corpo lúteo (QUESNEL *et al.*, 1998). Recentemente, o diâmetro do corpo lúteo foi relacionado com o peso do leitão ao nascimento (DA SILVA *et al.*, 2017). Dessa forma, o uso de progestágeno durante a última semana de lactação pode resultar em maior número de nascidos com maior peso.

Para a presente tese foram realizados dois experimentos que resultaram em três artigos. O primeiro artigo (**Effects of different amounts and type of diet during weaning-to-estrus interval on reproductive performance of primiparous and multiparous sows**) objetivou avaliar o efeito da quantidade e do tipo de ração durante o IDE sobre o desempenho reprodutivo de primíparas e multíparas. Além disso, foi avaliado o efeito dos tratamentos sobre o crescimento folicular e variação do peso corporal durante o IDE.

Devido à grande variabilidade encontrada no consumo de ração das fêmeas durante o IDE, surgiu a necessidade de identificar fatores que possam influenciar o apetite das fêmeas nesse período. Dessa forma, o segundo artigo (**Post-weaning feeding intake in primiparous and multiparous sows**) objetivou identificar fatores relacionados com o baixo consumo durante o IDE. Foram avaliados dados relacionados à condição corporal, aspectos lactacionais e de expressão de estro.

No terceiro artigo, (**Altrenogest treatment during the last week of lactation on the subsequent reproductive performance of primiparous and multiparous sows**) o objetivo foi avaliar o efeito do tratamento com Altrenogest durante a última semana de lactação sobre o desempenho reprodutivo, crescimento folicular, tamanho de *corpora lutea*, desempenho reprodutivo subsequente e peso do leitão ao nascer.

2. CAPÍTULO I - REVISÃO BIBLIOGRÁFICA

2.1 Crescimento folicular do parto à inseminação

Durante a gestação, a ação da progesterona produzida pelos corpos lúteos impede que ocorra o crescimento folicular até tamanhos pré-ovulatórios (QUESNEL; PRUNIER, 1995; QUESNEL, 2009). Contudo, após a luteólise, os níveis de progesterona e, após o parto, o estrógeno começam a diminuir, enquanto a pulsatilidade do LH aumenta. Dois a três dias após o parto, os níveis de LH voltam a diminuir, devido ao estímulo das mamadas da leitegada, bloqueando o crescimento folicular (DE RENSIS *et al.*, 1993). Essa redução na liberação do LH é mediada pela ação dos peptídeos opioides endógenos, os quais são capazes de inibir a liberação de LH e cuja a liberação é estimulada pela ação da mamada (QUESNEL; PRUNIER, 1995).

Logo após o parto, folículos ovarianos de até 5 mm podem ser observados. Já durante a lactação, apenas folículos pequenos e médios (≤ 3 mm) são encontrados (QUESNEL, 2009). Segundo Lucy *et al.* (2001), durante a terceira semana de lactação, ocorre o crescimento folicular em ondas não ovulatórias compostas de 20-30 folículos, os quais crescem até 4 – 6 mm antes do desmame. Esse crescimento está relacionado ao fato de que folículos de até 2 mm não são dependentes de gonadotrofinas para o seu crescimento. Já a não ocorrência da ovulação está relacionada ao fato de que folículos que atingem diâmetros entre 2 a 4 mm necessitam de FSH e de LH para continuar crescendo, sendo que a alta frequência de picos de LH é fundamental para o crescimento final e a maturação dessas estruturas (QUESNEL, 2009). Esse padrão de dinâmica folicular durante a lactação pode não ocorrer em todas as fêmeas, sendo possível haver inatividade ovariana, caracterizada pela presença de folículos de aproximadamente 2 mm ao longo de todo o período; formação de cistos foliculares ou ovulação antes do desmame (LUCY *et al.*, 2001).

Após o desmame, o estímulo da mamada cessa e, rapidamente, o padrão de secreção do LH muda de baixa frequência e alta amplitude para alta frequência e baixa amplitude (SHAW; FOXCROFT, 1985; VAN DEN BRAND *et al.*, 2000), permitindo a seleção dos folículos em um *pool* de estruturas foliculares já responsivas ao LH (QUESNEL, 2009). Segundo Van den Brand *et al.* (2000), fêmeas que apresentaram oito ou mais pulsos de LH em 12 horas apresentaram um diâmetro folicular maior dois dias após o desmame e um intervalo desmame-estro (IDE) menor quando comparadas com fêmeas que apresentaram sete ou menos pulsos em 12 horas (4,05 *vs.* 2,90 mm e 115 *vs.* 147 horas, respectivamente). Dessa forma, com um suporte adequado de LH, os folículos crescem até atingir o tamanho pré-ovulatório de 6-9 mm (KNOX; RODRIGUEZ -ZAS, 2001).

2.2 Fatores que influenciam a retomada da ciclicidade e desempenho pós-desmame

2.2.1 Condição corporal

Durante a lactação, ocorre um aumento nas demandas nutricionais da fêmea devido à grande produção de leite, sendo que essa maior exigência nem sempre é suprida pela quantidade de ração consumida pela fêmea, resultando em um cenário de maior perda de peso nesse período (BAIDOO *et al.*, 1992; ZAK *et al.*, 1997a; QUESNEL, 2009). Hoving *et al.* (2012) avaliaram 47 primíparas com maior ou menor perda de peso durante a lactação (>13,8% e ≤13,8% do peso vivo, respectivamente) e observaram que as fêmeas que perderam mais peso durante a lactação apresentaram redução de 21% na taxa de prenhez quando comparadas às que perderam menos peso (75 e 96%, respectivamente), e uma redução de aproximadamente 12% na taxa de sobrevivência embrionária. Além disso, as fêmeas que perderam mais peso durante a lactação apresentaram o pico de progesterona com um atraso de 1,4 dia em relação às fêmeas com menor perda de peso durante o período lactacional. A perda de peso durante a lactação também influencia o risco de ocorrência de retornos ao estro. Segundo Vargas *et al.* (2009), fêmeas de ordem de parto 1 e 2 que apresentaram uma perda de mais de 0,5 ponto de ECV tiveram 4,7 e 4,6 vezes mais chance de retornar ao estro, respectivamente, do que fêmeas de OP maior que 2 e com perda de ≤ 0,5 ponto de ECV durante a lactação. Esse maior percentual de retorno pode estar relacionado com uma alteração nas secreções que suportam o desenvolvimento embrionário, como ácido fólico, beta caroteno e vitamina A (FOXCROFT, 1997).

Assim como na lactação, fêmeas durante o IDE também podem perder condição corporal, prejudicando a fertilidade subsequente das fêmeas. Nesse sentido, alguns autores avaliaram a inseminação de primíparas no segundo cio após o desmame, para evitar a possibilidade de realizar inseminações durante o estado catabólico (WERLANG *et al.*, 2011). Werlang *et al.* (2011) registraram uma perda de peso de 7,2 kg, desde o desmame até a primeira inseminação, em fêmeas inseminadas no primeiro estro e um ganho de peso de 3,8 kg para fêmeas que foram inseminadas no segundo estro após o desmame. Patterson *et al.* (2006) também encontraram resultados semelhantes para primíparas que foram inseminadas no primeiro e no segundo estro após o desmame (perda de 7,2 kg e um ganho de 11, 9 kg; respectivamente), sendo que as fêmeas inseminadas no segundo estro apresentaram folículos maiores do que as fêmeas inseminadas no primeiro estro (8,2 *vs* 7,1, respectivamente). Além disso, uma maior sobrevivência embrionária aos 30 dias de gestação foi apresentada pelo grupo de fêmeas inseminadas no segundo estro após o desmame (77,4 *vs* 68,1%, respectivamente). Um acréscimo de aproximadamente dois leitões por leitegada também foi relatado, quando primíparas foram inseminadas no segundo estro pós-desmame (CLOWES *et al.*, 1994).

2.2.2 Nutrição durante a lactação e IDE

O efeito da alimentação sobre a reprodução parece ser resultado da ação de vários mediadores metabólicos, cuja produção é estimulada ou inibida de acordo com a nutrição dos animais, sendo que os mediadores mais importantes são a leptina, insulina e o *Insulin Growth Factor – I* (IGF-I). A leptina é produzida pelo tecido adiposo, sendo que em animais que se encontram em balanço energético positivo, a expressão do gene que codifica esse hormônio é estimulada pela hipertrofia das células adiposas. Contrariamente, os níveis sanguíneos de leptina diminuem rapidamente em consequência da privação de alimento e, também, em condições de balanço energético negativo (BARB *et al.*, 2001). O efeito da leptina parece ser mediado pela modulação da expressão hipotalâmica do neuropeptideo Y (NPY), estimulador do consumo voluntário e inibidor do LH (BARB *et al.*, 2005). A leptina inibe os efeitos do NPY pela competição dos mesmos receptores. Assim, quando a fêmea está em anabolismo, os níveis séricos de leptina aumentam, bloqueando o NPY e, consequentemente, estimulando a secreção LH.

Já a secreção da insulina é estimulada pelo aumento da concentração sanguínea de glicose, de alguns aminoácidos (principalmente a arginina e leucina) e de alguns ácidos graxos (como o ácido oleico e palmítico). A secreção da insulina também é controlada por alguns hormônios pancreáticos (como o glucagon e a somatostatina) e por neuropeptídeos gastrointestinais, os quais são liberados durante a digestão do alimento (PENZ JR *et al.*, 2009). A insulina se liga ao seu receptor e desencadeia uma série de eventos bioquímicos, alterando a capacidade de transporte das membranas e propiciando a entrada de nutrientes nas células (GUYTON; HALL, 2006), incluindo as células da granulosa (PENZ JR *et al.*, 2009). Zak *et al.* (1997a) relataram uma redução de 4,4 ng/mL para 2,1 ng/mL na concentração plasmática de insulina quando compararam fêmeas alimentadas de forma à vontade ou restrita durante a última semana de lactação. Além disso, foi observado que o tratamento com insulina aumentou em 2,4 o número de ovulações em relação às fêmeas não tratadas (COX *et al.*, 1987).

O IGF-I também é um sinalizador, assim como a leptina, entre o estado metabólico e a regulação neuroendócrina da reprodução (BARB *et al.*, 2001). Esse fator é produzido pelo fígado (PRUNIER; QUESNEL, 2000) e pode apresentar variações em sua concentração dependendo da alimentação do animal. Nesse sentido, um quadro de subnutrição poderia acarretar a redução da concentração de IGF-I no plasma sanguíneo e no líquido folicular. Uma vez que a concentração plasmática de IGF-I tem correlação com o peso do ovário e tamanho máximo dos folículos após o desmame (QUESNEL *et al.*, 1998), sugere-se que a foliculogênese possa ser prejudicada pela diminuição dos níveis de IGF-I, afetando, assim, o desempenho reprodutivo (ZAK *et al.*, 1997a).

Brooks; Cole (1972) observaram uma redução no IDE e uma maior taxa de concepção, em primíparas, quando ocorreu um aumento de 1,8 para 3,6 kg de ração/dia durante o IDE. Entretanto, não foram observadas diferenças na duração do IDE, taxa de concepção, no número total de leitões nascidos e na duração do estro quando as fêmeas multíparas foram alimentadas com diferentes quantidades de ração durante o IDE (1,8; 2,3; 3,6 e 4,5 kg de ração/dia; BROOKS *et al.*, 1975). A diferença entre os resultados desses trabalhos pode estar relacionada à perda de peso das fêmeas primíparas e multíparas durante a lactação. No estudo de Brooks; Cole (1972), a perda de peso foi de 20 kg, enquanto no estudo de Brooks *et al.* (1975) não ocorreram perdas. Assim, dependendo da perda de peso durante a lactação, um maior aporte de nutrientes pode diminuir o efeito deletério do catabolismo, trazendo benefícios para alguns parâmetros reprodutivos.

Baidoo *et al.* (1992) alimentaram fêmeas primíparas com duas quantidades de ração (3,0 ou 6,0 kg/dia) durante a lactação e o IDE e observaram uma maior perda de peso durante a lactação em fêmeas que foram alimentadas de forma restrita nesse período (39,0 kg para as fêmeas que receberam 3,0 kg/dia e 16,1 kg para as fêmeas alimentadas com 6,0 kg/dia). Além disso, os autores relataram um pior desempenho subsequente de fêmeas que receberam 3,0 kg/dia em relação às fêmeas alimentadas com 6,0 kg/dia (IDE: 7,3 *vs.* 6,0 dias; taxa de prenhez: 65,5 *vs.* 85,5% e sobrevivência embrionária: 67,0 *vs.* 81%). As fêmeas que receberam 3,0 kg/dia durante a lactação e que após o desmame foram alimentadas com 6,0 kg/dia apresentaram o mesmo percentual de sobrevivência embrionária e altura do pico de LH que os animais arraçoados com 6,0 kg/dia durante a lactação. Dessa forma, os autores relatam que alguns parâmetros podem não ser influenciados pela quantidade de ração fornecida para a fêmea após o desmame.

Na intenção de identificar qual componente da dieta (energético ou proteico) seria mais importante para fêmeas desmamadas que apresentam diferentes classes de perdas de peso, Grandhi (1992) avaliou 348 fêmeas desmamadas (168 primíparas; 180 secundíparas). Ambas as categorias de fêmeas foram classificadas em fêmeas com alta perda de peso (≥14 kg) e fêmeas baixa perda de peso (<14 kg) durante a lactação. Após o desmame, os animais receberam a ração Controle (2 kg; 2,95 Mcal ED, 13,2 % PB e 0,47% de lisina/kg de ração); Controle + gordura (provendo ~50% a mais de energia digestível/ dia) e Controle + lisina (provendo ~50% a mais de lisina/dia). Os grupos de alta perda de peso que consumiram dietas suplementadas com gordura ou lisina apresentaram maior número de fêmeas demonstrando sinais de estro em até sete dias após o desmame, quando comparado ao grupo Controle (85% e 75% *vs.* 68% respectivamente). Não houve diferença significativa em relação à duração do IDE, para primíparas ou para secundíparas; contudo, o maior aporte de energia durante o período pós-desmame aumentou o número de ovulações das fêmeas primíparas em comparação à dieta controle e à adição de lisina (13,5 *vs.* 10,7 e 9,9; respectivamente).

Dessa forma, o nível de energia da dieta parece ser um dos principais fatores que exercem grande influência na alimentação das fêmeas suínas durante o IDE. No entanto, é importante definir qual a melhor fonte energética. Nesse sentido, (VAN DEN BRAND *et al.*, 2001) alimentaram primíparas desmamadas com dietas adicionadas de gordura ou amido. Os autores observaram que o fornecimento da ração com amido resultou em uma maior porcentagem de fêmeas apresentando estro em até nove dias após o desmame (67%) em relação ao fornecimento de ração com gordura (52%). As fêmeas que consumiram a ração com gordura tiveram 1,6 vez mais chance de não manifestar o estro até 9 dias após o desmame de fêmeas alimentas com ração adicionada de amido. Os autores observaram que o fornecimento de ração com adição de amido aumentou a concentração plasmática de insulina, a qual apresenta associação positiva com a pulsatilidade de LH

(QUESNEL *et al.*, 1998). Sugere-se que, em fêmeas com níveis adequados de LH e um número adequado de folículos, não há influência da nutrição após o desmame. Entretanto, quando o número de pulsos de LH após o desmame for insuficiente e/ou o *pool* de folículos tem menor qualidade, é possível que a nutrição tenha uma importante função na estimulação da secreção de LH, influenciando no desenvolvimento dos folículos (VAN DEN BRAND *et al.*, 2000).

Apesar dessas informações, a ação dos mediadores sobre a reprodução ainda não está completamente elucidada, havendo, inclusive, estudos que não observaram o efeito desses mediadores sobre a reprodução (ROJKITTIKHUN *et al.*, 1993; DE RENSIS *et al.*, 2005). Deste modo, é possível que a nutrição exerça um efeito sobre a reprodução não através de mediadores isolados, como a insulina ou a leptina, mas, sim, através da interação de diferentes mediadores fundamentais para caracterizar o "*status*" metabólico do animal (HAZELEGER *et al.*, 2005). Além disso, é necessário considerar que a maioria dos trabalhos que avaliaram o efeito da alimentação de fêmeas suínas após o desmame sobre o desempenho reprodutivo foram realizados entre as décadas de 70 e 90, utilizando animais com genéticas bem diferentes das genéticas dos animais da suinocultura atual.

2.2.3 Ordem de parto

A relação existente entre a ordem de parto (OP) e a duração do IDE já é conhecida há anos (VESSEUR *et al.*, 1994). Primíparas geralmente apresentam um IDE maior em relação às fêmeas multíparas (VESSEUR *et al.*, 1994; GUEDES; NOGUEIRA, 2001). Recentemente, Mallmann *et al.* (2018) relataram que primíparas apresentaram um IDE de 5,8 dias comparado com 4,6 dias de fêmeas multíparas. Existem diversas explicações para justificar que primíparas sejam mais propensas a ter um IDE mais longo quando comparadas às multíparas. As primíparas possuem necessidade de nutrientes para o seu crescimento, apresentam uma baixa quantidade de reservas corporais, e uma menor capacidade de ingestão (KEMP *et al.*, 2018). No estudo de Guedes; Nogueira (2001), as primíparas perderam 20,2 kg durante a lactação, enquanto as fêmeas multíparas perderam 9,0 kg. Adicionalmente, os autores relataram que as primíparas perderam 4,4 kg durante a última semana de gestação, enquanto as multíparas ganharam 0,13 kg; demonstrando que o catabolismo pode iniciar já na fase final da gestação.

Com o avanço da seleção genética, as fêmeas suínas contemporâneas apresentam leitegadas numerosas já no primeiro parto, o que pode agravar o balaço energético negativo durante a fase de lactação. Dessa forma, o efeito da OP sobre o IDE também está associado a outros fatores que devem ser levados em consideração para a correta interpretação dos resultados. Segundo VESSEUR *et al.*(1994), há uma interação entre a OP e o sistema de alojamento. Os autores relataram que primíparas alojadas em baias coletivas apresentaram um IDE mais longo quando comparadas às primíparas alojadas em gaiolas (13 *vs.* 11 dias).

2.2.4 Duração da lactação

Durante a lactação, a fêmea suína se encontra em anestro fisiológico. Como mencionado anteriormente, o estímulo da mamada realizado pelos leitões leva a fêmea a secretar os peptídeos opioides endógenos, os quais irão bloquear a liberação do LH e FSH, por meio do bloqueio da liberação do GnRH (QUESNEL; PRUNIER, 1995). Dessa forma, quando o estímulo da mamada cessa, no momento do desmame, as gonadotrofinas voltam a ser liberadas (SHAW; FOXCROFT, 1985). Espera-se que 80-85 % das primíparas e 90-95% das multíparas apresentem estro em até sete dias após o desmame, considerando uma duração da lactação mínima de 15 dias (DALLANORA *et al.*, 2004).

Até o início dos anos 2000, as granjas costumavam empregar manejos de desmame precoce com o objetivo de aumentar o número de partos/fêmea/ano, resultando, inclusive, em lactações de duração de 14 dias (DIAL *et al.*, 1992). Contudo, efeitos como aumento no IDE, redução na taxa de parto e número de nascidos totais passaram a ser relatados (VESSEUR, 1997). Dessa forma, atualmente a maioria das granjas praticam desmames de 21 ou 25 dias, empregando lactações de curta duração, somente em casos de desafios sanitários (COSTA *et al.*, 2018).

Segundo Carregaro *et al.* (2006), o efeito da duração da lactação sobre o IDE é dependente da OP. Os autores demonstraram que para multíparas, lactações com duração de 15 dias ou mais já são suficientes para a estabilização do IDE (3-5 dias), enquanto primíparas necessitaram de lactações com duração de 20-24 dias para atingir um IDE de 3-5 dias. Isso pode ser devido a maturidade fisiológica incompleta quando comparada as multíparas (SCHMIDT *et al.*, 2018), o que pode resultar em prejuízos no desempenho reprodutivo posterior (CARREGARO *et al.*, 2006; COSTA *et al.*, 2018). Lactações muito curtas (< 10 dias) estão relacionadas com o aumento significativo do IDE (KOKETSU; DIAL, 1997; CARREGARO *et al.*, 2006), o que pode ser devido à recuperação uterina, uma vez que, embora a maioria dos eventos da involução uterina ocorram na primeira semana de lactação, o processo é finalizado ao redor dos 21-28 dias pós-parto (PALMER *et al.*, 1965).

Lactações mais longas são comumente relacionadas com um maior período de altas necessidades e, consequentemente, à maior perda de condição corporal. Fêmeas designadas como mães-de-leite podem ser submetidas a lactações de até 35 dias e, assim, podem apresentar maior chance de perdas acentuadas de peso. Bruun *et al.* (2016) observaram um maior percentual de fêmeas mães-de-leite (40,3 dias de lactação) apresentando estro após 7 dias pós-desmame, quando comparado a fêmeas desmamadas com 27,8 dias (19,9 *vs.* 11,8 %; respectivamente). Contudo, houve pouca diferença no IDE entre as fêmeas mães-de-leite e as fêmeas desmamadas com 27,8 dias (4,19 *vs.* 4,23 dias, respectivamente). É importante ressaltar que as fêmeas selecionadas para serem mães-de-leite nesse estudo apresentavam boa condição corporal e bom consumo voluntário de ração, pois foram escolhidas pelo proprietário/gerente das granjas.

2.2.5 Tamanho da leitegada e manejos dos leitões

Conforme já mencionado, a leitegada apresenta um papel fundamental no bloqueio reprodutivo durante a lactação, por meio do estímulo da cadeia mamária. Dessa forma, o número de leitões lactentes pode influenciar na entrada em estro após o desmame. De acordo com Vesseur *et al.* (1994) fêmeas com leitegadas contendo ≤ 8 leitões, no momento do desmame, apresentaram IDE mais curto quando comparadas às fêmeas com ≥ 9 leitões (7,4 *vs.* 8,2 dias; respectivamente). É possível que tenha ocorrido um menor desenvolvimento folicular nas fêmeas de leitegada com ≥ 9 leitões, contudo, essa associação ainda não é bem compreendida. Conforme observado no estudo de Quesnel *et al.* (2007), as primíparas que estavam amamentando 13-14 leitões apresentaram IDE semelhante a fêmeas com leitegadas de 7 leitões. Além disso, não foram encontradas diferenças significativas na secreção de LH. Segundo resultados de Koketsu; Dial (1997), que trabalharam com um banco de dados de 30 granjas, também não foi observada diferença no IDE em fêmeas com leitegadas de 1-7, 8-14 e ≥ 15 leitões.

O tamanho folicular foi negativamente correlacionado com o peso ao desmame (r = -0,36; VAN LEEUWEN *et al.*, 2010), o que pode estar relacionado ao fato de que leitões de diferentes tamanhos podem causar diferentes graus de estímulo no complexo mamário (KING *et al.*, 1997) e, consequentemente, podem resultar em diferentes graus de bloqueio no eixo reprodutivo, alterando o IDE.

Dessa forma, o peso dos leitões lactentes também pode ter efeito no IDE. De acordo com Bierhals *et al.* (2012), ao equalizar as leitegadas de primíparas, observaram que fêmeas que amamentaram apenas leitões leves (1,0 – 1,2 kg) tenderam a apresentar IDE menor quando comparadas às fêmeas com leitões médios (1,4 – 1,6 kg; 6,4 *vs.* 8,8 dias). Além disso, o grupo de fêmeas com leitões leves apresentou maior proporção de fêmeas com estro até o 7º dia pós-desmame quando comparadas a fêmeas que amamentaram leitões médios (83,9 *vs.* 58,6%).

Alguns manejos com a leitegada também podem alterar os mecanismos que resultam no anestro lactacional, como o desmame parcial, que consiste na retirada de parte da leitegada antes do final da lactação (TAROCCO *et al.*, 2000). De acordo com Terry *et al.* (2013), a remoção de parte de leitegada, independentemente do número de leitões removidos (0, 3, 5 ou 7), e o início do estímulo com o macho aos 18 dias de lactação resultaram em um maior número de fêmeas apresentando estro até o dia do desmame (30 dias pós-parto), quando comparado às fêmeas do grupo que permaneceu com os 10 leitões durante toda a lactação (90 *vs*. 56%; respectivamente). Além disso, os autores relataram que 5% das fêmeas apresentaram estro no dia 18 (dia da remoção dos leitões), sugerindo que o aumento dos pulsos de LH inicia antes do 18° dia após o parto. Esses dados corroboram os resultados de Zak *et al.* (2008), os quais demonstram que o desmame parcial, aos 18 dias de lactação, aumenta a concentração plasmática e o número de pulsos de LH em até 10 horas após a remoção dos leitões (0,3 ng/ml e 4 pulsos/10h, respectivamente), quando comparado com fêmeas desmamadas aos 21 dias (0,22 ng/ml e 2 pulsos/10h; respectivamente). Além disso, um maior número de folículos com diâmetro > 3 mm, no primeiro dia após o desmame, e um IDE mais curto foram observados no grupo em que se realizou o desmame parcial em comparação ao grupo controle (7,3 *vs.* 4,0 folículos; 4,3 *vs*. 5,6 dias, respectivamente).

Outro manejo capaz de influenciar o IDE é o aleitamento interrompido. De acordo com os resultados demonstrado por Kuller *et al.* (2004), ao separar as fêmeas dos leitões por 12 horas por dia, do dia 14 ao 25 de lactação (desmame), ocorre um menor intervalo desmame-ovulação e se observa um maior percentual de fêmeas entrando em estro durante a lactação quando comparado com fêmeas controle (4,7 *vs*. 5,3 dias; 22,0 *vs.* 3,0%, respectivamente). Esses resultados ainda podem ser afetados pela idade das fêmeas, considerando que fêmeas mais velhas apresentam sinais de estro mais facilmente durante a lactação quando submetidas ao aleitamento interrompido quando comparadas as primíparas (SOEDE *et al.*, 2012b).

2.2.6 *Efeito macho*

Após o desmame, no manejo usual das granjas, é recomendado a exposição das fêmeas desmamadas diariamente ao macho, desde o dia do desmame até o momento da última inseminação. Esse manejo ocorre em dois diferentes momentos: após o desmame, com o objetivo de estimular o crescimento folicular e ovulação e durante a detecção do estro, a fim de detectar o estro e predizer a ovulação (KEMP *et al.*, 2005).

A efetividade da ação de exposição ao macho sobre o IDE pode estar vinculada à exposição precoce da fêmea ao macho (KEMP *et al.*, 2005). Segundo Walton (1986), a exposição ao macho após o desmame resulta em um maior percentual de fêmeas entrando em estro em até 15 dias, quando comparadas a fêmeas sem a exposição do macho após o desmame (82 *vs.* 48%, respectivamente). Nesse mesmo sentido, Langendijk *et al.* (2000) relataram uma redução no IDE de 137 horas para 128 horas para fêmeas sem e com exposição ao macho, respectivamente. Contudo, o número de exposições ao dia e a distância em que as fêmeas são alojadas dos machos podem interferir nos resultados, uma vez que tanto fêmeas estimuladas mais de uma vez ao dia como fêmeas alojadas próximas a machos após o desmame apresentam menor taxa de expressão de estro (KNOX *et al.*, 2002; KNOX *et al.*, 2004). Dessa forma, uma exposição frequente ou contínua pode induzir a uma habituação da fêmea ao macho, resultando em menores taxas de expressão de estro (KNOX *et al.*, 2002).

A relação entre o manejo com o macho sobre a expressão de estro das fêmeas talvez seja explicada por um estímulo sobre a liberação de LH pela hipófise (KEMP *et al.*, 2005). Uma maior frequência dos pulsos de LH foi correlacionada com um maior crescimento folicular e um IDE reduzido (VAN DEN BRAND *et al.*, 2000). Segundo Kingsbury; Rawlings (1993), a exposição das fêmeas ao macho aumentou a frequência de liberação e a concentração média de LH, o que resultaria em maior crescimento folicular. Geralmente, as fêmeas produzem quantidades adequadas de LH após o desmame, e nesses casos o estímulo do macho não representaria um efeito adicional; no entanto, para fêmeas que apresentem uma deficiência de LH o estímulo seria benéfico (KEMP *et al.*, 2005). Contudo, em termos práticos, o estímulo com o macho é realizado em todas as fêmeas desmamadas, iniciando no dia do desmame.

2.3 Controle do crescimento folicular com o uso de progestágenos

O altrenogest é um progestágeno sintético com atividade progesterônica e anti-gonadotrofica, cuja administração é realizada por via oral. A lipossolubilidade desse hormônio permite que ele penetre nas células-alvo no hipotálamo, ligando-se em seus receptores. Como consequência, ocorre um *feedback* negativo sobre a liberação de GnRH, resultando na inibição da liberação de LH (VAN LEEUWEN *et al.*, 2015). O altrenogest é o único progestágeno comercialmente disponível na suinocultura e pode ser utilizado com diferentes propósitos, como: sincronização do ciclo estral de leitoas (REDMER; DAY, 1981; MARTINAT-BOTTÉ *et al.*, 1995; DE RENSIS *et al.*, 2018; WANG *et al.*, 2018), controle do momento do parto (GAGGINI *et al.*, 2013) e manipulação do IDE (SOEDE *et al.*, 2012a).

2.3.1 Uso do Altrenogest após o desmame

Prolongar o IDE de fêmeas com elevado nível de catabolismo lactacional é uma estratégia que foi desenvolvida visando proporcionar maior período de recuperação pós-desmame (SOEDE *et al.*, 2012a). Uma das formas de prolongar o IDE é o “skip-a-heat” que consiste em inseminar a fêmea somente no segundo estro após o desmame. Contudo, esse manejo resulta em 21 dias não produtivos a mais por fêmea. Posteriormente, estudos demonstraram que a utilização de altrenogest para prolongar o IDE é eficaz para melhorar o desempenho reprodutivo com menos dias não produtivos na granja (SOEDE *et al.*, 2012a).

O melhor desempenho reprodutivo subsequente de fêmeas suínas com o emprego de altrenogest é atribuído a um maior período de recuperação após o desmame (SOEDE *et al.*, 2012a). Contudo, o uso desse progestágeno também está associado a um maior crescimento folicular (VAN LEEUWEN *et al.*, 2010; VAN LEEUWEN *et al.*, 2015). O bloqueio que o altrenogest exerce sobre liberação das gonadotrofinas parece ser variável ao longo do tratamento. Após a administração do altrenogest, realizada de forma diária, o bloqueio das gonadotrofinas ocorre por 4,5 horas no dia do desmame (VAN LEEUWEN *et al.*, 2015) a 9 horas após a administração do altrenogest no décimo terceiro dia de tratamento (VAN LEEUWEN *et al.*, 2011b). Após esse período a supressão sobre o GnRH cessa, e dessa forma, como a supressão das gonadotrofinas não ocorre durante todo o período de 24 horas, pode ocorrer o crescimento folicular.

Durante os primeiros 5-6 dias de tratamento com altrenogest, os folículos se desenvolvem até atingirem ~4,5 mm. Após esse período, os folículos diminuem para ~ 4,0 mm e permanecem nesse tamanho até o final do tratamento (VAN LEEUWEN *et al.*, 2010; VAN LEEUWEN *et al.*, 2015). A concentração plasmática de estradiol aumenta até o segundo dia de tratamento e, após, ocorre uma diminuição a níveis pré-desmame. Esse declínio é atribuído à redução do estímulo realizado pelo LH (VAN LEEUWEN *et al.*, 2015) já que o LH estimula a produção de estradiol (GUTHRIE *et al.*, 1990). Além disso, a redução do nível de estradiol é provavelmente acompanhada pela redução na produção de inibina, já que folículos atrésicos tem produção reduzida de inibina (GUTHRIE *et al.*, 1997) e esses fatores podem resultar em maior secreção de FSH, responsável por aumentar o tamanho do antro folicular (ITOH *et al.*, 2002), resultando em maior diâmetro folicular (VAN LEEUWEN *et al.*, 2015). Contudo, a redução no tamanho folicular e a baixa produção de estradiol indica que possa haver um *turnover* dos folículos e uma nova onda folicular seja recrutada, mas estabilize em 4,0 mm devido ao menor período de ação do LH conforme o avanço do tratamento (VAN LEEUWEN *et al.*, 2011b).

Além disso, o tratamento com altrenogest após o desmame levou ao aumento de 0,3 a 3,4 no número de ovulações de Patterson *et al.* (2008), 6 % a mais na taxa de parto e de 2 a 3 leitões a mais no tamanho de leitegada (VAN LEEUWEN *et al.*, 2011c). Contudo, trabalhos que iniciaram o fornecimento do progestágeno 3 horas após o desmame relataram uma redução na taxa de parto e no número de nascidos, o que provavelmente estaria relacionado a uma supressão inadequada do crescimento folicular, de forma a propiciar o desenvolvimento de folículos persistentes (MIHM *et al.*, 1994).

2.3.2 Uso do altrenogest antes do desmame

Durante a última semana de lactação, ocorre a seleção de folículos que crescem até ~5 mm e depois regridem para que um novo *pool* de folículos seja recrutado (LUCY *et al.*, 2001). Contudo, como relatado por VAN LEEUWEN *et al.* (2011c), a eficácia do tratamento de 4 a 8 dias com o altrenogest após o desmame em melhorar o desempenho reprodutivo é dependente do tamanho folicular que a fêmea apresenta no início do tratamento. Fêmeas que apresentam folículos grandes (> 4,5 mm) no início do tratamento apresentaram taxa de parto de 71, 22 e 83% com tratamento por 4, 8 e 15 dias, respectivamente. É possível que os folículos maiores cresçam durante o período de tratamento, atingindo um tamanho pré-ovulatório. Dessa forma, ocorreria a ovulação de oócitos envelhecidos. Nesse sentido, avaliou-se o fornecimento de Altrenogest ao final da lactação, para evitar o crescimento folicular antes do desmame. Contudo, iniciar o fornecimento de Altrenogest três dias ou um dia antes do desmame não alterou a dinâmica folicular ou melhorou o desempenho reprodutivo, quando comparado ao controle ou ao tratamento iniciado no desmame (VAN LEEUWEN *et al.*, 2011a).

Objetivando controlar melhor a dinâmica folicular na última semana de lactação e, assim, melhorar o desempenho de fêmeas desmamadas em estações desfavoráveis, Lopes *et al.* (2017) forneceram altrenogest, durante 6 dias antes do desmame (-8 a -2 dias; dia 0 = desmame), para fêmeas primíparas e multíparas em duas épocas do ano (inverno e primavera e verão e outono). Os autores relataram um aumento no diâmetro folicular no início do estro e maior tamanho de leitegada para fêmeas tratadas com altrenogest, em comparação às fêmeas do grupo controle (7,6 *vs.* 7,3 mm e 14,0 *vs.* 12,3 nascidos totais, respectivamente), independentemente da estação do ano. Contudo, não houve diferença no número de folículos contados por meio da ultrassonografia transretal e na taxa de parto.

A qualidade folicular pode resultar não só em um maior tamanho de leitegada, mas também em maior peso dos leitões. Vários fatores podem afetar o peso ao nascimento dos leitões tais como: maturação oocitária heterogênea (KNOX, 2005), variação na duração da ovulação (POPE *et al.*, 1990), a posição da implantação do embrião (PERRY; ROWELL, 1969) e a eficiência placentária (WILSON *et al.*, 1999). Dessa forma, Kitkha *et al.* (2017) associaram o fornecimento de altrenogest, iniciando 4 dias antes do desmame e finalizando no segundo dia pós-desmame (6 dias de tratamento), com o uso ou não de indutor de ovulação (hCG). A associação de altrenogest com hCG, 72 horas após o final do tratamento com progestágeno, resultou em menor desvio padrão do peso ao nascer (0,32 vs. 0,40 kg). Contudo não houve diferença quanto ao peso ao nascer, coeficiente de variação do peso ao nascer e à porcentagem de leitões leves. Além disso, o grupo tratado apenas com altrenogest apresentou um desvio padrão do peso ao nascer maior do que o grupo controle (0,40 *vs.* 0, 39, respectivamente).

CAPÍTULO II – PRIMEIRO ARTIGO CIENTÍFICO

EFFECTS OF DIFFERENT AMOUNTS AND TYPE OF DIET DURING WEANING-TO-ESTRUS INTERVAL ON REPRODUCTIVE PERFORMANCE OF PRIMIPAROUS AND MULTIPAROUS SOWS

ARTIGO ACEITO PARA PUBLICAÇÃO NA REVISTA

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Effects of different amounts and type of diet during weaning-to-estrus interval on reproductive performance of primiparous and multiparous sows

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Short title: Nutrition and performance of weaned sows

Abstract

During weaning-to-estrus (**WEI**) the sows are usually fed with high feed level to improve the reproductive performance. However, the WEI has been reduced over the years which may reduce the impact of feed level on performance in the modern genetic lines. The aim of this study was to evaluate the effect of two feeding levels (**MFL**: 2.7 kg/day and **HFL**: 4.3 kg/day) and two diet types (gestation: 13.67 MJ/kg of metabolizable energy [**ME**] and 0.62% of standard ileal digestible [**SIDLys**] and lactation: 14.34 MJ ME/kg and 1.20% of SIDLys) offered during the WEI on reproductive performance. In total, 19.0% of sows were excluded from the analysis due to feed intake below 75% (9.6% and 28.5% in MFL and HFL groups, respectively), remaining 254 primiparous and 806 multiparous sows. Follicular size and change in body weight were measured in subsamples of 180 and 227 females, respectively. Data were analyzed considering the sow as the experimental unit. Feeding level, diet type, parity, and their interactions were included as fixed effects, whereas the day of weaning was considered as a random effect. The feed intake of MFL and HFL groups averaged 2.5 ± 0.02 kg/day and 3.8 ± 0.02 kg/day, respectively. There was an interaction between feeding level and parity for daily feed intake. Within HFL, multiparous sows consumed 181 g/d more than primiparous sows ($P < 0.01$), but no difference was observed within MFL ($P > 0.05$). Both primiparous and multiparous sows lost proportionally less weight when fed HFL than MFL gestation diet during WEI. The percentage of weight loss was lower in HFL than in the MFL group in multiparous sows fed the lactation diet. The WEI was not affected by feeding level, diet type or its interaction ($P > 0.05$), but it was longer in primiparous than in multiparous sows ($P =$

0.001). There was no effect of feeding level, diet type, parity or their interactions on anestrus and farrowing rates. Multiparous sows showed greater follicular size, and greater numbers of total born and born alive piglets in the subsequent cycle than primiparous sows (P < 0.05). In conclusion, feeding weaned primiparous and multiparous sows with 4.3 kg/day of a gestation (58.78 MJ ME and 26.66 g SID Lys) or a lactation diet (61.66 MJ ME and 51.60 g SID Lys) does not improve follicular size and reproductive performance in the subsequent cycle.

Key words: body weight, follicular growth, nutrition, reproduction, swine

Implications

Short weaning-to-estrus interval (WEI) is frequent nowadays, which was confirmed by 93.6% of sows expressing estrus within 5 days after weaning. Although sows commonly receive a high level of feed during WEI, this study shows that increasing the feed intake during this short period of WEI is not relevant, even in sows with poorer body condition at weaning. As a representative number of sows did not consume at least 75% of the offered amount, more feed represents wastage for some sows. Costs can be reduced by offering a lower feed amount of gestation diet (2.7 kg/day) to sows during WEI.

1. Introduction

The weaning-to-estrus interval (**WEI**) is an important contributor to the number of non-productive days in sow farms. This period has been constantly decreasing over the years, ranging from 13 to 17 days in the 1980's (Bryant *et al.,* 1985; Johnston *et al.,* 1986) to 4-6 days, on average, in the second decade of 2000's (Kemp *et al.,* 2018), with more than 80% of sows expressing estrus until 5 days post-weaning (Poleze *et al.,* 2006).

The follicular development begins before sow is weaned, with follicles that can grow up to 5 mm during the third week of lactation (Lucy et al., 2001). Most sows appear to have synchronized waves of follicle development at the end of lactation, although great part of the follicular phase takes place during WEI (Lucy et al., 2001). Follicles usually grow from 2-3 mm at weaning (Quesnel, 2009) up to 6-9 mm prior to ovulation (Knox and Rodriguez-Zas, 2001). Therefore, follicular growth may be affected by nutrition before weaning and during the WEI period (Quesnel *et al.*, 2000; Van den Brand *et al.,* 2000).

Weight loss during lactation can impair reproductive performance in the subsequent cycle (Schenkel *et al.,* 2010). Sows with greater weight loss have lower follicle quality, oocytes with reduced fertilizing capability, and impaired embryo development and survival (Clowes *et al.,* 2003). Higher feed intake during WEI may partly prevent this negative impact on reproductive performance. Although the WEI was not affected by post-weaning feed level (overall, 57.5% of sows expressed estrus within 8 days of weaning), the ovulation rate (14.8 vs. 13.0) and litter size (10.0 vs. 8.8 piglets) of the subsequent farrowing were respectively higher in primiparous sows receiving 4 kg/day than 1.5 kg/day of gestation diet between weaning and mating (King and Williams, 1984). Feed restriction during lactation (3.0 vs. 6.0 kg/day) resulted in a larger WEI (7.3 vs. 5.9 day), but the post-weaning feeding level (3.0 vs 6.0 kg/day) did not affect the WEI in either non-restricted (5.9 vs. 6.0 day) or fed-restricted (7.5 vs. 7.1 days) sows during lactation (Baidoo et al., 1992). However, sows non-restricted during lactation had higher embryo survival when fed-restricted after weaning than sows nutritionally restricted (85.0% vs. 64.0%) during both lactation and post-weaning periods (Baidoo *et al.,* 1992). Additional fat in the feed during the post-weaning period seemed to increase the ovulation rate, embryo survival, and embryo weight in sows with greater lactational weight loss (Grandhi, 1992). Thus, there is a common recommendation for *ad libitum* access to feed during WEI, or also, the use of a more energetic diet, such as a lactation diet in sows with excessive loss of body reserves (Close and Cole, 2001). However, increasing the post-weaning feed intake has not always resulted in improved reproductive performance. The amount of feed provided during the post-weaning period (2 kg/day or *ad libitum* feeding) has not influenced the WEI or number of piglets born alive in the subsequent cycle, even after feed restriction during lactation (Carroll *et al.,* 1996). Considering that nowadays the WEI is shorter than in previous decades, it is essential to know if nutritional manipulations during this short period improve subsequent reproductive performance. We hypothesized that high nutritional level during WEI no longer benefits sows with short WEI. Recent information on this topic is scarce, with Graham *et al*. (2015) reporting no improvement in reproductive performance by increasing the amount of gestation diet to sows with a good body condition score at weaning. The aim of this study was to evaluate the effect of two feed amounts (2.7 and 4.3 kg/day) and different diet types (gestation and lactation), provided during WEI, on body weight change, follicular size, and subsequent reproductive performance of primiparous and multiparous sows.

2. Materials and methods

Animals and housing

The study was performed in a commercial sow farm with an inventory of 5 000 sows, located in Santa Catarina State, Southern Brazil. During the treatment period (August to October), the temperature inside the barn ranged from 20.3 to 28.7 °C. Primiparous and multiparous Landrace × Large White crossbred sows (PIC Camborough, Hendersonville, TN) from 14 weaning batches were used. All sows were housed in farrowing crates (2.20 × 0.70 m) with *ad libitum* access to feed and water since the day they were moved in. After weaning, sows were housed in individual gestation crates (2.20 × 0.60 m) with *ad libitum* access to water. As feed troughs were not separated from one crate to the next, the sows of the same treatment were housed side by side.

Experimental design

The experimental design consisted of combinations of two feed intake levels offered during WEI (**MFL**: moderate feeding level - 2.7 kg/day and **HFL**: high feeding level - 4.3 kg/day), two types of diet (lactation and gestation diet; Table 1), and two parity order categories (primiparous and multiparous) in a 2 × 2 × 2 factorial arrangement. The levels of metabolizable energy (**ME**) and standard ileal digestible lysine (**SID Lys**) daily offered in MFL gestation diet, HFL gestation diet, MFL lactation diet, and HFL lactation diet, were, respectively, the following: 36.91, 58.78, 38.72 and 61.66 MJ ME; and 16.74, 26.66, 32.40 and 51.60 g SID Lys. The sows were uniformly distributed to the treatments according to the following characteristics: parity order, caliper units at weaning, caliper unit change during lactation, total piglets born at previous farrowing, number of piglets weaned and lactation length.

Sample size

Initially, 1 320 sows were selected for the study. Eleven sows showed estrus on weaning day and could not be included in the study. Due to the variability in feed intake among sows, only sows that consumed at least 75% of offered feed were considered for analysis. This procedure aimed to avoid having HFL sows with a feed intake below or close to 2.7 kg/day, which corresponded to the MFL group. This cut would still allow a difference of at least 0.53 kg in feed intake between the maximum intake in MFL (2.7 kg) group and the minimum intake in HFL (3.23 kg).

In total, 19.0% of sows were excluded (249/1309) due to feed intake below 75%, being 9.6% (63/657) in MFL group and 28.5% (186/652) in HFL group. Within the MFL group, 9.0% and 9.8% primiparous and multiparous sows were excluded, respectively. Within the HFL group, 38.5% and 25.1% primiparous and multiparous sows were excluded, respectively. Following this procedure, 1 060 sows (254 primiparous and 806 multiparous) remained for reproductive performance evaluation. Furthermore, subsamples of 180 and 227 sows were used to respectively evaluate the follicle size at 96, 72, 48 and 24 h before ovulation and the change in body weight during WEI.

Nutritional and reproductive management

The diets were given daily from the day of weaning until the first insemination. The sows were fed three times a day, at 0700, 1200 and 1800 h, and feed wastage was recovered and weighed (scale Belmak ELP 30, with a precision of 2 g, São Paulo, Brazil) once a day. Sows were daily fed 2.0 kg gestation feed from the first artificial insemination until day 4 of gestation. From day 5 until day 35 of gestation, the sows with BCS < 3 and ≥ 3 were fed 2.8 and 2.0 kg/day, respectively. From day 36 until farrowing, all sows received 1.8 kg/day. Estrous detection was performed once a day in the presence of a mature boar. For post-cervical artificial insemination, pooled semen doses containing 1.5×10^9 sperm cells were used at estrous onset and repeated every 24 h while sows were in standing estrus (maximum of three inseminations). Sows not showing estrous signs until 10 days after weaning were considered in anestrus.

Data collection and measurements

At housing in farrowing room (approximately at day 112 of gestation) and at weaning, body condition score (**BCS**; 1= thin and 5= fat; Young *et al.,* 2004), backfat thickness (**BFT**) and caliper unit (scale 1 to 25; Knauer and Baitinger, 2015) were measured. The BFT was measured at the P2 point ([6.5 cm away from the midline of the vertebral column at the last rib level, considering both sides] with A-mode ultrasonography - Renco Lean Meter - Renco Corporation, Minneapolis, MN) in 219 and 761 primiparous and multiparous sows, respectively. The sows were weighed with a bar scale (Tru Test EW6, Auckland, New Zealand) with 500 g precision, at weaning and at breeding. The WEI, anestrus rate, farrowing rate, and litter size of subsequent farrowing were recorded. Females that returned to estrus after the first post-weaning insemination were not included in the statistical analyses for litter size.

Follicular growth

Daily evaluations of follicular growth were performed from weaning until ovulation using transrectal ultrasonography (model A6V, Sonoscape, Shenzhen, China) with a linear transducer (model 6761V, 11-5 MHz, SonoScape, Shenzhen, China). The three largest follicles of each ovary were measured daily (Knox and Rodrigues Zas, 2001). A noticeable reduction in the size and number of larger follicles from previous evaluation was considered as the ovulation had occurred. An additional evaluation was performed at 24 h after to confirm the ovulation status.

Statistical analysis

All data were analyzed using the Statistical Analysis System software, version 9.3 (SAS Inst. Inc., Cary. NC). The results were considered significant at $P \leq 0.05$. Data are expressed as Least Squares Means (**LSmeans**) ± Standard error of the mean in the text, whereas RMSE is used in Tables. Each sow was considered as an experimental unit. The variables daily feed intake, WEI, and litter size were analyzed using the GLIMMIX procedure and LSmeans were compared using the Tukey-Kramer test. The farrowing rate and anestrus rate were analyzed as binary responses using logistic regression models. In all models, feeding level, diet type, parity, and their interactions, were considered as fixed effects. Day of weaning was considered as a random effect. When the interaction among fixed factors was significant, the results were explored accordingly, hence the effects of main factors were not discussed.

Analysis of follicular size concerning days after weaning were performed separately for each day since the number of sows with evaluations decreased as they expressed estrus. For these analyses, 180 sows (42 primiparous and 138 multiparous) were used in D1, D2 and D3 after weaning, whereas 170 and 106 sows were respectively used in D4 and D5 after weaning (weaning day was considered as day 0: **D0**). The follicular development relative to ovulation was analyzed as a repeated measure considering all the sows that had evaluation for 3 days before ovulation. In this model, feeding level, diet type, parity, time point (days before ovulation), and their interactions, were included in the model as fixed effects. Six sows in anestrus and six sows with ovarian cysts could not be included in this analysis, remaining 39 and 129 primiparous and multiparous sows, respectively.

Additional analyses were performed to investigate whether the variation in follicular size was related to WEI. For this, follicle size on each day after weaning was compared between different WEIs. The models contained the fixed effect of WEI length (3, 4, 5 or > 5 days) and weaning day as a random factor, whereas parity class was kept in the model, when significant, to account for the influence of parity on follicular size.

To investigate whether the effect of feed intake on WEI, farrowing rate and litter size was dependent on body condition of sows, classes of body reserves at weaning were created: **BFTW** (BFT at weaning <10.5 and ≥10.5mm, for both primiparous and multiparous sows), **BCSW** (BCS at weaning <3.0 and ≥ 3.0, for both primiparous and multiparous sows), and **CaliperW** (Caliper at weaning <11 and ≥ 11, and <12 and ≥ 12 for primiparous and multiparous sows, respectively). These classes were created considering the median of each variable, resulting in approximately 50% of sows in each class, except when the natural distribution of values did not allow to be close to 50%.

3. Results

On average, the sows had 3.0 ± 0.05 parities, 15.1 ± 0.09 total piglets born at previous farrowing, 11.9 ± 0.04 piglets weaned and 20.0 ± 0.1 days of lactation length. Caliper, BFT and BCS at weaning averaged 11.0 ± 0.06 units, 10.4 ± 0.07 mm and 2.7 ± 0.01, respectively. Changes during lactation averaged -0.4 ± 0.06 caliper units, -0.5 ± 0.06 mm BFT, and -0.2 ± 0.01 units in BCS. None of those variables was different among the treatments ($P \geq 0.11$). The follicular size at weaning was similar between feeding levels (3.3 ± 0.12 vs. 3.2 ± 0.13 for MFL and HFL, respectively; $P = 0.70$), diet type (3.3 ± 0.13 vs. 3.2 ± 0.12 for gestation and lactation diet, respectively; $P = 0.27$) but lower in primiparous than multiparous sows (3.0 ± 0.14 vs. 3.5 ± 0.11; $P < 0.001$).

Daily feed intake

The feed intake of MFL and HFL groups averaged 2.5 ± 0.02 kg/day and 3.8 ± 0.02 kg/day, respectively. Feed intake was affected by feeding level, parity order and its interaction (Table 2; $P < 0.001$). No difference was observed between primiparous and multiparous sows within MFL ($P = 0.06$); however, within HFL, the primiparous sows consumed 181 g/day less than multiparous sows ($P < 0.001$). Diet type, and the interactions feeding level

× diet type, parity order × diet type, and feeding level × diet type × parity order did not influence feed intake ($P > 0.30$).

Body weight at breeding and change in body weight during weaning-to-estrus interval

As expected, multiparous were heavier than primiparous sows at breeding (199.6 ± 1.84 vs. 156.5 ± 3.08 kg; $P < 0.001$; Table 2). No significant effect was detected for feeding level, diet type or interactions ($P > 0.26$). Absolute weight change during WEI was affected by feeding level and parity order. Weaned sows fed HFL lost less body weight than those fed MFL (-5.3 ± 1.03 kg vs. -10.5 ± 0.94 kg; $P < 0.001$). Multiparous sows lost more ($P < 0.001$) absolute body weight during WEI (-10.7 ± 0.89 kg) than primiparous sows (-5.0 ± 1.07 kg). When analyzing the relative body weight loss, diet type and 2-way interactions were not significant ($P > 0.07$). However, significant effects of feeding level and parity ($P < 0.001$), as well as a significant 3-way interaction (feeding level × diet type × parity) were observed ($P = 0.03$). For gestation diet, both primiparous and multiparous sows lost proportionally less weight when fed HFL than MFL. Nevertheless, when lactation diet was offered, the percentage of weight loss was lower in the HFL than the MFL group only in multiparous sows, with no difference in primiparous sows.

Follicular size

The follicular size after weaning (Figure 1A) was not affected by feeding level ($P \geq 0.11$), diet type ($P \geq 0.07$) or interactions between these two factors or with parity category ($P \geq 0.13$) at any day of evaluation.

Multiparous sows had larger follicular size than primiparous sows at D1, D2, D3, and D4 (Figure 1 A; $P < 0.05$) but not at D5 after weaning ($P = 0.39$). The follicle size at 72, 48 and 24 h (Figure 1B) before ovulation was not affected by feeding level ($P = 0.36$), diet type ($P = 0.29$), or any interaction among the fixed factors ($P > 0.07$). Mean follicular size during the 72 h before ovulation was greater in multiparous than in primiparous sows ($P = 0.02$). Follicular size increased as ovulation approached, and it was larger at 24 or 48 h than at 72 h before ovulation (Figure 1 B; $P < 0.001$).

Follicular size according to weaning-to-estrus interval

The variation in follicular size among sows with different WEI lengths is shown in Table 3. At weaning and on D2 after weaning, larger follicle size was observed in sows with WEI of 3 days than in sows with longer WEI ($P < 0.02$). On D1, sows with WEI of 3 day had a larger follicle size than sows with WEI of 4 or 5 days, which had different follicle size between them ($P \leq 0.05$). Follicle size at D3 was larger in sows with WEI of 3 or 4 days than in sows with WEI longer than 5 days ($P \leq 0.04$). On D4 after weaning, the follicle size was larger in sows with WEI of 4 or 5 days than in sows with WEI longer than 5 days ($P \leq 0.005$). The follicle size at D5 after weaning was not different between sows with WEI of 5 and WEI longer than 5 days ($P = 0.32$).

Reproductive performance

Estrous expression occurred in 72.4% and 93.6% of the sows within 4 and 5 days after weaning, respectively, with 92.2% (977/1060) of sows expressing estrus within 3 to 5 days. Feeding level, diet type and its interaction had no effect on WEI, anestrus rate, farrowing rate, total born and born alive piglets (*P* > 0.10). However, multiparous sows had shorter WEI (4.6 ± 0.12 days vs. 5.3 ± 0.21 days; *P* = 0.001), more total piglets born (15.3 ± 0.12 vs. 13.9 ± 0.23 piglets) and piglets born alive (14.4± 0.12 vs. 13.3 ± 0.22 piglets) than primiparous sows (*P* < 0.001; Table 2). Furthermore, when analyzed according to body condition classes at weaning, WEI, farrowing rate and total of piglets born were not affected by the feed level (*P* ≥ 0.19 and ≥ 0.22 for primiparous and multiparous sows, respectively), classes of body reserves (*P* ≥ 0.24 and ≥ 0.09 for primiparous and multiparous sows, respectively) or the interaction between feed level and classes of body reserves at weaning (Fig. 2; *P* ≥ 0.09 and ≥ 0.23 for primiparous and multiparous sows, respectively).

4. Discussion

The WEI is one of the main components of non-productive days (Dial *et al.,* 1992). Prolonged WEI can affect sow productivity by reducing the number of farrowings per sow per year. The WEI is a time for starting the recovery of body reserves lost during lactation so that subsequent performance is not compromised, mainly in sows undergoing a greater lactational catabolism. Thus, there is a general recommendation to increase feed allowance or the energy content of the diet for weaned sows during the entire WEI. However, the WEI is nowadays shorter than several decades ago. While >10 days was common in the 1970s (Brooks and Cole, 1972), at the present time about 4 to 6 days is typical (Poleze *et al.,* 2006; Iida and Koketsu, 2014). In this new scenario, a shorter interval may be insufficient to allow sows to recover their body reserves before breeding. To elucidate the benefits of *ad libitum* feeding and/or greater diet density to contemporary dam lines during this phase, the present study was structured as a factorial arrangement to determine the impact of feeding level and diet type on the performance of sows with different parities. It is important to mention that the aim was not to evaluate an extreme reduction but a moderate reduction in feed intake during WEI.

Parity order effect

Low parity sows, especially primiparous, have lower reproductive performance compared with multiparous sows, which might be due to an immature endocrine system and reduced feed intake capacity (Koketsu et al., 2017). Indeed, in this study, multiparous sows consumed 181 g/day more than primiparous sows when feed allowance was higher. The same pattern is also commonly observed when sows receive a high feed level during lactation (Koketsu and Dial, 1997).

The reduced feed intake during lactation in primiparous sows could result in small follicles at weaning (Zak et al., 1997b), taking more time to reach the pre-ovulatory size (Lucy et al., 2001). Weaning occurs at random stages of follicular development, causing variation in WEI (Lucy et al., 2001). We confirmed that primiparous sows had smaller follicles than multiparous sows at weaning, what could have contributed to their longer WEI.

Although primiparous sows have lower feed intake and are more susceptible to have reduced gonadotrophins secretion (van den Brand *et al*., 2000), no difference in anestrus rate was found between primiparous and multiparous sows. Also, parity did not affect the farrowing rate. It is important to highlight that more than 90 % of sows were inseminated within 3 to 5 days after weaning, which has been reported to ensure a high farrowing rate (Poleze *et al.*, 2006).

The reduction in subsequent litter size observed in primiparous sows might be related to body reserves losses during lactation. Schenkel *et al.* (2010) reported smaller second litter in sows with a weight loss >10%, body protein loss >10%, body fat loss >20%, or a BCS loss ≥1.0 point. Although in the present study the body reserve losses were not so pronounced, primiparous sows lost more caliper units (-1.73 vs. -0.03), BCS (-0.52 vs. -0.12) and BFT (-1.35 vs. -0.27 mm) than multiparous sows ($P < 0.001$; data not shown). Thus, primiparous might have a lower ovulation rate (King and William, 1984) and or embryo survival (Baidoo *et al*., 1992), compromising the subsequent litter size.

Ford *et al*. (2003) reported that the wet weight of mammary glands reduced to about 50, 40, and 30% of pre-weaning weight by days 4, 5, and 7 after weaning. Based on data reported by Ford *et al*. (2003), estimated losses in sows with 14 teats, due exclusively to mammary gland involution, should be 3.3, 4.0, and 4.7 kg at 4, 5, and 7 days after weaning, respectively. One of the major determinants of milk production and mammary growth is the size of suckling litter (Hurley, 2001), with mammary gland mass increasing as the litter size increases. In the present study, multiparous sows had more weaned piglets than primiparous sows (11.9 vs.11.7 piglets; $P = 0.041$; data not shown). Thus, it can be assumed that multiparous sows had more mammary tissue to be involuted, explaining their higher body weight loss during WEI.

Diet type effect

In each phase, diets differ in terms of energy, protein and amino acid contents. During WEI, the dietary supplementation of fat improved estrous expression until 7 days after weaning and reproductive performance in sows with significant weight and fat losses during lactation (Grandhi, 1992). High dietary energy was also associated with a higher ovulation rate (Cox *et al*., 1987). However, in the present study, there was no effect of diet type on any parameter evaluated. It is important to point out that diets used by Grandhi (1992) provided approximately 50% more daily energy and lysine intakes, whereas the lactation diet used in the present study had approximately 5% and 95% more metabolizable energy and lysine than the gestation diet.

Feeding level effect

Previous reports showed a high variability in feed intake during lactation (Koketsu *et al*., 1996). Our findings suggest that similar variation can occur during WEI, even with no *ad libitum* access to feed. In the present study, almost 30% of the sows fed 4.3 kg/day had a feed intake below 75% of the offered feed. Surprisingly, even in MFL treatment (2.7 kg/day), almost 10% of the sows had a partial feed intake. After weaning, the sows are under considerable stress due to the abrupt removal of the piglets and change in accommodation, and generally have a reduced appetite for a few days (Close and Cole, 2001), which may have contributed to the variation in feed intake.

Weaned sows can lose weight because they persist in a catabolic state after weaning, even when fed *ad libitum* (Carroll *et al.,* 1996). Body weight losses ranging from 5.7 to 10.0 kg, during WEI, have been previously reported in primiparous sows, whose feed intake was not restricted during lactation (Carroll *et al.,* 1996; Zak *et al.,* 1998). In the present study, mobilization of body reserves during WEI was reduced in sows receiving more feed, showing that body reserve losses during WEI were, to a certain extent, buffered by a greater feeding level, in both primiparous and multiparous sows.

Sows with short WEI rapidly switch their LH secretion pattern from low frequency/high amplitude to high frequency/low amplitude pulses immediately after weaning, whereas sows with extended WEI show less pronounced or absent LH fluctuation (van den Brand *et al.,* 2000; Kemp *et al.,* 2018). Previous studies have shown that a greater feeding level reduced the WEI (Brooks and Cole, 1972) or had no effect in primiparous (King and Williams, 1984; Carroll *et al.,* 1996), or in multiparous sows (Brooks *et al.,* 1975). Similarly, in the present study, the WEI was not affected by feeding level, in agreement with other studies in which 3.0 or 6.0 kg (Baidoo *et al.,* 1992), and 2.7, 3.6 or 5.5 kg/day (Graham *et al.,* 2015) were offered to sows immediately after weaning. Surprisingly, even sows with lower body reserves at weaning did not show a decrease in WEI when fed HFL. Some factors may explain the discrepancy in results between studies: longer lactation periods, such as 42 days, and the likely greater catabolism experienced by primiparous sows (Brooks and Cole, 1972) in contrast to weaning performed at 28 days (Baidoo *et al.,* 1992) or approximately 20 days (Graham *et al.,* 2015; present study). Furthermore, the increased feeding level was offered for 14 days on average (Brooks and Cole, 1972), whereas the increased feeding level was offered for shorter periods (less than 7 days) in the present study and in other studies in which WEI was not affected by post-weaning feeding level (Baidoo *et al.,* 1992; Graham *et al.,* 2015). The resistance of sows to losses in body reserves during lactation on changing WEI has been consistently demonstrated over the years (van den Brand *et al*., 2000; Schenkel *et al.,* 2010; Kemp et al., 2018).

Both time and duration of feed restriction may affect to what degree the low feeding level negatively influence follicular growth. Feeding restriction during a 28-days lactation period was associated with smaller follicles after weaning (Zak *et al.*, 1997b). These authors reported a greater number of small follicles (≤ 5 mm) at 108 h after weaning, in sows restricted from day 22 to 28 of lactation, and a lower number of oocytes reaching metaphase II, compared to those restricted from farrowing to day 21 and then fed to appetite from day 22 to 28 of lactation. Thus, the stage of follicular development, which begins before weaning, affects the WEI (Lucy *et al.,* 2001). In the present study, females were not fed-restricted during lactation, and feed intake during WEI was not likely limited enough to impair follicular growth. Indeed, follicle size at weaning and soon after weaning was already larger in sows with shorter WEI, indicating that follicle development is likely more associated with conditions before weaning than with the feed level after weaning. In agreement, larger follicles by Day 3 after weaning were also previously reported in sows with short intervals from weaning to ovulation (Bracken et al., 2003).

The farrowing rate was not affected by feeding level, confirming the results reported by Brooks *et al*. (1975) and Graham *et al*. (2015). On the other hand, Brooks and Cole (1972) found a decrease of 12.5% in farrowing rate and an increase of 25-33% in anestrus rate in primiparous sows fed 1.8 kg/day, compared to sows fed 2.7 or 3.6 kg/day during WEI, with no sign of cyclic activity at slaughter (42 days after weaning) in anestrus sows fed 1.8 kg/day. It is likely that the offer of 0.9 kg/day more in the present study (2.7 vs. 1.8 kg/day) than in that of Brooks and Cole (1972) compensated the loss of body reserves during lactation. Furthermore, for sows with a BCS ≥ 2.75, the amount of 2.7 kg/day provided during WEI was proven to be enough to obtain very high (≥ 95%) conception rates (Graham *et al.,* 2015). In our study, this moderate amount of feed also seemed to be adequate even for sows with low body condition at weaning, ensuring satisfactory subsequent reproductive results.

The litter size was not affected by feeding levels in both primiparous and multiparous sows, in agreement with some previous results (Brooks et al., 1975; Carroll et al., 1996; Graham et al., 2015). In contrast, Brooks and Cole (1972) observed a tendency for litter size to be larger in sows fed 3.6 kg/day than in sows fed 1.8 kg/day, during WEI. Likewise, King and Williams (1984) reported a greater ovulation rate and litter size for primiparous sows that received more feed between weaning and mating (4.0 vs. 1.5 kg/day). The number of piglets born is affected by various factors, such as ovulation rate, fertilization rate, and embryo survival (Kemp *et al.,* 2018), and these factors can be directly affected by feeding restriction. Zak *et al*. (1997a) observed greater ovulation rate in lactating primiparous sows with higher feeding levels than those under feed restriction (19.9 and 15.4 corpora lutea, respectively). Hormones such as insulin act on granulosa cells, improving the recruitment of preovulatory follicles and preventing follicular atresia (Cox *et al.,* 1987). Additionally, metabolic mediators like IGF-I amplify FSH action. When IGF-I is low in plasma and follicular fluid, as in restricted sows, the follicular recruitment of follicles may be altered (Prunier and Quesnel, 2000). Feed restriction impairs follicular development and oocyte maturation status (Zak *et al.,* 1997b) and, consequently, embryo survival (Zak *et al.,* 1997a). Furthermore, King and Williams (1984) mentioned that an increase in feed intake during WEI is only effective in increasing the litter size in situations where litter size is limited by ovulation rate and the WEI is long.

In conclusion, feeding weaned primiparous and multiparous sows with 4.3 kg/day of a gestation diet (58.78 MJ ME and 26.66 g SID Lys) or a lactation diet (61.66 MJ ME and 51.60 g SID Lys) does not improve the follicular size and reproductive performance in the subsequent cycle. In this scenario, it can be recommended to feed weaned sows with 2.7 kg/day of a gestation diet (36.91 MJ of ME and 16.74 g SID Lys).

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Declaration of interest

The authors declare no conflict of interest.

Ethics statement

All management and procedures for this study were approved by the CEUA – Ethical Committee of Animal Utilization/ UFRGS (Universidade Federal do Rio Grande do Sul), process nº 34482.

Software and data repository resources

None of the data or models are deposited in an official repository.

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Table 1. *Composition of the experimental diets (as-fed basis)*

Ingredient	Gestation	Lactation
Corn	82.66	66.62
Soybean meal	13.80	26.06
Meat and bone meal	-	1.00
Soybean oil	-	2.82
Vitamin and mineral premix[1]	0.50	0.50
Dicalcium phosphate	0.96	0.69
Limestone	1.26	0.97
Salt	0.50	0.50
L-Lys Hcl	0.13	0.46
DL-Met	0.02	0.15
L-Thr	0.06	0.17
L-Trp	-	0.05
Phytase	0.01	0.01
Toxin binder[2]	0.10	-
Total	100.00	100.00
Calculated analysis		
SID[3] AA[4], %		
Lysine, %	0.62	1.20
Methionine + Cystine: Lysine, %	70.00	56.00
Threonine: Lysine, %	74.00	62.00
Tryptophan: Lysine, %	20.00	20.00
Valine: Lysine, %	85.00	61.00
ME[5], MJ/kg	13.67	14.34
CP, %	13.58	19.18
Ca, %	0.79	0.71
STTD[6] P, %	0.27	0.28
Na, %	0.23	0.24
Cl, %	0.45	0.60

[1]Provided per kilogram of gestation diet: 10 800 IU of vitamin A; 2 460 IU of vitamin D_3; 72 IU of vitamin E; 3.08 mg of vitamin K_3; 2.30 mg of vitamin B_1; 5.06 mg of riboflavin (B_2); 2.76 mg of pyridoxine (B_6); 30.82 µg of vitamin B_{12}; 30.82 mg of niacin; 23.80 mg of pantothenic acid; 1.93 mg of folic acid; 0.47 mg of biotin; 1.6 g of choline; 0.40 mg of selenium; 115.95 mg of iron; 25.0 mg of copper; 40.77 mg of manganese; 138.07 mg of zinc; 0.42 mg of iodine. Provided, per kilogram of lactation diet: 11 000 IU of vitamin A; 2 400 IU of vitamin D_3; 80 IU of vitamin E; 2.68 mg of vitamin K_3; 2.00 mg of vitamin B_1; 4.4 mg of riboflavin (B_2); 2.4 mg pyridoxine (B_6); 26.8 µg of vitamin B_{12}; 26.8 mg of niacin; 12.0 mg of pantothenic acid; 1.68 mg of folic acid; 0.37 mg of biotin; 1.90 g of choline; 0.400 mg of selenium; 113.20 mg of iron; 50.0 mg of copper; 42.37 mg of manganese; 131.67 mg of zinc; 1.26 mg of iodine.
[2]Mycofix (Biotin, São Paulo, Brazil).
[3]SID = standardized ileal digestible.
[4]AA: Amino acids.
[5] ME = Metabolizable energy; energy values of ingredients were obtained from NRC 2012.
[6]STTD = standardized total tract digestible.

Table 2. *Effects of diet type (gestation or lactation) and feeding level (MFL: 2.3 kg/d or HFL: 4.7 kg/d) during the weaning-to-estrus interval (WEI) on feed intake, body weight (BW) changes during WEI and reproductive performance of primiparous and multiparous sows (Last Square means)*

	Parity		Feed Level		Diet Type			
Variables	Prim	Mult	MFL	HFL	Gestation	Lactation	RMSE	Effects[3]
Number of sows	254	806	594	466	512	548		
ADFI, kg	3.1	3.2	2.5	3.8	3.2	3.2	0.25	F***, P***, F×P**
BW at breeding[1], kg	156.5	199.6	176.1	180.1	178.0	178.2	23.30	P***
BW change[1], kg	-5.0	-10.7	-10.5	-5.3	-7.4	-8.3	5.83	F***, P***
BW change[1], %	-2.9	-5.0	-5.5	-2.5	-3.8	-4.2	2.8	F***, P***, F×D×P**
WEI, d	5.3	4.6	4.8	5.1	4.9	5.0	3.3	P**
Anestrus rate[2], %	5.5	3.3	4.1	4.5	3.9	4.7	19.76	ns
Farrowing rate, %	89.9	93.1	93.1	90.0	92.6	90.6	26.79	ns
Total piglets born	13.9	15.3	14.6	14.6	14.6	14.7	3.30	P***
Piglets born alive	13.3	14.4	13.8	13.8	13.8	13.8	3.16	P***

F: feeding level; D: diet type; P: parity order; ADFI: average daily feed intake; Prim: primiparous; Mult: multiparous.
[1]Evaluated in a subsample of 227 sows.
[2]Anestrus: sows not showing estrus until 10 d after weaning.
[3]The factors or interactions not presented here were not significant ($P > 0.05$) for any variables; ns= any factor was significant ($P > 0.05$).
*** $P < 0.001$, ** $P < 0.01$.
ADFI - F×P interaction: within HFL (Prim: 3.7a kg × Mult: 3.9b kg) and within MFL (Prim: 2.5 kg × Mult: 2.6 kg).
BW change, % - F×D×P interaction: Prim gestation (MFL: -5.58a × HFL: -0.03b); Prim lactation (MFL: -4.07 × HFL:-2.08); Mult gestation (MFL:-5.76a × HFL: -3.69b); Mult lactation (MFL: -6.52a × HFL: - 4.20b). a,b are different at $P < 0.05$.

Table 3. *Follicle size at weaning (D0) and after weaning according to weaning-to-estrus interval (WEI) length of primiparous and multiparous sows (Least square means)*

Days relative to weaning	Weaning-to-estrus interval, days 3 (n = 8)	4 (n = 122)	5 (n = 39)	>5 (n = 11)	RMSE
D0	4.3^{a}	3.2^{b}	3.0^{b}	3.3^{b}	0.58
D1	4.5^{a}	3.9^{b}	3.6^{c}	4.0^{ab}	0.58
D2	5.1^{a}	4.3^{b}	4.1^{b}	4.1^{b}	0.65
D3	5.3^{a}	5.0^{a}	4.8^{ab}	4.4^{b}	0.72
D4[1]	-	5.1^{a}	5.1^{a}	4.3^{b}	0.66
D5[1]	-	-	5.4	5.0	0.86

[1] Sows with WEI shorter than 4 and 5 days were not included in the analysis of follicular size on day 4 and 5, respectively.

RMSE = Root Mean of square error.

^{abc} indicate differences among WEI lengths, within each day ($P < 0.05$).

There was no difference on D5 ($P = 0.32$).

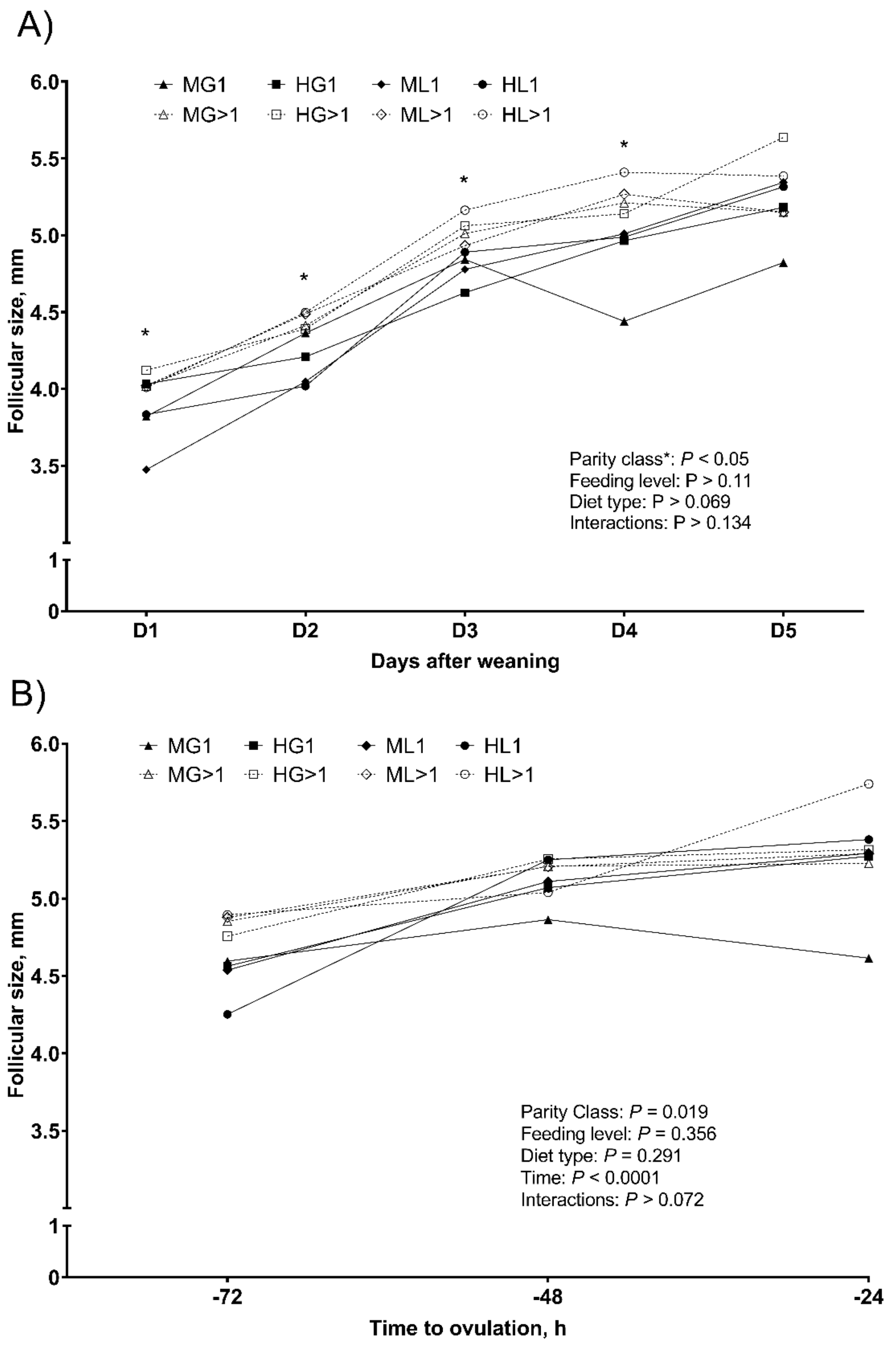

Figure 1. Follicular size after weaning (A) or before ovulation (B) according to two levels (M: Moderate: 2.7 kg/day or H: high: 4.3 kg/day) of different types of diet G: gestation or L: lactation diet) offered during the weaning-to-estrus interval in primiparous (1) or multiparous sows (>1). (*) Asterisks differ statistically at $P \leq 0.05$.

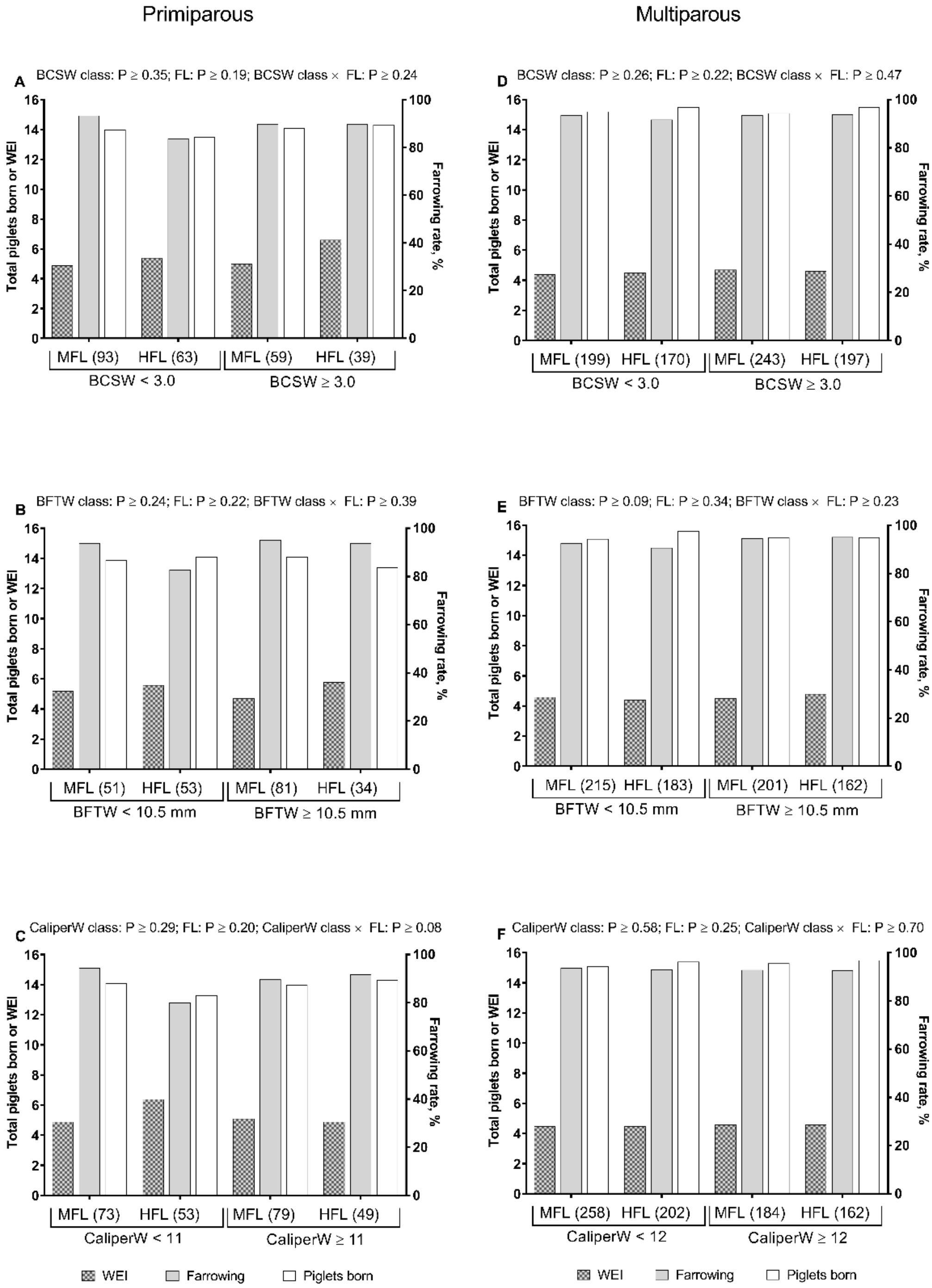

Figure 2. Weaning-to-estrus interval (WEI), farrowing rate and total piglets born according to body reserves at weaning (body condition score – BCSW, backfat thickness - BFTW, and Caliper units - CaliperW) and the feed level (MFL: Moderate - 2.7 kg/day or HFL: high - 4.3 kg/day) offered during the WEI in primiparous (A, B, C) and multiparous sows (D, E, F).

Values inside the parentheses: number of sows in each class.

CAPÍTULO III – SEGUNDO ARTIGO CIENTÍFICO

POST-WEANING FEEDING INTAKE IN PRIMIPAROUS AND MULTIPAROUS SOWS

ARTIGO A SER SUBMETIDO

Post-weaning feeding intake in primiparous and multiparous sows

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ABSTRACT: To investigate the effect of some sow factors on feed intake (FI) during weaning-to-estrus interval (WEI) in 142 primiparous and 458 multiparous sows. At 112 d of gestation and at weaning, caliper unit, backfat thickness (BFT) and body condition score (BCS) were measured, and a subsample of 171 sows was weighed at weaning. During WEI, sows received 4.3 kg/d of feed and the wastage was recorded. Sows were classified in two classes of FI: lower than 75% (LOWFI) or more than or equal to 75% (HIGHFI) of the offered feed. Estrous detection was performed once a day in the presence of mature boars. Primiparous sows had lower FI than multiparous sows ($P < 0.001$). The FI was lower on estrous day than at 2 or 3 d preceding estrus ($P \leq 0.05$). In primiparous sows, the FI was negatively affected in sows with higher BFT at 112 d of gestation ($P = 0.003$), higher BFT, caliper or body weight at weaning, shorter lactation length or fewer weaned piglets ($P \leq 0.035$). Changes in body reserves during lactation had no effect on FI of primiparous sows ($P \geq 0.505$). Higher caliper units, BFT or BCS at 112 d of gestation ($P \leq 0.004$), higher BFT at weaning ($P = 0.032$) or higher body reserve losses during lactation negatively affected the FI in multiparous sows ($P \leq 0.011$). There were no differences in WEI ($P \geq 0.112$) and farrowing rate ($P \geq 0.717$) between LOWFI and HIGHFI primiparous and multiparous sows. Multiparous sows of HIGHFI class had greater litter size ($P = 0.011$) than LOWFI sows, but their litter size was also higher in previous farrowing ($P = 0.014$). The FI intake during WEI was lower in primiparous sows, on day of estrous expression or in sows with better body condition. Furthermore, primiparous sows with shorter lactations or with fewer weaned piglets also had reduced FI during WEI. However, the reduction in feed intake was not enough to impair the subsequent reproductive performance.

Keywords Body condition; Feed consumption; Reproductive performance; Sow; Weaning-to-estrus interval

1. Introduction

Over the years, genetic selection has focused on pigs with increased growth rate, feed efficiency, lean tissue, and low backfat thickness, consequently affecting body composition and appetite of sows (Close and Cole, 2001; Kim et al., 2013). Indeed, it has been demonstrated that selection for lean growth efficiency reduces the voluntary feed intake (VFI) during lactation (Kerr and Cameron, 1996). Furthermore, sows have been also selected for increased litter size and milk production (Kim et al., 2013). Therefore, the current commercial sows are leaner, with higher growth rate, lower VFI and with greater nutritional requirements than sows of 3 to 4 decades ago.

Sows need nutrients for maintenance and milk production and, when young, for their growth. However, during lactation, the feed intake is usually insufficient to meet all nutritional requirements and sows mobilize body reserves to maintain milk production, resulting in a catabolic state (Quesnel, 2009). Feed intake during lactation can be affected by several factors such as parity, body weight and body composition (Williams, 1998; Eissen et al., 2000). It is well documented that excessive maternal body loss negatively affects subsequent reproductive performance (Baidoo et al., 1992; Quesnel, 2009; Schenkel et al., 2010). Catabolic sows may have longer weaning-to-estrus interval (WEI; Baidoo et al., 1992), lower ovulation rate, embryo survival (Zak et al., 1997) and smaller litter size (Schenkel et al., 2010).

An adequate amount of feed during WEI decreases, in part, the negative effect of body condition loss during lactation (Baidoo et al., 1992). After weaning, sows are usually fed *ad libitum* (Close and Cole, 2001), aiming to restore maternal reserves to ensure adequate reproductive performance in the next cycle (Menegat et al., 2018). An increase in embryo survival has been reported in restricted primiparous sows during lactation when fed with high feeding levels during WEI (Baidoo et al., 1992). Nonetheless, as WEI has decreased from 10 d or more in the 1970s to currently 4 to 5 d (Brooks and Cole, 1972; Sbardella et al., 2014), it is necessary to understand which factors may affect feed intake during this short period of time before a new mating. Although factors that affect the VFI of lactating sows have been thoroughly investigated (Revell et al., 1998; Eissen et al., 2000), to our knowledge, there are no studies concerning the pattern of feed intake in weaned sows. The aim of this study was to investigate whether parity, estrous expression, body weight, backfat thickness (BFT), body condition score (BCS), caliper units, number of weaned piglets, or lactation length affect the feed intake in primiparous and multiparous sows during WEI. Furthermore, the effects of feed intake during WEI on farrowing rate and litter size were investigated.

2 Materials and methods

2.1 Animal care

The Ethical Committee of Animal Utilization (CEUA) of Federal University of Rio Grande do Sul (UFRGS) approved all management and trial procedures for this study, under the process no. 34482.

2.2 Animals, housing and management

The study was performed in a commercial sow farm with an inventory of 5,000 sows, located in Santa Catarina State, in Southern Brazil. The minimum and maximum temperatures inside the barns averaged 20.3 and 28.7°C, respectively, during the experimental period (August to October), which corresponded to the end of winter and the beginning of spring in the Southern Hemisphere.

A total of 142 primiparous and 458 multiparous (3.6 ± 0.07; 2 to 7 farrowings) Landrace × Large White (PIC Camborough®, Hendersonville, TN) were used. During lactation, all sows were housed in farrowing crates (2.20 × 0.70 m) with *ad libitum* access to feed and water. After weaning, sows were housed in individual gestation crates (2.20 × 0.60 m) with *ad libitum* access to water. From weaning until breeding the sows were fed 4.3 kg/d of corn-soybean meal gestation (3.27 Mcal ME, 13.58% CP and 0.62% SID Lys) or lactation (3.43 Mcal ME, 19.18% CP and 1.20% SID Lys) diets, three times a day at 700, 1300 and 1800 h. The feed wastage was recovered and weighed (Belmak ELP 30® scale, with a precision of 2 g) once a day for sows that expressed estrous signs until 10 d after weaning. Sows were fed 2.0 kg of gestation diet daily from the time of artificial insemination until day 4 of gestation. From day 5 until day 35 of gestation, the sows with BCS <3 and ≥ 3 were fed 2.8 and 2.0 kg/d, respectively. From day 36 of gestation until farrowing, all sows received 1.8 kg/d.

Estrous detection was performed once a day in the presence of a mature boar, from weaning until sows showed standing reflex in the back-pressure test. The sows in estrus were inseminated using the post-cervical technique with pooled semen doses containing 1.5×10^9 sperm cells (45 mL of total volume) at estrous onset and at 24-h intervals during standing estrus.

2.3 Data and measurements

At housing into the farrowing room (approximately at 112 d of gestation) and at weaning, BCS (1 = thin and 5 = fat; Young et al., 2004) was determined, BFT at the P2 point (6.5 cm away from the midline of the vertebral column at the last rib level, considering both sides) was measured with A-mode ultrasonography (Renco Lean Meter - Renco Corporation, Minneapolis, MN), and caliper units (scale 1 to 25; Knauer and Baitinger, 2015) were measured. A total of 46 primiparous sows and 125 multiparous sows were randomly selected to evaluate the weight at weaning. Sows were weighed with a bar scale (Tru Test EW6, Auckland, New Zealand) with 500 g of precision. The number of weaned piglets, lactation length, previous litter size, and subsequent farrowing rate and litter size were recorded.

2.4 Statistical analysis

All the data were analyzed using the Statistical Analysis System Software, version 9.3 (SAS Inst. Inc., Cary. NC). The GLIMMIX procedure was used for both analyses of variance and logistic regression models. The results were considered significant at $P \leq 0.05$ and a p-value between 0.05 and 0.10 was considered a tendency. Data are expressed as LSmeans ± standard error of the mean. The sow was considered the experimental unit. Five sows that expressed estrus on weaning day were not included in the analyses. The average daily feed intake (ADFI) was not affected by diet type, in both primiparous (P = 0.108) and multiparous (P = 0.110) sows. Therefore, data concerning lactation and gestation diets were pooled for further analyses

The feed intake on the first 4 d after weaning was compared between primiparous and multiparous sows using an analysis of variance. Because the feed intake was no more recorded as the sows expressed estrus, the number of sows with information about feed intake decreased over the time after weaning. Therefore, the feed intake after weaning was analyzed separately for each day. The probability of sows consuming less than 75% of the offered feed on each day after weaning was also compared between primiparous and multiparous sows. For this analysis, sows were separated in two feed intake classes: sows with ADFI less than 75% of total daily feed amount offered (LOWFI) and sows consuming more or equal to 75% of total daily feed amount offered (HIGHFI). The probability of belonging to the LOWFI class was analyzed as a binary response using logistic regression models. The models contained parity as a fixed effect and day of weaning as a random effect.

The feed intake relative to days before estrous expression was analyzed as a repeated measure. Sows with at least 3 d of feed intake before the estrous day, corresponding to sows in estrus between 4 and 10 d after weaning (91.2% of the sows), were included in this analysis. The analysis model contained the fixed effects of parity, day relative to estrus, and parity × day interaction, as well as the day of weaning as a random effect.

For the analyses used to investigate the effects of body traits (at 112 d of gestation, at weaning and changes during lactation), the number of weaned piglets or lactation length on feed intake, primiparous and multiparous sows were analyzed separately. The variables concerning body traits were firstly included as continuous variables in logistic regression models to analyze the probability of belonging to LOWFI class; the resulting probability values were used to calculate sensitivity and specificity values. The sows were separated in two classes for each body trait based on maximal sensitivity and specificity values. Thereafter, the variables were included in logistic regression models as fixed classificatory variables to analyze the effect of each body trait on the probability of belonging to the LOWFI group in primiparous or multiparous sows. Univariate models were used because coefficient of correlation values among body traits were higher than 0.40 ($P < 0.003$; data not shown), denoting the existence of collinearity.

The farrowing rate was compared between LOWFI and HIGHFI classes as a binary response using logistic regression models. Litter size and WEI were compared between LOWFI and HIGHFI classes using an analysis of variance.

3. Results

3.1 Characteristics of sows

At weaning, primiparous and multiparous sows had, respectively, the following characteristics: 162.9 ± 3.87 vs. 209.6 ± 2.35 kg of body weight; 10.4 ± 0.22 vs. 10.3 ± 0.16 mm BFT; 10.7 ± 0.20 vs. 11.2 ± 0.14 caliper units; 2.6 ± 0.04 vs. 2.8 ± 0.02 BCS points, and 11.5 ± 0.14 vs. 11.9 ± 0.10 weaned piglets. The lactation length was 20.0 ± 0.06 d.

3.2 Parity and feed intake

Overall, LOWFI occurred in 28.0% (168/600) of the sows; the ADFI was 3.8 kg/d for HIGHFI sows and 2.7 kg/d for LOWFI sows. The minimum percentage values for ADFI were 29.0% and 25.9% in primiparous and multiparous sows, respectively (Figure 1). Percentages of sows that consumed less than 50% were 5.6% and 3.1% whereas those that consumed more than 90% of the offered feed were 22.5% and 41.3% in primiparous and multiparous sows, respectively. Primiparous sows had an ADFI lower than in multiparous sows (3.3 ± 0.08 vs. 3.6 ± 0.06 kg/d; $P < 0.001$). An ADFI below 75% of the total amount offered (< 3.2 kg) was observed in 38.7% (55/142) of primiparous sows and 24.7% (113/458) of multiparous sows ($P = 0.001$). Up to 4 d after weaning, the ADFI was lower and the chance of belonging to LOWFI class was greater in primiparous than in multiparous sows ($P \leq 0.05$; Table 1). Differences between parities in these two variables decreased gradually, and at day 5 after weaning, they were no longer affected by parity class ($P \geq 0.269$; Table 1).

3.3 Estrous expression and feed intake

The percentage of sows expressing estrus up to 10 d after weaning was 96.8% (581/600). Most sows expressed estrus within 4 or 5 d after weaning (88.8%; 533/600). Primiparous sows had longer WEI than multiparous sows (5.3 ± 0.31 vs. 4.5 ± 0.18; $P = 0.015$). Feed intake on days preceding the expression of estrus was affected by the interaction parity × day before estrus ($P = 0.050$; Figure 2). In primiparous sows, the feed intake was lower ($P = 0.040$) on estrous day than day 2 and tended to be lower than day 3 ($P = 0.063$) before estrus. There was no difference in feed intake between day 1 before estrus and estrous day ($P = 0.103$) or among days 1, 2 and 3 before estrus in primiparous sows ($P \geq 0.454$). Multiparous sows had lower feed intake on estrous day than in all the preceding three days ($P < 0.001$). Feed intake was lower on day 1 before estrus than on days 2 and 3 before estrus ($P < 0.001$), whereas there was no difference between days 2 and 3 before estrus ($P = 0.979$). On estrous day, the feed intake was not different between primiparous and multiparous sows ($P = 0.206$), but primiparous sows had a lower feed intake than in multiparous sows on days 1, 2 and 3 preceding estrous expression ($P < 0.005$).

3.4 Body traits and feed intake

Primiparous sows with BFT ≥ 12.5 mm at 112 d of gestation had higher odds of belonging to the LOWFI class ($P = 0.003$). Significant higher odds of belonging to LOWFI class were observed when multiparous sows had caliper units ≥ 12, BFT ≥ 12.5 mm or BCS ≥ 3.0 at 112 d of gestation ($P \leq 0.004$; Table 2). Primiparous sows with higher body reserves at weaning (caliper unit > 12, BFT ≥ 10.5 mm and body weight ≥ 157.5 kg) had higher odds for the occurrence of low feed intake ($P \leq 0.020$; Table 3). For multiparous sows, BFT > 12 mm at weaning resulted in a greater chance of sows being included in the LOWFI class than sows with lower BFT values (*P* = 0.032; Table 3); a tendency for more LOWFI multiparous sows was observed when they had caliper units >12 (*P* = 0.070; Table 3). The occurrence of LOWFI was not affected by BCS at weaning in both primiparous and multiparous sows (*P* ≥ 0.689; Table 3). Weaned litter size ≤ 11piglets and lactation length < 20 d resulted in higher odds (*P* ≤ 0.035) for the occurrence of LOWFI in primiparous sows but not in multiparous sows (*P* ≥ 0.272; Table 3). Changes in body reserves during lactation had no effect on feed intake in primiparous sows (*P* ≥ 0.505; Table 4). In contrast, multiparous sows with higher losses of body reserves (caliper, BFT and BCS) during lactation had greater odds for LOWFI (*P* ≤ 0.011; Table 4).

3.5 Feed intake and reproductive performance

The WEI was not different (*P* ≥ 0.112) between LOWFI and HIGHFI classes in both primiparous (4.8 ± 0.75 vs. 5.6 ± 0.60) and multiparous (4.2 ± 0.28 vs. 4.6 ± 0.19) sows, respectively. Likewise, primiparous (87.0 ± 4.79% and 87.1 ± 3.83%) and multiparous (93.9 ± 2.35% and 92.9 ± 1.56%) sows had no differences in subsequent farrowing rates (*P* ≥ 0.717) between LOWFI and HIGHFI classes, respectively. Multiparous sows of the LOWFI class had smaller litter size at previous farrowing (14.6 ± 0.28 vs. 15.4 ± 0.17 piglets; *P* = 0.014), as well as in the subsequent farrowing (14.4 ± 0.37 vs. 15.4 ± 0.24 piglets; *P* = 0.011), than HIGHFI multiparous sows, respectively. No differences in initial (14.8 ± 0.47 vs. 14.6 ± 0.42 piglets; *P* = 0.637) or subsequent (14.7 ± 0.49 vs. 13.8 ± 0.39 piglets; *P* = 0.162) litter size were observed between LOWFI and HIGHFI classes, respectively, in primiparous sows.

4 Discussion

The feed intake can be affected by several factors, including those associated with environment, diet, production phase, and individual characteristics of sows (Eissen et al., 2000); all these factors act together as a multifactorial system to affect feed intake (Forbes, 2009). In the present study, HIGHFI and LOWFI sows consumed on average 89.6% and 62.6% of the offered feed, respectively. Only 22.5% and 41.3% of primiparous and multiparous sows, respectively, had an ADFI higher than 90%, showing the individual variability in feed intake during WEI, which is consistent with the great variability reported in feed intake during lactation periods (Koketsu et al., 1996).

One of the mechanisms of feed intake regulation is by the action of mechano-, chemo-, and osmoreceptors acting according to the filling of the gastrointestinal tract (Eissen et al., 2000; Forbes, 2009). The lower ADFI and the greater probability of having low feed intake during WEI observed in primiparous sows, shows the importance of gastric capacity as a factor affecting VFI. In a previous study (Thingnes et al., 2012), feed intake during lactation decreased by 14% in primiparous sows compared with multiparous sows.

Weaning is a stressful event to the sow due to the abrupt separation from the litter and moving to the gestation facility (De Passillé and Robert, 1989; Close and Cole, 2001). After the abrupt removal of piglets and change in accommodation place, the sow is under considerable stress and generally can consume less than in the lactation period (Close and Cole, 2001). However, there is great individual variation in time sows spend with their litters over the lactation period (Bøe, 1991), indicating that there are different degrees of maternal bond to their piglets. This could result in different responsiveness of sows to the separation from their litters, probably contributing to the individual variation in feed intake during WEI. We can speculate that primiparous sows of the present study suffered more with the separation from their piglets than multiparous sows, considering that differences between parities in ADFI (0.53 to 0.10 kg) and in percentages of LOWFI sows (28.4% to 8.0%) gradually decreased from the first to fifth day after weaning.

Reduced appetite is associated with estrous expression in swine females (Gordon, 1997). In the present study, both primiparous and multiparous sows decreased their feed intake on estrous day. However, in multiparous sows, the decrease in feed intake was more gradual than in primiparous sows. Decreased accessibility to the udder and a higher proportion of nursings terminated by the sow were observed in second-parity sows than in first-parity sows, as the lactation progresses (Thodberg et al., 2002). The authors supported the theory that effort put into the offspring is lower in less competent and less effective mothers than in older and more competent individuals. As most primiparous sows of the present study expressed estrus 4 or 5 days after weaning, the third- and second-day preceding estrus corresponded to the first or second day after weaning. We postulate that primiparous sows, due to lack of experience with the weaning process, may undergo more stress associated with weaning, which could contribute to their relatively low feed intake immediately after weaning, but this hypothesis remains to be tested.

The negative effect of a better body condition on feed intake during WEI was consistently shown in the present study. Particularly in primiparous sows, percentages of LOWFI sows increased by 25% to 43% when BFT at the end of gestation or at weaning, and caliper or body weight at weaning were higher. On the other hand, 11% to 19% more multiparous sows had reduced feed intake when body reserves were higher at the end of gestation (caliper, BFT or BCS) or at weaning (BFT). The negative effect of high body reserves at farrowing on feed intake during lactation is well known (Eissen et al., 2000; Mallmann et al., 2018). It is noteworthy that in the present study the feed intake was compromised, even after weaning, in sows with higher body reserves at farrowing. Thus, we can assume that the mechanisms that reduce the feed intake at beginning of lactation are still acting in the after-weaning period. This probably also explains the apparently paradoxical negative effect of high body reserve losses during lactation on feed intake of multiparous sows. Indeed, it was confirmed that sows with higher losses (BFT, caliper or BCS) during lactation had higher BFT values (+2.56 mm), caliper units (+2.08) and BCS scores (+0.48), respectively, at the end of gestation than their counterparts that lost less body reserves ($P < 0.001$; data not shown). We speculate that they ate less because they were fatter at the beginning of lactation. Although they had higher body reserve losses during lactation, they kept on consuming less feed during WEI. Fat sows have more adipose tissue and its turnover releases fatty acids and glycerol into the bloodstream, and these metabolites signalize the central nervous system to reduce VFI (Williams, 1998). Additionally, adipose tissue releases leptin, a hormone that inhibits the function of neuropeptide Y, hence decreasing the VFI (Barb et al., 2005). Leptin concentration has been shown to be negatively correlated with daily feed intake during lactation in parity-2 sows (Estienne et al., 2000). Furthermore, milk production represents at least 70% of nutritional requirements, and sows with a high milk production have greater feed intake (Strathe et al., 2017). However, fat sows have lower capacity to produce milk and, thus, may have a reduced drive to eat (Eissen et al., 2000).

There is a positive correlation between litter size and milk production (Auldist et al., 1998); from eight to 14 piglets, each additional piglet represents an increase of 0.325 kg/d in milk production during late lactation (24 to 28 d). Thus, sows with large litters have greater energy requirements, increasing the VFI (Eissen et al., 2000). Indeed, sows with high milk production usually have a high feed intake, but also a high mobilization of body reserves (Strathe et al., 2017). In the present study, primiparous sows with fewer weaned piglets had a greater probability to be classified as LOWFI sows. With fewer suckling piglets, the feed intake of these sows was probably reduced, and they reached weaning with a better body condition. In fact, primiparous sows with fewer weaned piglets had higher BFT values (11.0 ± 0.32 vs. 10.0 ± 0.29 mm; $P = 0.008$) and caliper units (11.1 ± 0.33 vs. 10.4 ± 0.29; $P = 0.05$) at weaning than those with more weaned piglets, respectively. Shorter lactation length was considered a factor that influenced feed intake during WEI in primiparous sows but not in multiparous sows. Feed intake was probably reduced in these sows because a lower whole milk production is expected with shorter lactation periods, hence less energy expenditure, less feed intake and better body condition at weaning. This assumption was confirmed by higher weights (176.6 ± 8.70 vs. 161.0 ± 6.49 kg; $P = 0.035$) and caliper units (11.3 ± 0.38 vs. 10.4 ± 0.28; $P = 0.020$) at weaning in primiparous sows with shorter lactation lengths.

Feeding weaned sows during WEI with a high feed amount is a common practice in pig production, aiming to start the recovery of body reserves lost during lactation. Especially in sows with high lactational catabolism, this management is proposed to improve the subsequent reproductive performance (Baidoo et al., 1992; Menegat et al., 2018). Increased litter size has been reported in primiparous sows fed 3.6 kg/d compared to those fed 1.8 kg/d during WEI (Brooks and Cole, 1972). The increase in the number of piglets born could be associated with a higher ovulation rate as confirmed by the increase of 1.8 ovulations when the post-weaning feed amount was increased from 1.5 to 4.0 kg/d (King and Williams, 1984). In the present study, the increase of one piglet born in HIGHFI multiparous sows was probably not caused by the increased feed intake during WEI, because those sows had already on average more 0.8 piglet born in previous farrowing than LOWFI sows. Furthermore, LOWFI sows consumed, on average, 2.7 kg/d, which is considered adequate for sows in good body condition at weaning (≥ 2.75 BCS score) to ensure a good reproductive performance (Graham et al., 2015).

Regardless of the effects of body reserves on feed intake, it is important to emphasize that weaned sows would cope with two limiting factors capable of reducing feed intake after weaning: stress associated with the separation from their piglets and estrous expression. Therefore, the impact of post-weaning feeding strategies will also depend on individual responses of sows to these events. In current herds, usually with short WEI, optimum post-weaning feeding has become less relevant, considering that follicles are recruited directly after weaning and develop to preovulatory sizes within 5 to 6 d (Soede and Kemp, 2015). For sows with pronounced lactational body reserve losses, however, increased post-weaning feeding level may still be important to assure an adequate reproductive performance.

5 Conclusion

In conclusion, feed intake during WEI was lower in primiparous sows, on the day of estrous expression or in sows with better body condition. Furthermore, feed intake during WEI was also reduced in primiparous sows with shorter lactation length or with fewer weaned piglets. However, the reduction in feed intake was not enough to impair the subsequent reproductive performance.

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Table 1. Feed intake and percentage of primiparous and multiparous sows consuming less than 75% of the offered feed (LOWFI) for 5 d after weaning (LSmeans ± SEM)

Item	Primiparous	Multiparous	p-value	Difference[a]
Day 1	n = 142	n = 458		
Feed intake, kg	3.16 ± 0.128	3.69 ± 0.112	< 0.001	0.53
LOWFI, %	45.6 ± 8.59	17.2 ± 4.60	< 0.001	28.4
Day 2	n = 141	n = 455		
Feed intake, kg	3.42 ± 0.068	3.79 ± 0.045	< 0.001	0.37
LOWFI, %	34.7 ± 4.48	18.0 ± 2.20	< 0.001	16.7
Day 3	n = 140	n = 452		
Feed intake, kg	3.28 ± 0.087	3.54 ± 0.060	0.003	0.26
LOWFI, %	38.8 ± 4.62	27.8 ± 2.72	0.014	11.0
Day 4	n = 136	n = 430		
Feed intake, kg	2.99 ± 0.143	3.26 ± 0.128	0.003	0.27
LOWFI, %	52.5 ± 6.47	42.7 ± 5.25	0.054	9.80
Day 5	n = 66	n = 103		
Feed intake, kg	3.52 ± 0.133	3.62 ± 0.114	0.467	0.10
LOWFI, %	30.2 ± 7.32	22.2 ± 5.46	0.269	8.00

The numbers of sows having the feed intake recorded on each day decreased as they expressed estrus after weaning.

[a] Difference in feed intake (kg) or percentage points of LOWFI sows between parities.

Table 2. Results of logistic regression analysis for the probability of sows consuming less than 75% of the offered feed (LOWFI) according to classes of body traits at 112 d of gestation in primiparous and multiparous sows

Item	Primiparous			Multiparous			p-value	
	Class 1	Class 2[c]	Odds ratio[d]	Class 1	Class 2[c]	Odds ratio[d]	Primiparous	Multiparous
Caliper units	≥ 12 (99)	< 12 (43)	1.10	≥ 12 (229)	< 12 (229)	1.90	0.806	0.004
	39.4 ± 4.91	37.2 ± 7.37	(0.52 to 2.31)	30.6 ± 3.04	18.8 ± 2.58	(1.23 to 2.94)		
BFT[a], mm	≥ 12.5 (65)	< 12.5 (77)	2.92	≥ 12.5 (127)	< 12.5 (331)	2.62	0.003	< 0.001
	52.3 ± 6.19	27.3 ± 5.07	(1.44 to 5.92)	38.6 ± 4.32	19.3 ± 2.17	(1.67 to 4.11)		
BCS[b]	≥ 3.0 (116)	< 3.0 (26)	1.53	≥ 3.0 (288)	< 3.0 (170)	2.12	0.360	0.002
	40.5 ± 4.56	30.8 ± 9.05	(0.61 to 3.84)	29.5 ± 2.69	16.5 ± 2.84	(1.31 to 3.43)		

Values are expressed as percentages of LOWFI sows in each class (LSmeans ± SEM).
Number of sows for each class of body traits is within parentheses.
[a] BFT: Backfat thickness.
[b] BCS: body condition score.
[c] Class 2 of each variable was used as the reference class for odds ratios.
[d] Values within parentheses correspond to lower and upper confidence limits for odds ratios.

Table 3. Results of logistic regression analysis for the probability of sows consuming less than 75% of offered feed (LOWFI) according to classes of body traits at weaning, number of weaned piglets and lactation length in primiparous and multiparous sows.

	Primiparous			Multiparous			p-value	
Item	Class 1	Class 2[d]	Odds ratio[e]	Class 1	Class 2[c]	Odds ratio[d]	Primiparous	Multiparous
Caliper unit	> 12 (25)	≤ 12 (117)	2.89	> 12 (120)	≤ 12 (338)	1.54	0.020	0.070
	60.0 ± 9.80	34.2 ± 4.38	(1.18 to 7.06)	30.8 ± 4.22	22.5 ± 2.27	(0.96 to 2.45)		
BFT [a], mm	≥ 10.5 (71)	< 10.5 (71)	3.20	> 12 (93)	≤ 12 (365)	1.73	0.002	0.032
	52.1 ± 5.93	25.3 ± 5.16	(1.57 to 6.55)	33.3 ± 4.89	22.5 ± 2.18	(1.05 to 2.84)		
BCS[b]	≥ 2.75 (59)	< 2.75 (83)	1.15	≥ 2.75 (252)	< 2.75 (206)	1.09	0.689	0.691
	40.7 ± 6.39	37.3 ± 5.31	(0.58 to 2.29)	25.4 ± 2.74	23.8 ± 2.97	(0.71 to 1.68)		
Weight, kg[c]	≥ 157.5 (29)	< 157.5 (17)	9.23	≥ 214 (53)	< 213 (72)	0.81	0.011	0.595
	55.2 ± 9.23	11.8 ± 7.81	(1.70 to 50.20)	30.2 ± 6.31	34.7 ± 5.61	(0.38 to 1.75)		

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Weaned piglets	≤ 11 (59)	> 11 (83)	2.12	≤ 11 (157)	> 11 (301)	0.87	0.035	0.533
	49.1 ± 6.51	31.3 ± 5.09	(1.06 to 4.25)	22.9 ± 3.35	25.6 ± 2.51	(0.55 to 1.36)		
Lactation, d	< 20 (39)	≥ 20(103)	2.74	< 20 (174)	≥ 20 (284)	0.78	0.010	0.272
	56.4 ± 7.94	32.0 ± 4.60	(1.28 to 5.89)	21.8 ± 3.13	26.4 ± 2.62	(0.50 to 1.22)		

Values are expressed as percentages of LOWFI sows in each class (LSmeans ± SEM).

Number of sows for each class of body traits is within parentheses.

[a] BFT: Backfat thickness.

[b] BCS: body condition score.

[c] Weight was measured in 46 primiparous and 125 multiparous sows.

[d] Class 2 of each variable was used as the reference class for odds ratios.

[e] Values within parenthesis correspond to lower and upper confidence limits for odds ratios.

Table 4. Results of logistic regression analysis for the probability of sows consuming less than 75% of offered feed (LOWFI) according to classes of losses in body reserves from 112 d of gestation up to weaning in primiparous and multiparous sows

Item	Primiparous			Multiparous			p-value	
	Class 1	Class 2[c]	Odds ratio[d]	Class 1	Class 2[c]	Odds ratio[d]	Primiparous	Multiparous
Caliper units	≥ 0 (116)	< 0 (26)	1.01	≥ 0 (303)	< 0 (155)	1.88	0.975	0.011
	38.8 ± 4.52	38.5 ± 9.54	(0.42 to 2.45)	28.4 ± 2.59	17.4 ± 3.05	(1.16 to 3.05)		
BFT[a], mm	> 1 (72)	≤ 1 (70)	0.80	> 1 (142)	≤ 1 (316)	2.07	0.517	0.001
	36.1 ± 5.66	41.4 ± 5.66	(0.40 to 1.58)	34.5 ± 3.99	20.2 ± 2.26	(1.33 to 3.23)		
BCS[b]	≥ 0.5 (96)	< 0.5 (46)	1.28	≥ 0.5 (180)	< 0.5 (278)	2.02	0.505	0.001
	40.6 ± 5.01	34.8 ± 7.02	(0.61 to 2.68)	32.8 ± 3.50	19.4 ± 2.37	(1.31 to 3.11)		

Values are expressed as percentages of LOWFI sows in each class (LSmeans ± SEM).

Number of sows for each class of body traits is within parentheses.

[a] BFT: Backfat thickness.

[b] BCS: body condition score.

[c] Class 2 of each variable was used as the reference class for odds ratios.

[d] Values within parenthesis correspond to lower and upper confidence limits for odds ratios.

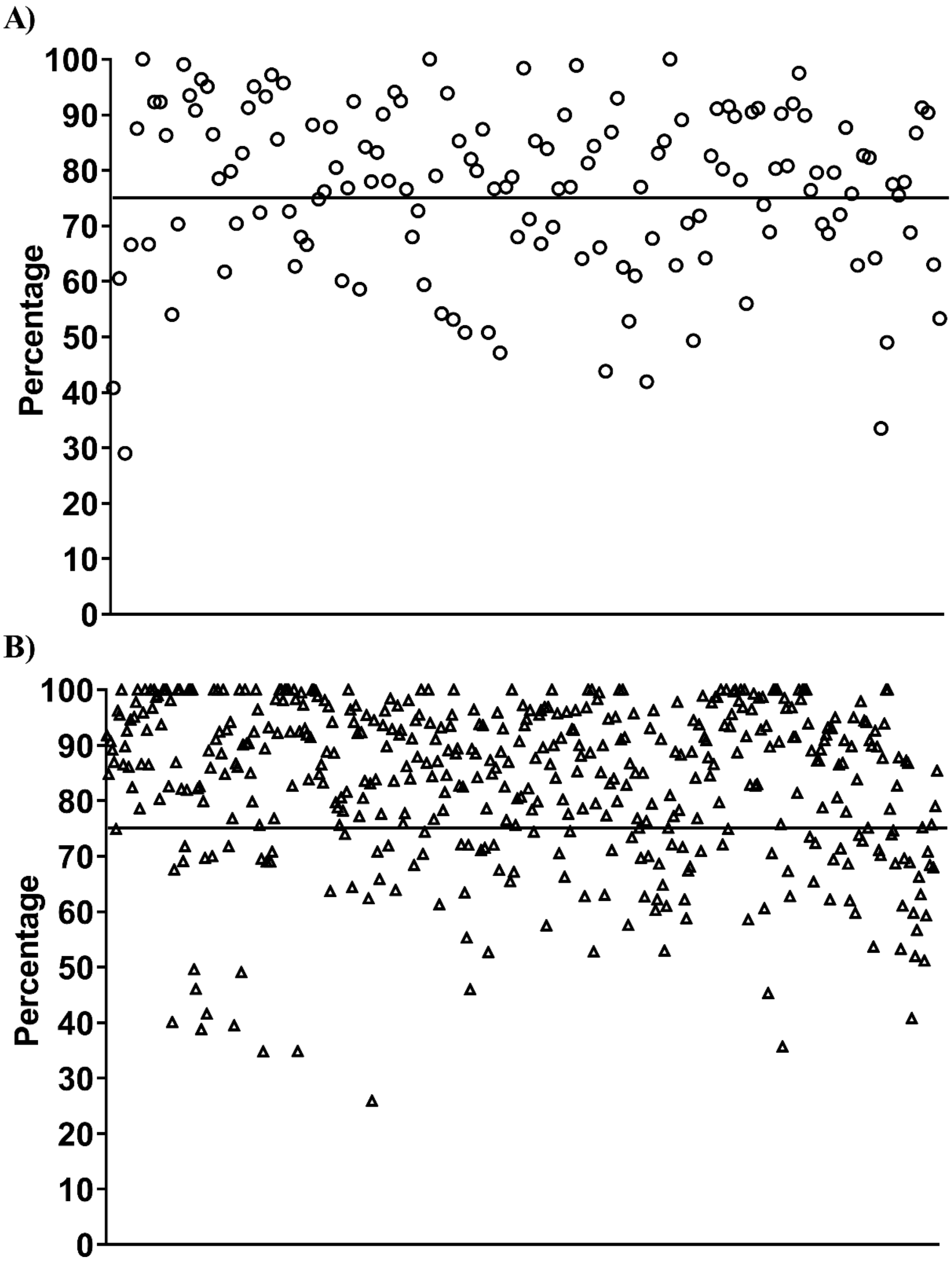

Figure 1. Percentage of average daily feed intake during weaning-to-estrus interval relative to the total feed offered (4.3 kg/d) in primiparous (A) and multiparous sows (B).

Black horizontal line represents 75% of consumption, which was used to separate the sows into feed intake classes. Each open circle (primiparous) or open triangle (multiparous) represents a sow.

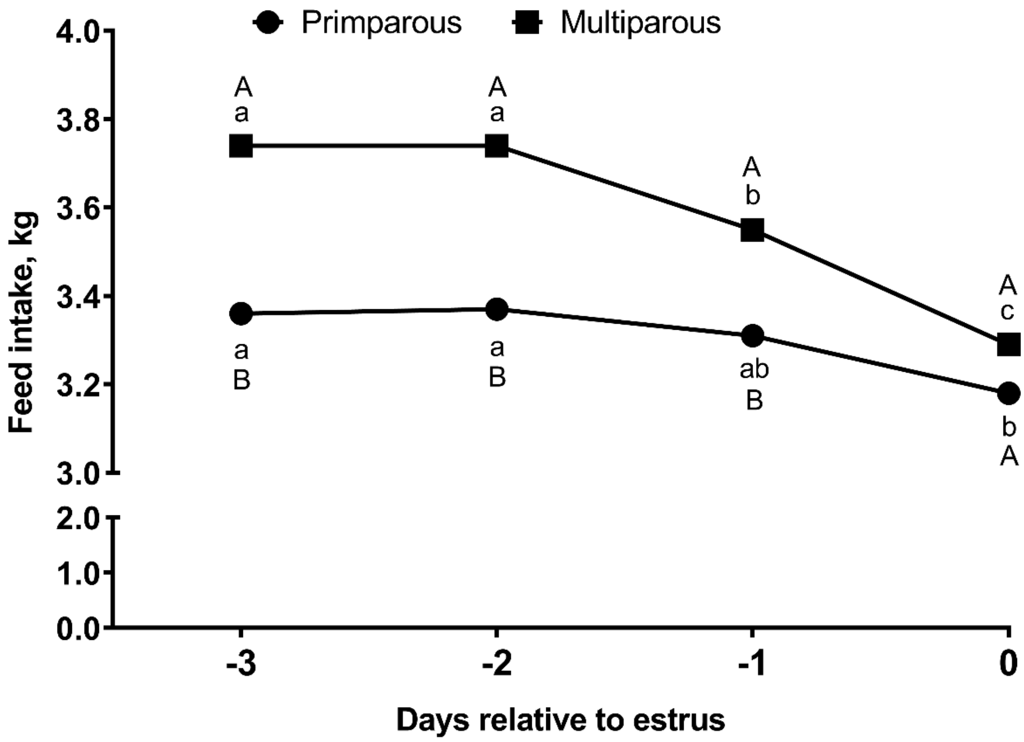

Figure 2. Feed intake in primiparous and multiparous sows relative to estrous day (day zero).

Sows with weaning-to-estrus interval of 4 to 10 d were included in this analysis to have at least 3 d of feed intake recorded before estrus.

Parity × day: p=0.050.

A, B indicate difference between primiparous and multiparous sows within each day.

a, b, c indicate differences among days within each parity class.

CAPÍTULO IV – TERCEIRO ARTIGO CIENTÍFICO

ALTRENOGEST TREATMENT DURING THE LAST WEEK OF LACTATION ON THE SUBSEQUENT REPRODUCTIVE PERFORMANCE OF PRIMIPAROUS AND MULTIPAROUS SOWS

ARTIGO A SER SUBMETIDO

Altrenogest treatment during the last week of lactation on the subsequent reproductive performance of primiparous and multiparous sows

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Abstract

The aim of this study was to evaluate the follicular growth, corpora lutea size (CL), estrus expression and subsequent reproductive performance of sows treated with Altrenogest during the last seven days of a 3-week lactation. A total of 81 primiparous and 319 multiparous sows were allocated into two treatments: CONT (control group) and ALT (20 mg/day of Altrenogest during the last seven days of lactation). Subsamples of 20 primiparous sows and 97 multiparous were randomly selected for evaluation of follicular growth and 26 multiparous sows for serum progesterone analysis at day 21 of gestation. At 21 day of pregnancy CL measurement was performed by ultrasound. Once in estrus, sows were post-cervically inseminated with pooled doses with 1.5×10^9 sperm cells, at estrus onset and each 24 hours during boar standing period. Sows not showing estrus until 10 days after weaning were considered in anestrus. The variables weaning-to-estrus interval, CL size, progesterone concentration, litter size in the subsequent cycle and piglet birth weight were evaluated using GLIMMIX procedure and compared using Tukey-Kramer-test. Anestrus, pregnancy, farrowing and adjusted farrowing rate were evaluated as binary response using a logistic regression. Follicular size was analyzed as repeated measure during treatment and after weaning. Treatment was considered as fixed effect. During the treatment period follicular size was smaller in ALT sows than CONT sows ($P < 0.001$). However, after treatment, ALT sows showed a greater follicular size than CONT sows ($P = 0.003$). There was less ALT sows showing estrus at day three and four after weaning ($P \leq 0.05$) than CONT sows. At 21 days of gestation ALT sows showed greater CL size and lower CL size variation ($P < 0.001$) than CONT sows. Anestrus rate, pregnancy rate, farrowing rate, adjusted farrowing rate, litter size in the subsequent cycle, piglet birth weight, litter birth weight and birth weight variation did not differ between treatments ($P > 0.144$). In conclusion, ALT treatment during a 3-week lactation period concentrated estrus expression, increase the follicular and CL size; however, there was no improvements on the reproductive performance.

Keywords: Progestagen, reproduction, follicle development, piglet birth weight

1. Introduction

During lactation, ovaries shows four distinct patterns of follicular growth:1) no activity, 2) formation of cystic follicles, 3) ovulation during lactation and 4) growth in synchronized waves [1]. The selection for more productive sows resulted in short weaning-to-estrus interval by rapid stimulation of LH release from the hypothalamus-pituitary system at weaning increasing the chance of selection of compromised follicles [2]. Thus, if the weaning occurs when a follicular wave is growing, the sow will ovulate follicles selected during a period of lactation more prone to suffer the deleterious effects of negative energetic balance, resulting in smaller follicles [3] with less development ability [4].

The follicle is composed by an oocyte, follicular fluid theca cells and layer of granulosa cells. The number of granulosa cells is strongly correlated with follicular size, which make the follicular size an indicator of quality and thus, larger follicles are more supportive of cytoplasmic maturation than small ones [5]. However, at follicular recruitment, selection and at estrus, there is an heterogeneity within the follicle population [6] and this characteristic during follicular growth might affect the embryo development and diversity, resulting in different embryo capacity to survive in the uterus and further, more developed embryos produce estrogens that changes the uterine environment in their advantage [7, 8]. A greater follicle size, is also correlated with the corpora lutea (CL) size [9], and has been recently correlated with piglet birth weight [10].

Altrenogest treatment after weaning has been associated with an increase of follicle size at ovulation [11] and litter size [12] in weaned sows. Recently, Lopes, Bolarín [13] treated sows with Altrenogest during the last six days of lactation and reported an increase of total born in the subsequent farrowing due an improve in the follicular size. Thus, we hypothesize that Altrenogest treatment during the last week of lactation improve the follicle size at ovulation, resulting in, not only a larger litter size, but larger corpora lutea size and consequently higher birth weight. Therefore, the aim of this study was to evaluate the effect of Altrenogest treatment during the last seven days of 3-week lactation period on follicle growth, corpora lutea size and reproductive performance in the subsequent cycle.

2. Materials and methods

All management and procedures for this study were approved by the CEUA –Ethical Committee of Animal Utilization/ UFRGS (Universidade Federal do Rio Grande do Sul), process nº 35919.

2.1 Animals, housing and feeding

The study was performed in a commercial sow farm with an inventory of 5,000 sows located in Santa Catarina State, in Southern Brazil. During the seven weeks of treatment period (October to December), the temperature inside the barn ranged from 22.7 to 29.2ºC.

A total of 81 Primiparous and 319 multiparous Landrace × Large White crossbred sows (PIC Camborough®, Hendersonville, TN) were used. The sows were moved to the farrowing room around 112 days of gestation and were housed in farrowing crates (2.20 × 0.70 m) with *ad libitum* access to corn-soybean lactation diet (3.35 Mcal ME/kg, 19% of crude protein and 1.2 % of digestible lysine) and water since they were moved in. After weaning, sows were housed in individual gestation crates (2.20 × 0.60 m) with *ad libitum* access to water and 2.7 kg/day of corn-soybean meal gestation diet (3.25 Mcal ME/kg, 13 % of crude protein and 0.6 % of digestible lysine). From the first AI until day 4 of gestation, sows were daily fed 2.0 kg of gestation feed. From day 5 until day 35 of gestation, sows with body condition score (BCS) ≤ 3 and > 3 were fed 2.8 and 2.0 kg/d, respectively. From day 36 until farrowing, all sows received 1.8 kg/d.

2.2 Experimental design

To ensure that all sows were in the same lactational stage, only sows with expected lactation length at weaning of 19-21 days (19.87 ± 0.04) were used. The animals were selected on eight days before the expected weaning date during seven consecutive weeks and allocated into the treatments according to parity order, total piglets born in the last farrowing, number of nursing piglets, caliper units at day of allocation into the treatments and variation in the caliper units (difference between caliper units at the moment of allocation into the treatments and day 112 of gestation day). The experimental design consisted of two treatment groups: Control (**CONT**), sows receiving no treatment, and Altrenogest (**ALT**), sows treated with 20 mg/day of Altrenogest (Regumate ®, MSD, São Paulo, Brazil) during the last seven (D-7 until D-1; weaning was considered day zero - D0). The hormonal administration was performed every day in the morning (8:00 am), directly into the mouth of the sows.

2.3 Measurements

Body condition score (BCS; 1 = thin and 5 = fat; [14]) and caliper (scale 1 to 25 units; [15]) were recorded at the moment of housing in the farrowing room, eight days before weaning and at weaning.

Reproductive data related to weaning-to-estrus interval, anestrus rate, farrowing rate and litter size were also recorded. The birth weight of born alive and stillborn was recorded within 12 hours after birth, using a 1 g precision scale (Belmak ELP 30, São Paulo, Brazil). The mummified fetus was not weighted; however, the number of these piglets were recorded to be included in the litter size analysis.

2.4 Estrus detection and artificial insemination (AI)

Estrus detection was performed once a day in the presence of a mature boar starting on the day of the weaning. The sows were post-cervically inseminated with pooled semen doses with 1.5×10^9 sperm cells, at estrus onset and each 24 hours after during boar standing period (maximum 3 AI). Sows not showing estrus sign until 10 days after weaning were considered in anestrus.

2.5 Ultrasound analysis

A subsample of 20 primiparous and 97 multiparous sows was randomly selected to follicular growth evaluation. The size of the three largest follicles were recorded [16]. The evaluation was performed once a day from seven days before weaning until ovulation using a transrectal ultrasonography (model A6V, Sonoscape, Shenzhen, China) with a linear transducer (model 6761V, 11-5 MHz, SonoScape, Shenzhen, China). An additional evaluation was performed 24 hours after ovulation. The ovulation was considered complete when there was fewer large follicles relative to the previous observation.

At 21 days after the first insemination, the diameter of the corpora lutea (CL) from both ovaries of inseminated sows (N = 373) were evaluated using transrectal ultrasonography. The five largest CL of each ovary was recorded totalizing 10 CL per sow [10].

Pregnancy detection was performed 25 days after the first insemination using transabdominal ultrasound (model C351, 6.0-2.0 MHz, SonoScape, Shenzhen, China).

2.6 Blood collection and progesterone (P4) analysis

Twenty-six sows were randomly selected to P4 analysis. At 21 days after insemination, and the blood was collected using a syringe and a needle (40×12). After collection, the blood was placed in tubes and centrifugates at 5,000 RPM per five minutes. The serum was placed in propylene tubes (1.5 ml) and stored at -20ºC. Plasma progesterone concentrations were determined using a progesterone competitive ELISA kit (AccuBind ® ELISA, Monobind Inc, Costa Mesa, CA, USA). The assay had a sensitivity of 0.10 ng/mL and intra- and inter-assay coefficients of variation of less than 10%.

2.7 Statistical analysis

Eight sows were excluded: 2 ALT sows died and 6 were culled by locomotor problems after weaning (3 ALT and 3 CONT). Thus, 80 primiparous and 312 multiparous sows remained in the analysis.

All data were analyzed using the Statistical Analysis System software, version 9.3 (SAS Inst. Inc., Cary. NC). The results were considered significant at $P \leq 0.05$ and as a tendency at $P < 0.1$. Data are expressed as Least Square Means (LS Means) ± Stand Error of the mean (SEM). Each sow was considered as an experimental unit.

The variables WEI, caliper at 14 d, BCS at 14d, caliper at weaning, BCS at weaning, total born in the previous farrowing, CL size, progesterone concentration, litter size in subsequent cycle, piglet and litter birth weight were analyzed using GLIMMIX procedure and compared using Tukey-Kramer test. Coefficient of variation (CV) of CL size was analyzed as beta distribution. Anestrus, pregnancy rate, farrowing and adjusted farrowing rate was analyzed as binary response using logistic regression. For adjusted farrowing rate, sows culled by non-reproductive reasons and dead sows were not included in the analysis. Follicular size was analyzed as repeated measure during the treatment period and after weaning. For follicular size, sows in anestrus were not include in the analysis. Initially, in all models were included treatment, parity order and their interaction as fixed effect. However, no interaction between treatment and parity order was observed for none of those variables, thus, the primiparous and multiparous sows were analyzed together and only treatment was considered as fixed effect. The week was included as random effect when it is fitted in the model.

3. Results

3.1 Characteristics of sows

At the beginning of the treatment the sows used in the study had the following characteristics: 2.92 ± 0.08 of parity order, 12.56 ± 0.10 of caliper units and 2.84 ± 0.02 of BCS at 14 days of lactation, -0.06 ± 0.10 and -0.05 ± 0.02 of caliper units and BCS change during 14 days of lactation. Also, the sows had 15.96 ± 0.14 total born in the previous farrowing, 19.87 ± 0.04 days of lactation length and 12.90 ± 0.06 nursing piglets. None of these characteristics were different between the treatments (P ≥ 0.162).

3.2 Follicular development and weaning-to-estrus interval (WEI)

The Altrenogest treatment during the last seven days of lactation affected the follicle development (Figure 1). The follicle size during lactation was smaller in ALT sows then CONT sows (3.29 vs. 3.52 mm; P < 0.001). At weaning (D0), follicles were larger than at beginning of the treatment (D-7; 3.72 ± 0.04 vs. 3.28 ± 0.1mm; P = 0.011). After weaning, ALT sows had greater follicular size than CONT sows (5.30 vs. 5.03 mm P = 0.003). Also, follicles were greater at 24 h before ovulation than 96 h (5.72 vs. 4.37 mm, P < 0.001) irrespectively of the treatment. There was no interaction between day of evaluation and during lactation (P = 0.536) or after weaning (P = 0.668) and the treatment.

ALT sows tended to show longer WEI than CONT sows (P = 0.072; Table 1). Also, there was less ALT sows showing estrus signs until day 3 and 4 after weaning (P < 0.05) than CONT sows (Figure 2).

3.3 Corpora lutea traits and P4 analysis

The data is on Table 1.ALT sows had greater CL size (P < 0.001) and lower CV of CL (P < 0.001) size than CONT sows. However, there was no difference between treatments on P4 concentration (P = 0.570).

3.4 Reproductive performance and traits at birth

There was no difference in anestrus, pregnancy, farrowing and adjusted farrowing rate between the treatments ($P > 0.221$). Also, there was no difference for total number of piglets born, born alive, piglet birth weight and litter birth weight ($P > 0.143$; Table 1).

3.5 Correlation among traits

There was a positive relation between follicular size 24 h before the ovulation and CL size at 21 days of gestation ($r=0.28$; $P = 0.003$). However, there was no correlation between CL size and P4concentration ($P= 0.524$) and CL size and piglet birth weight ($P = 0.645$).

4. Discussion

The Altrenogest administration during the last seven days of lactation concentrated the estrus expression and improved the ovarian traits however, no benefits in reproductive performance was found. The tendency of longer WEI in ALT sows reported in our study, is due to lower estrous expression of treated sows on day 3 and 4 after weaning. This result is in agreement with Fernández, Díaz [17] that reported 86.2 % of primiparous sows treated with Altrenogest during 5 days after weaning showed estrus in 4 to 7 d after Altrenogest withdrawal. In the present study, 97.40% of ALT sows showed estrus within 4 to 7 d compared 93.68% of CONT sows. Using ALT during last 6 d before weaning, Kitkha, Boonsoongnern [18] reported a numeric increase in estrus expression up to 7 days in sows treated with Altrenogest than control sows (95.12 vs. 90.00, respectively). The altrenogest might provide a standardization of follicle size in the sows treated, improving follicular development and follicular uniformity [13, 19] and consequently there is greater follicle growth homogeneity, resulting in more synchronicity of estrus expression. Furthermore, under commercial conditions, the use of Altrenogest during last seven days of lacatation reduce the number of sows showing estrus up 3 days, which could have impaired reproductive performance [20], concentrate the inseminations and favor the use of fixed time of artificial insemination, as in some protocols, the ovulation inducer is administrated only 96 hours after weaning [21].

The administration of Altrenogest increases circulating progestagen resulting in a negative feedback on GnRH released by the hypothalamus and consequently inhibition of FSH and LH release from the anterior hypophysis [22], decreasing the follicular growth. Also, the piglets suckling behavior stimulates the sow to release peptidergic neurotransmitters such as serotonin and dopamine that act blocking the GnRH secretion by the hypothalamus and consequently the LH secretion [23]. In the present study, the Altrenogest treatment, together with the suckling intensity, better suppressed the follicular growth during lactation. However, the suppression of follicle growth by Altrenogest after weaning seems to be less pronounced than under lactation and, even under progestogen action, the follicles grows until 6 days of treatment [11, 24]. The Altrenogest treatment results in almost complete inhibition of LH pulses; however, this effect is temporary, blocking the LH release during the first 9h after, with low-frequency high pulses 15h after Altrenogest administration which might allow the follicle growth [25]. In our study, on weaning day, 24 hours after the last ALT administration, the follicular size was not different between treatments ($P = 0.999$), and follicular size were larger in ALT sows until ovulation. This result is in agreement with Lopes, Bolarín [13] that reported an increase in the follicle size at estrus onset in sows treated with Altrenogest during lactation. Furthermore, others studies also reported a greater preovulatory follicle in sows receiving oral progestogen after weaning [11, 12, 24, 26].

A greater follicle size results in greater CL size [9, 27], thus, our hypotheses were that Altrenogest administration would result in a greater preovulatory follicle and CL size. Indeed, Altrenogest treatment during last week of lactation resulted, not only, in greater CL size at 21 days of gestation but also in lower variation among the CL diameter. A greater uniformity in follicle pool were reported in sows when they were treated with Altrenogest from 4 days before until 2 days after weaning [19]. According these authors, the incomplete LH release suppression during ALT treatment allow the follicular growth from small to medium size resulting in more homogeneous pool. This hypothesis is supported by the authors since the treatment with two doses of Altrenogest per day resulted in lower follicular uniformity. In the present study, only the three larger follicles in each animal were measured and therefore they probably were not representative of the uniformity. However, as there is a higher uniformity in CL size and correlation between CL size and follicle size [3, 9], we can assume that follicle pool was also more homogeneous.

Corpora lutea produce progesterone, a hormone with major importance for maternal support of conceptus survival and development [28]. Thus, it is expected that larger CL size results more systemic P4 concentration [10]. However, in the present study, no difference between treatments and also no correlation was found between CL size and P4 concentration which is in accordance with previous report [10].

Ovarian cysts are reported in some study evaluating the Altrenogest treatment as contributing with anestrus rate [29]. This effect may be related with the dosage lower than 20 mg/day [30, 31]. In the present study, only two sows (one

CONT and one ALT) developed ovarian cysts which could be explained by the right dosage used; and thus, no effect on the anestrus rate was observed.

There are no reports in the literature of compromised reproductive performance after altrenogest treatment during lactation [13, 18, 26]. However, Van Leeuwen, Martens [26] observed that fertility after Altrenogest treatment for less than eight days after weaning could be impaired in sows with larger follicles at beginning of the treatment. This might be due the partially suppression of LH during the treatment [25, 30]. The larger follicles are more responsive to LH than smaller ones and thus, these follicles could grow and ovulate “aged” oocytes [12]. However, in the present study, only 2 % of the sows had lager follicles (> 4 mm) at the beginning of the treatment and thus, we can assume that only “new” follicles were ovulated.

The effect of ALT during last week of lactation has contradictory effects on litter size. There are reports showing an increase of 1.8 piglets in the total born [13] while others, as the present study, found no differences [18]. According to Lopes, Bolarín [13], an increase in litter size would be a result of greater quality follicles and more health viable embryos after fertilization. During lactation, sows usually are in negative energetic balance [32], resulting in poor ovulation rate, embryo survival [33] and reproductive performance [34]. In our study, the sows did not show a high body condition loss during entire lactation, only 2 caliper units on average (P= 0.677; data not shown). ALT treatment after weaning increase the ovulation rate, number of viable embryos [35] and litter size [12]. However, the improvement in these parameters is also correlated with more time to recover the body loss after weaning. In our study, the treatment was performed during lactation, providing no additional time for body recovery. However, in this study, the negative energy balance was not marked, around 1.5 caliper units during lactation, thus the deleterious effect of catabolism might be not so evident in the control group.

Recently, Da Silva, Laurenssen [10] observed a positive linear correlation between CL size at 21 days with piglet birth weight ($\beta = + 37.6 \pm 17.8$ g/mm). The authors hypothesized that: 1) A larger CL produce more P4 favoring the embryonic growth and piglet weight at birth, however there was no correlation between CL weight and P4 concentration, which is in agreement with our study that found no correlation between P4 and CL size; 2) Conceptus elongation and maternal recognition of pregnancy may influence luteal vascularization through the effect of PGE2 and Vascular Endothelial Growth Factor and thereby increase the CL size. In the present study, even with CL size of 8.19 mm, similar with 8.4 mm reported by Da Silva, Laurenssen [10], no effects on litter characteristics at birth were found. Kitkha, Boonsoongnern [18] also found no difference on piglet birth weight when sows were treated with Altrenogest during the end of lactation. However, when the Altrenogest treatment was followed by an ovulation inducer (hCG), the variation in piglet birth weight was reduced [18]. In the present study, Altrenogest treatment only increased 0.5 mm of CL size, while Da Silva, Laurenssen [10] reported a difference of, at least, 1.2 mm between the classes with lower and greater CL size (5.5 to 7.8 mm and 9.0 to 10.5 mm, respectively) and consequently piglet birth weight (1250 and 1320 g, respectively). Furthermore, there was a little variation in CL size with more than 92% of sows having on average a CL size between 7.5 and 9.9 mm, which contribute with no different results. Also, factors that influence follicle size at weaning and consequently the CL size, as number of nursing piglet [36] were controlled between treatments. However, not only follicles uniformization is important to the variation of birth weight, but other factors also affect these variables, such as uterine crowding in contemporaneous sows [37, 38].

5. Conclusion

The ALT treatment during the last seven days of 3-week lactation concentrate the estrus expression after four days after weaning, increase follicular size 24 h before ovulation and corpora lutea size at 21 days of gestation. Reproductive performance and piglet birth weight were not affected by the use of altrenogest during lactation.

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Table 1. Reproductive performance, piglets birth weight and progesterone concentration of primíparous and multiparous sows treated with Altrenogest during the last seven days of lactation.

	Control	Altrenogest	P-value
n	197	195	-
WEI, d	4.36±0.07	4.54±0.07	0.072
Anoestrus rate[a], %	3.55±0.01	1.54±0.01	0.221
Pregnancy rate, %	94.71±0.02	94.27±0.02	0.851
Farrowing rate, %	89.47±0.02	90.10±0.02	0.839
Adjusted farrowing rate[b], %	90.91±0.02	92.02±0.02	0.700
Total piglets born	15.76±0.28	15.37±0.27	0.325
Piglets born alive	14.79±0.26	14.26±0.26	0.144
Birth weight variation, %	22.82±0.50	22.58±0.49	0.730
Piglets birth weight, g	1322±19	1336±19	0.462
Litter birth weight, g	19630±311	20037±308	0.149
CL size[c], mm	7.94±1.0	8.44±1.0	< 0.001
Variation coefficient of CL size %	8.89±0.72	7.41±0.61	< 0.001
Progesterone[d], ng/ml	31.81± 3.38	34.47 ± 3.13	0.570

Altrenogest: sows receiving 20 mg/day of Altrenogest from D-7 until D-1 of lactation. Weaning was considered D0; Control: no hormonal treatment; WEI: weaning-to-estrus interval CL: Copora lutea

[a] Sows not showing estrus signs until ten days after weaning.

[b] Sows culled by non-reproductive reasons and dead sows are not included in this analysis.

[c] Measured at 20.60 days of gestation, on average.

[d] Blood was collected from a subsample of 26 sows (14 ALT and 12 CONT) at 21 days after the first insemination.

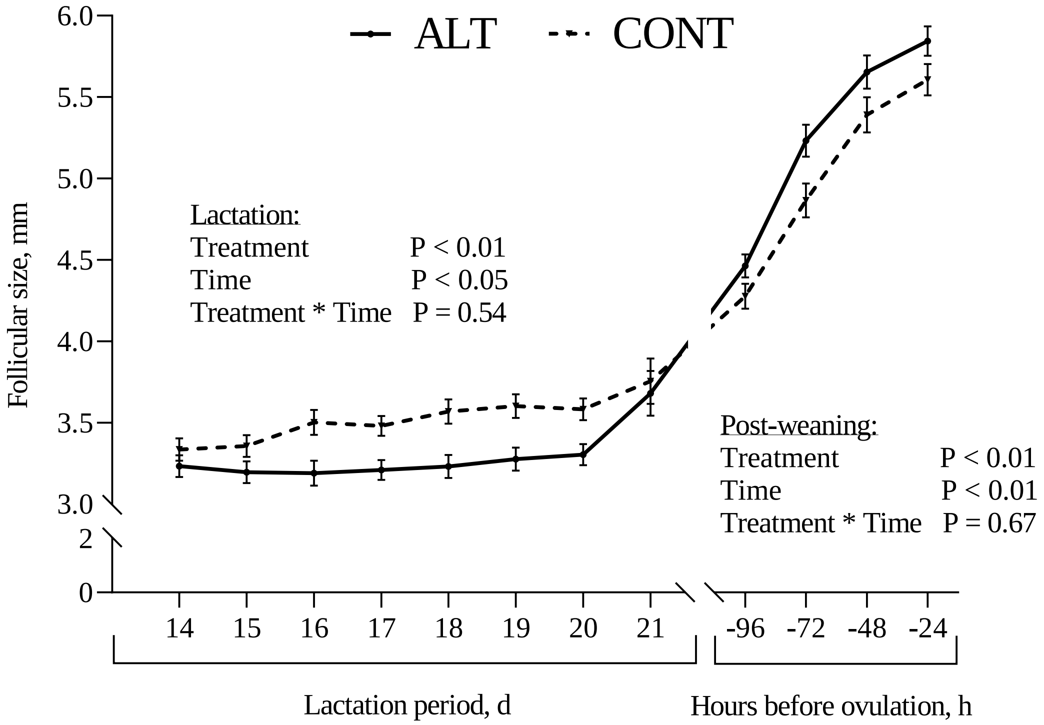

Figure 1. Follicle size during lactation and after weaning of sows treated with Altrenogest during the last seven days of lactation.

Black line: sows receiving Altrenogest during last seven days of lactation; dotted line: control group. Hour 0 was assumed as ovulation moment.

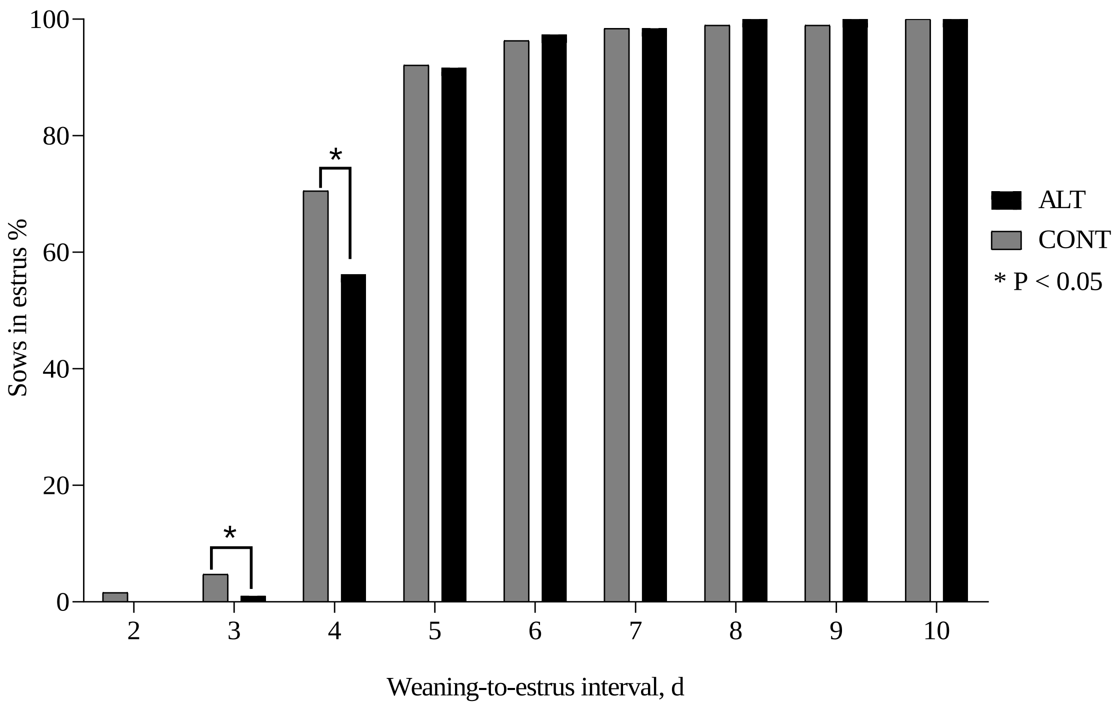

Figure 2. Cumulative frequency of estrus expression in sows after Altrenogest treatment for the last seven days of lactation.

ALT: received 20 mg/d of Altrenogest during the last seven days of lactation; CONT: no hormonal treatment.

MATERIAL SUPLEMENTAR

Durante o primeiro experimento, foram mensuradas variáveis de condição corporal no momento da inseminação e a variação desses parâmetros durante o IDE de acordo com a categoria, tipo de dieta e nível de alimentação durante o IDE. Como esperado, multíparas apresentaram mais unidades de caliper (10,76 ± 0,17 vs. 10,24 ± 0,22; P = 0,007) e maior ECV (escore corporal visual; 2,83 ± 0,03 vs. 2,69 ± 0,05; P < 0,01), do que primíparas. A espessura de toucinho (ET) não foi diferente entre as categorias (P = 0, 65). O nível e o tipo de ração não afetaram nenhum dos parâmetros no momento da inseminação (P ≥ 0,23).

Durante o IDE, não houve interação entre o nível de ração, o tipo da dieta e a categoria para unidades de caliper, ECV e ET (P > 0,05). Os principais efeitos foram relacionados ao nível alimentar. Fêmeas que receberam 4,3 kg/d perderam menos unidades de caliper (-0,12 ± 0,20 vs. -0,43 ± 0,19; *P* < 0,01), ET (-0,34 ± 0,19 vs. -0,69 ± 0,18 mm; *P* < 0,001) do que as fêmeas que receberam 2,7 kg/d. Fêmeas que receberam ração lactação perderam mais ET (-0,66 ± 0.20 mm) do que fêmeas que receberam ração gestação (-0,37 ± 0.20 mm; *P* = 0.006)

Tabela 1. Efeitos do tipo de dieta (gestação ou lactação) e nível de ração (2,7 ou 4,3 kg/d) durante o interval desmame-estro (IDE) de primíparas e multíparas sobre reservas corporais na inseminação e mudanças durante o IDE (LSmeans ± Erro Padrão da Média)[1]

Categoria:	Primíparas				Multíparas							
Dieta:	Gestação		Lactação		Gestação		Lactação		EPM	P-value		
Nível:	2,7 kg/d	4,3 kg/d	2,7 kg/d	4,3 kg/d	2,7 kg/d	4,3 kg/d	2,7 kg/d	4,3 kg/d		Nível	Dieta	OP
Número de fêmeas	48	26	51	37	168	128	175	136				
Inseminação												
Caliper, un	10,40	10,19	10,32	10,04	10,66	10,76	10,72	10,91	0,44	0,79	0,96	<0,01
ET, mm	10,10	9,55	10,02	9,61	9,77	9,97	9,67	9,54	0,42	0,23	0,43	0,65
ECV	2,69	2,68	2,72	2,66	2,79	2,87	2,83	2,83	0,06	0,69	0,71	<0,01
Variação durante o IDE												
Caliper, un	-0,53±	-0,11	-0,32	-0,01	-0,51	-0,23	-0,36	-0,12	0,29	<0,01	0,18	0,56
ET, mm	-0,57	-0,04	-0,91	-0,58	-0,66	-0,30	-0,62	-0,52	0,28	<0,01	<0,01	0,84
ECV	0,08	0,17	0,09	0,07	0,00	0,06	0,04	0,07	0,06	0,11	0,93	0,08

Nível: Nível de ração; OP: ordem de parto; ET: espessura de toucinho; ECV: escore corporal visual.

[1] Tratamentos oferecidos do desmame até a primeira inseminação.

3. CONSIDERAÇÕES FINAIS

A lactação é uma das fases em que a fêmea apresenta maiores necessidades nutricionais. São necessários nutrientes para a mantença, produção de leite, e no caso de primíparas, para o crescimento. Dessa forma, o consumo durante a lactação é geralmente insuficiente para atender todas as necessidades e com isso, a matriz mobiliza suas reservas corporais para suprir as suas necessidades entrando em um estado catabólico. Nos casos em que ocorre um grau muito acentuado de catabolismo, pode ocorrer um comprometimento no desenvolvimento folicular e desempenho reprodutivo pós-desmame.

Como formas de solucionar esse problema, as granjas usualmente aumentam a quantidade de ração, em muitos casos recomendam o fornecimento a vontade durante o intervalo desmame-estro (IDE) e as vezes trabalhando com uma ração mais energética e principalmente mais proteica, como a lactação. O foco dessa prática é recuperar a fêmea de um estado catabólico e para melhorar o crescimento folicular, taxa ovulatória e desempenho reprodutivo. Nas últimas décadas, esse manejo tem sido aplicado nas unidades de produção de forma parcialmente empírica, sem comprovação cientifica. No entanto, o perfil do IDE mudou consideravelmente, passando de 13 - 17 dias nos anos 80 (BRYANT *et al.*, 1985; JOHNSTON *et al.*, 1986) para 4-5 dias nos dias de hoje. Essa mudança resultou na necessidade de novos estudos sobre essa temática (GRAHAM *et al.*, 2015). Com o objetivo de preencher essa lacuna o presente estudo foi realizado no qual essa prática não apresentou aumento na produtividade das fêmeas, independente da categoria e do estado corporal ao desmame.

Além disso, uma parcela expressiva das fêmeas que receberam alta quantidade de ração não ingeriu a quantidade total. Esse baixo consumo foi associado a alguns fatores ligados a condição corporal, expressão de estro e ordem de parto. Contudo, mesmo fêmeas que consumiram pouco durante o IDE não apresentaram redução no desempenho reprodutivo subsequente. Dessa forma, com os presentes resultados, a indústria pode adotar uma nova estratégia alimentar durante o IDE visando reduzir custos com a alimentação de fêmeas além de reduzir a excreção de dejetos.

A adoção dessa estratégia de alimentar as fêmeas com uma quantidade moderada de ração gestação (2,7 kg/d) ao invés de alta quantidade (4,3 kg/d), como demonstrado no presente trabalho, resultaria em uma redução de aproximadamente 18 kg/fêmea/ano, considerando um IDE médio de 4,5 dias e 2,5 partos/fêmea/ano. Além disso, geralmente, após o desmame as fêmeas são alojadas em galpões de gestação e dessa forma o uso de ração gestação se torna mais fácil já que para utilizar a ração lactação seria necessário ou um silo e uma linha específica para ração lactação ou que seja fornecida manualmente. Para o emprego dessa prática deve-se ter em mente que no presente trabalho o nível 2,7 kg/dia foi assegurado para todas as fêmeas. Dessa forma, a regulagem dos *drops* e a conferência da quantidade que está sendo entregue para cada fêmea deve ser feita com periodicidade. Além disso, é importante salientar que o estudo foi realizado com apenas uma linhagem genética, e assim novas avaliações devem ser realizadas com genéticas diferentes.

Outra estratégia avaliada foi a utilização de progestágenos durante a última semana de lactação. Como mencionado anteriormente, fêmeas que apresentam um elevado catabolismo apresentam uma pior qualidade folicular devido a seleção de folículos que cresceram sob um ambiente adverso nos últimos dias de lactação, resultando em pior desempenho reprodutivo. Na última semana de lactação, ocorre o desenvolvimento de ondas foliculares, onde um grupo de 20-30 folículos crescem até aproximadamente 5 mm e após regridem para permitir o desenvolvimento de uma nova onda. Contudo, se o desmame ocorrer durante o crescimento de uma onda folicular, esses folículos, selecionados durante a lactação, mais sujeitos a sofrer influência de uma restrição alimentar, chegariam à ovulação. Dessa forma, o bloqueio do crescimento folicular durante a última semana de lactação pode garantir que os folículos serão selecionados após o desmame. Nos resultados encontrados neste estudo, o tratamento com altrenogest melhorou as características ovarianas (tamanho folicular, tamanho de corpo lúteo e maior uniformidade de *corpora lútea*), mas não melhorou o desempenho reprodutivo subsequente.

Além da melhora das qualidades ovarianas, uma maior concentração de fêmeas expressando estro no dia cinco pós-desmame foi encontrada no grupo altrenogest. Dessa forma, essa estratégia pode ser utilizada para uma maior concentração das inseminações ou mesmo para a aplicação de protocolos de inseminação artificial em tempo fixo (IATF). Contudo, é importante ressaltar que esse manejo, de fornecer o altrenogest às fêmeas, deve ser realizado diariamente, o que torna a prática laboriosa. A administração de alrenogest uma vez ao dia é adequada para a supressão folicular para evitar a entrada em estro, contudo, surge a dúvida se para outras funções, como um aumento expressivo no diâmetro folicular e do corpo lúteo a dosagem e a frequência utilizada no presente estudo é adequada ou se o progestágeno é o mais adequado para a supressão folicular. Dessa forma, estudos futuros são necessários para elucidar essas questões.

Dessa forma, com o presente trabalho pode se concluir que o fornecimento de alta quantidade de ração ou o uso de ração lactação não constituem uma prática vantajosa em fêmeas modernas com o IDE de 4-5 dias. Além disso, fêmeas com melhor condição corporal ao parto e ao desmame e primíparas possuem mais chance de apresentar baixo consumo durante o IDE. O uso de altrenogest na última semana de lactação aumentou o diâmetro folicular após o desmame, o tamanho de corpo lúteo e a uniformidade da *corpora lutea* e concentrou a expressão de estro em até cinco dias após o desmame, porém não influenciou o desempenho reprodutivo nem o peso dos leitões ao nascer.

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