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FLÁVIO CARVALHO DE AQUINO

DESEMPENHO E VIABILIDADE ECONÔMICO-FINANCEIRA DA TERMINAÇÃO DE OVINOS EM CONFINAMENTO DESTINADOS À AGROINDÚSTRIA

Teresina

2025

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Orientador: Prof. Dr. Marcos Cláudio Pinheiro Rogério

Coorientador: Prof. Dr. Fernando Henrique Melo Andrade Rodrigues de Albuquerque

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(Paulo Ricardo Zargolin)

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RESUMO GERAL

O objetivo deste estudo foi avaliar o desempenho, rendimento de carcaça e a viabilidade da terminação em confinamento de ovinos para produção de carne, alimentados com dietas de alto concentrado. Foram utilizados 72 ovinos (36 machos e 36 fêmeas) dos genótipos Santa Inês e F1 Dorper x Santa Inês. Adotou-se o delineamento inteiramente ao acaso, em arranjo fatorial 3 x 2 x 2, com três dietas (Dieta controle-DC, Dieta NRC 2007-DNRC e Dieta Alto Grão-DAG), dois genótipos, dois sexos e seis repetições. Ovinos alimentados com as dietas DC e DNRC apresentaram maiores consumos de MS, MO, FDN, FDA, hemicelulose, celulose e NDT em relação à DAG, exceto para o consumo de PB, EE que foram semelhantes. Os machos F1 Dorper x Santa Inês apresentaram menor consumo de MS, MO, FDN, FDA, celulose e NDT, quando comparado ao Santa Inês. Nas fêmeas, o genótipo F1 Dorper x Santa Inês mostrou consumo superior para estas variáveis. Para o desempenho, houve efeito dos fatores dieta e sexo. As dietas DC e DNRC foram semelhantes e superior à DAG em relação à PCF. A dieta DC foi superior a DNRC e à DAG para GMPT e GPT. Os machos foram superiores às fêmeas, exceto para ECCI e ECCF. Para medidas repetidas no tempo, houve interação entre dieta e sexo para ganho de peso total, em que a DC e a DNRC apresentaram maior ganho de peso em relação à DAG, e os machos apresentaram maior ganho de peso quando comparado às fêmeas. Para o ganho de peso médio diário, verificou-se efeito de dieta e sexo, sendo que a dieta DC e a DNRC apresentaram maior ganho de peso médio diário até os 42 dias, contudo, superadas pela dieta DAG após esse período. Em relação ao sexo, os machos mostraram maior ganho de peso médio diário que as fêmeas. O escore de condição corporal inicial, apresentou efeito de dieta e do fator tempo apenas para o genótipo Santa Inês. O escore de condição corporal final, observou-se efeito de sexo, genótipo e do fator tempo, com fêmeas apresentando escore superior aos machos. Para o rendimento de carcaça, houve efeito de dieta para rendimento de carcaça quente e fria, onde a DC diferiu da DNRC, sendo semelhante à DAG. Os machos apresentaram maior desempenho em relação às fêmeas, exceto para o rendimento de carcaça quente e fria. Os custos anuais de produção, a aquisição de animais, alimentação e o custo de oportunidade foram os itens de maior composição. Em relação ao custo operacional efetivo a aquisição de animais, alimentação e mão de obra foram os intens de maior participação. Os indicadores econômicos e financeiros para os cordeiros foram positivos, mostrando a viabilidade do sistema. Para as fêmeas, a resposta se repetiu, exceto para os indicadores econômicos, onde a renda líquida foi negativa para o genótipo F1 Dorper x Santa Inês alimentadas com a DAG. Conclui-se que ovinos Santa Inês e F1 Dorper x Santa Inês alimentados com à DC, independente do sexo, apresentam desempenho, rendimento de carcaça e viabilidade econômico-financeira.

Palavras-chave: Escore de Condição Corporal; Rendimento de Carcaça; Custos de produção; Análise econômica.

GENERAL ABSTRACT

The objective of this study was to evaluate the performance, carcass yield, and feasibility of feedlot finishing of sheep for meat production, fed high-concentrate diets. Seventy-two sheep (36 males and 36 females) from the Santa Inês and F1 Dorper x Santa Inês genotypes were used. A completely randomized design was adopted in a 3 x 2 x 2 factorial arrangement, with three diets (Control Diet-DC, NRC 2007 Diet-DNRC, and High Grain Diet-DAG), two genotypes, two sexes, and six replicates. Sheep fed the DC and DNRC diets showed higher intakes of DM, OM, NDF, ADF, hemicellulose, cellulose, and TDN compared to DAG, except for CP and EE intakes, which were similar. F1 Dorper x Santa Inês males exhibited lower DM, OM, NDF, ADF, cellulose, and TDN intakes compared to Santa Inês. In females, the F1 Dorper x Santa Inês genotype showed higher intakes for these variables. For performance, there were effects of diet and sex. The DC and DNRC diets were similar and superior to DAG for ADG. The DC diet was superior to DNRC and DAG for FCR and DFI. Males outperformed females, except for FIADG and FICF. For repeated measures over time, there was a diet x sex interaction for total weight gain, where DC and DNRC showed higher weight gain compared to DAG, and males had higher weight gain than females. For average daily gain, diet and sex effects were observed, with DC and DNRC showing higher ADG up to 42 days, but surpassed by DAG thereafter. Regarding sex, males showed higher ADG than females. Initial body condition score showed effects of diet and time only for the Santa Inês genotype. Final body condition score showed effects of sex, genotype, and time, with females having higher scores than males. For carcass yield, there were diet effects on hot and cold carcass yield, where DC differed from DNRC but was similar to DAG. Males showed better performance than females, except for hot and cold carcass yield. Annual production costs, animal acquisition, feed, and opportunity cost were the largest cost components. For effective operational cost, animal acquisition, feed, and labor were the items with the greatest participation. Economic and financial indicators for lambs were positive, demonstrating system feasibility. For females, the response was similar, except for economic indicators, where net income was negative (C9). In conclusion, Santa Inês and F1 Dorper x Santa Inês sheep submitted to DC, regardless of sex, showed performance, carcass yield, and economic-financial viability.

Keywords: Body Condition Score. Sheep finishing. Production costs. Economic analysis.

1. INTRODUÇÃO GERAL

A ovinocultura tem conquistado espaço crescente no cenário da pecuária nacional, especialmente pela maior produtividade animal, adaptação, rusticidade e valorização da carne ovina no mercado consumidor (Santos *et al.*, 2023). Nesse contexto, a terminação intensiva de cordeiros é uma estratégia cada vez mais adotada pelos produtores que buscam melhorar a eficiência produtiva dos sistemas de produções e atender as exigências de qualidade e padronização da agroindústria (Lopes *et al.*, 2025).

O confinamento de ovinos permite maior controle da dieta, do manejo e do ambiente, fatores que interferem diretamente no desempenho zootécnico dos animais e por consequência no rendimento de carcaça, característica fundamental para a indústria frigorifica e rentabilidade do sistema de produção (Pereira *et al.*, 2023; Saldanha *et al.*, 2022).

A utilização de dietas balanceadas e o uso de dietas de alto concentrado favorecem o consumo de matéria seca, conversão alimentar, maior ganho de peso, rendimento de carcaça e o desenvolvimento de características desejáveis de carcaça (Cartaxo *et al.*, 2017; Pazdiora *et al.*, 2019). Esses resultados influenciam de forma positiva na qualidade da carne e no valor de comercialização do produto final. Contudo, apesar dos benefícios zootécnicos é fundamental avaliar também a viabilidade econômico-financeira (Alves *et al.*, 2024; Barros *et al.*, 2009), considerando especialmente os custos com aquisição de animais, alimentação, sanidade, mão de obra, manutenção e depreciação de instalação e equipamentos, custo de oportunidade e demais fontes de custo que compõem o custo total de produção (Alves *et al.*, 2024; Maia, 2024).

Dessa forma, é essencial o desenvolvimento de estudos que combinem indicadores produtivos, econômicos e financeiros na avaliação de sistemas de produção de cordeiros (Alves *et al.*, 2024; Lopes *et al.*, 2025), permitindo não apenas o aprimoramento técnico da atividade, mas também o fortalecimento da cadeia produtiva da carne ovina, especialmente a agroindústria.

Diante do exposto, o objetivo geral do estudo foi avaliar o desempenho produtivo, econômico e financeiro da terminação de ovinos em confinamento de grupos genéticos especializados para produção de carne, alimentados com dietas formuladas para alto desempenho visando atender aos padrões demandados pela agroindústria frigorífica.

2. REFERENCIAL TEÓRICO

2.1 Demanda da agroindústria da carne ovina para os produtores

A oferta constante de ovinos é fundamental para atender ao mercado consumidor e a sustentabilidade da cadeia produtiva de ovinos de corte (Hernández-García *et al.*, 2024; Lucio-Ruíz *et al.*, 2024). Destaca-se, que essa oferta é variável ao longo do ano, entre regiões e mercados (Mandolesi *et al.*, 2020), que são influenciados por fatores como sazonalidade, condições climáticas, disponibilidade de alimentos, ciclos reprodutivos, políticas e, especialmente, preços da carne (Alves *et al.*, 2017; Eustáquio Filho *et al.*, 2011; Sepúlveda, Maza e Mantecón, 2010).

À agroindústria da carne ovina interessam quantidade, oferta constante, maciez da carne (Kantono *et al.*, 2021), assim como animais com características padronizadas em relação à idade de abate, peso, sexo, rendimento de carcaça, acabamento de carcaça e a relação músculo: osso (Kantono *et al.*, 2021; Pereira *et al.*, 2023). Os preços praticados referem-se a esses padrões e especialmente a padrões mínimos relativos à qualidade da carcaça (Van Der Merwe, Brand e Hoffman, 2020), além da agregação de valor conforme a localização geográfica, certificação da carne e exigências do mercado (Bernabéu *et al.*, 2018; Sepúlveda, Maza e Mantecón, 2010).

Nesse sentido, a fim de garantir um padrão mínimo (composição química, física e nutricional da carne), a indústria da carne ovina tem concentrado esforços para ofertar animais para o mercado com o maior rendimento de carcaça, na medida em que essa característica otimiza o processo e amplia a oferta e qualidade da carne (Farrell *et al.*, 2020; Johnson *et al.*, 2023). O rendimento da carcaça é um parâmetro importante e de forte impacto econômico para a produção ovina, pois relaciona-se diretamente à rentabilidade e eficiência do sistema (Heimbuch *et al*., 2023; Van Der Merwe, Brand e Hoffman, 2020).

Diante desse objetivo, produtores têm utilizado raças e genótipos especializados para a produção de carne, que incluem Suffolk, Santa Inês, Dorper e seus cruzamentos (Brant *et al.*, 2021; Cartaxo *et al.*, 2017; Heimbuch *et al.*, 2023). Esses grupamentos genéticos são utilizados pela precocidade, conformação da carcaça, maiores rendimentos de cortes, área de olho de lombo, menor conversão alimentar e deposição de gordura subcutânea combinado ao elevado ganho de peso médio (Lunesu *et al*., 2023; Oliveira *et al*., 2018; Sousa *et al*., 2024). Esses indicadores são fundamentais para propor um cordeiro com peso corporal mínimo de 38,0 kg, carcaça pesando acima de 17,0 kg e rendimendo médio mínimo acima de 45% (Rosas-Rodríguez *et al.*, 2022; Souza *et al*., 2016), especialmente indicando o ponto de abate, peso, classe sexual, rendimento de carcaça, acabamento de carcaça e relação músculo: osso desejáveis ao mercado (Gois *et al.*, 2018; Monteiro, Brisola e Vieira Filho, 2021). A oferta de animais com características que seguem um padrão de qualidade constitui ainda um grande desafio (Luz *et al.*, 2017), especialmente considerando a necessidade de equilibrar custos de produção e valores pagos ao produtor (Souza *et al.*, 2014).

Nos atuais sistemas de produção ovina, a demanda da agroindústria da carne concentra-se na oferta de cordeiros que apresentam peso corporal final igual ou superior a 38,0 kg, carcaça fria pesando acima de 17,0 kg e rendimento médio mínimo de 45%, sendo o rendimento ótimo para animais cruzados, como o F1 Dorper x Santa Inês próximo à 50% (Cartaxo *et al*., 2021; Pereira *et al*., 2023; Sousa *et al*., 2024; Souza *et al*., 2016). Em relação às cordeiras destinadas ao abate, a exigência produtiva é por cordeiras com peso médio corporal final igual ou superior a 35,0 kg, carcaça com peso mínimo de 16,0 kg e rendimento médio de carcaça superior a 45% (Homem Junior *et al.*, 2015; Wildeus *et al.*, 2021), sendo o rendimento ótimo próximo a 50%.

A variabilidade dos sistemas de produção (extensivo, semi-intensivo e intensivo) e a utilização de animais não especializados na produção de carne implicam em variabilidade na produção e por consequência em menor eficiência produtiva (Argyriadou *et al.*, 2022; Murphy, Freking e Bennett, 2023). Além disso, a falta de organização da cadeia, gestão ineficiente, ausência de um planejamento alimentar, financeiro e a baixa utilização de ferramentas tecnológicas apropriadas para cada tipo de sistema utilizado (Costa *et al.*, 2007; Santos e Julião, 2020).

A oscilação na oferta da carne é um problema geralmente associado à má apresentação do produto, seja pela textura indesejada ou excesso de gordura que dificulta o atendimento da demanda do mercado (Brand *et al.*, 2018), especialmente por conta da utilização de animais mais velhos, com maior deposição de gordura na carcaça (Brand *et al*. 2018; Van Der Merwe *et al*. 2020), reduzindo a qualidade em termos de perfil nutricional e químico.

Por sua vez, essa oscilação permite uma compreensão abrangente e focada sobre a dinâmica da oferta de cordeiros para os frigoríficos, essenciais para a maximização da produtividade e da sustentabilidade da indústria ovina (Monteiro, Brisola e Vieira Filho, 2021; Santos *et al.*, 2023). Além disso, a literatura discute que a carne de cordeiro possui perfil nutricional, quantitativo e qualitativo para para satisfazer as exigências da agroindústria (Facciolongo *et al.*, 2018; Senegalhe *et al.*, 2014). Uma vez que, se caracteriza por apresentar carne macia, de sabor suave, odor agradável e menor deposição de gordura (Cartaxo *et al.*, 2017; Zeola *et al.*, 2021).

2.2 Padrão de ovinos para terminação em confinamento

O peso, escore de condição corporal e a idade ideal para o início e fim da terminação em confinamento variam em função da raça, sexo e sistema de produção (Brand *et al*., 2018, Van der Merwe, Brand e Hoffman, 2020). Considerando as raças Santa Inês, Dorper e seus cruzamentos os ovinos são desmamados entre 75 e 90 dias de idade, variando de 18 a 20 kg (Cartaxo *et al.*, 2017) e pesos vivos ao abate variando de 30,0 a 43,0 kg, para evitar que as carcaças sejam classificadas como excessivamente gordas (Brand *et al.*, 2017; Gallo *et al.*, 2014). Entretanto, para cordeiros o peso corporal final considerado ideal é de no mínimo 38,0 kg (Cartaxo *et al.*, 2021), enquanto que para fêmeas o peso corporal é de 35,0 kg (Homem Junior *et al.*, 2015).

Ao avaliar o impacto da introdução da raça Dorper no desempenho zootécnico, eficiência alimentar, características de carcaça e qualidade da carne de cordeiros Santa Inês, criados em sistema intensivo no semiárido brasileiro, Souza *et al*. (2016), relataram que o ponto ideal para o abate ocorre quando a espessura de gordura é de, no mínimo, 3 milímetros, resultando em pesos corporais finais de 30,3 kg, 36,8 kg e 36,7 kg para os grupos genéticos Santa Inês, ½ Dorper e Santa Inês, e ¾ Dorper e Santa Inês, respectivamente.

Esse estudo reforça a precocidade da raça Dorper, refletindo em melhor eficiência alimentar e maior desempenho (Cloete *et al.*, 2007). Além disso, esses resultados destacam não apenas a viabilidade, mais também a vantagem econômica, devido principalmente ao maior ganho diário (233,8 g/dia), maior ingestão de matéria seca (1102,5 g/dia), maior conversão alimentar (4,8) dos cordeiros Dorper, além de atingirem a espessura de gordura mais rápido (132 dias de idade) (Souza *et al*. 2016).

Nesse contexto, além da raça, a classe sexual, que inclui machos não castrados, castrados e fêmeas, exerce grande influência no desempenho produtivo e na qualidade da carcaça, sendo as fêmeas mais precoce na deposição de gordura (Wildeus *et al*. 2021; Prache et *al*. 2022). Essa influência é observada em diversos aspectos, incluindo ganho médio diário de peso para machos (341,33 g/dia) em comparação as fêmeas (266,33 g/dia), rendimento do lombo, com fêmeas apresentando superioridade (13,4% e 11,9%) em relação a machos, rendimento verdadeiro para machos não castrado e no caso das fêmeas estas apresentam maior escore de condição corporal (3,30), percentual de gordura, espessura de gordura subcutânea (4,5 mm e 2,2 mm) e concentração de extrato etéreo (Homem Junior *et al*., 2015; Macedo Junior *et al*., 2019) Para os autores essas diferenças para machos e fêmeas podem ser explicadas pelo dimorfismo sexual que modifica a estrutura corporal e prepara as fêmeas para reprodução.

O escore de condição corporal é uma ferramenta fundamental dentro de um sistema de produção ovina, pois permite monitorar o balanço energético das ovelhas, as variações das reservas corporais, além de conhecer a relação entre o peso das cordeiras as taxas produtivas e reprodutivas dos rebanhos comerciais (Cannas e Boe, 2003; Corner-Thomas *et al.*, 2015). A raça Santa Inês e o genótipo ½ Dorper x ½ Santa Inês apresentaram escore de condição corporal de 2,5 como critério para entrada no confinamento, a conversão alimentar resultou na média de 3,62, com dez dia a menos no confinamento em comparação aqueles abatidos com escore entre 4,0 e 5,0, porém, animais excessivamente gordos, com escore corporal variando de 4,0 a 5,0 apresentam maior deposição de gordura, depreciando o rendimento de carcaça, além de aumentar o tempo de confinamento e os custos de produção (Cartaxo *et al.*, 2008).

Para os aspectos sanitários, são necessários cuidados além da nutrição com o uso de medidas de controle e prevenção de doenças na propriedade com vistas a assegurar a qualidade do produto, redução dos custos de produção e a saúde do animal (Fox *et al.*, 2018). Nesse sentido, as doenças parasitárias causadas principalmente por nematoides são as principais limitantes na produção ovina, causam perdas econômicas significativas devido a redução no ganho de peso, consumo de ração, produção de lã e rendimento de carcaça (Albuquerque *et al.*, 2023; Erez *et al.*, 2023). Adicionalmente a isso, a vacinação contra doenças comuns, como clostridioses e pneumonia e a utilização de anti-helmínticos para o controle de parasitas gastrointestinais são medidas essenciais para garantir a eficiência produtiva (Erez *et al.*, 2023; Soares *et al.*, 2023).

Nesse sentido, é recomendável o uso do método Famacha, técnicas laboratoriais, como a contagem de ovos por fezes, cultivos de larvas e o exame clinico realizado no animal no controle de parasitas gastrointestinais e ectoparasitas para evitar perdas econômicas decorrentes da infestação parasitária (Moreira *et al.*, 2021; Rodrigues *et al.*, 2023).

2.3 Estratégias de manejo alimentar para o incremento da eficiência alimentar e desempenho produtivo de ovinos

Em um sistema de terminação de ovinos, diversos são os tipos de dietas utilizadas para intensificar o sistema de produção, otimizar a eficiência alimentar e o desempenho produtivo do rebanho (Van Der Merwe, Brand e Hoffman, 2020; Wu *et al.*, 2021). Entre as dietas comumente utilizadas estão as concentradas proteicas e concentradas energéticas, variando quanto a densidade energética e a relação volumoso/concentrado (Rocha *et al.*, 2016; Sánchez-Zárate *et al.*, 2022).

Estas dietas são amplamente utilizadas para terminação de cordeiros em confinamento (Van der Merwe, Brand e Hoffman, 2020; Van de Vyver, Beukes e Meeske, 2013), pois apresentam maior ganho de peso médio diário, menor tempo de confinamento, maior peso de carcaça, maiores espessuras de gordura dorsal e parede corporal, pontuações de marmoreio do lombo, rendimento dos cortes, maior peso corporal final e peso corporal total do trato digestivo, além de maior eficiência no crescimento animal, equilíbrio do peso de abate com a quantidade de gordura e melhorias significativa de conversão alimentar (Gallo *et al.*, 2014; Jaborek *et al.*, 2017).

Ao estudar os efeitos da inoculação do Lentilactobacillus buchneri (L. buchneri) e do tempo de armazenamento da silagem de milho flint sobre os parâmetros nutricionais, fermentativos e de desempenho de cordeiros F1 Dorper x Santa Inês, verificou-se para o desempenho dos cordeiros que houve interação entre a inoculação e o tempo de armazenamento, com aumento significativo do ganho de peso médio diário (0,216 g/dia para 0,238 g/dia), melhoria na eficiência alimentar dos animais alimentados com silagem armazenada por mais tempo, além disso cordeiros alimentados com silagem inoculada por 120 dias apresentaram maior ingestão de matéria seca, proteína e amido (Rossi *et al.*, 2023). Esse trabalho mostra que a utilização de grupos genéticos especializado para produção de carne combinado a estratégias nutricionais atendem as demandas de carcaças exigidas pela indústria ovina.

O sucesso da atividade ovina é dependente de diversos fatores que incluem grupo genéticos especializado na produção de carne, sistemas de produção, planejamento do produtor, oferta, padronização da carcaça (Brand *et al.*, 2017; Kenyon, Maloney e Blache, 2014; Santos *et al.*, 2023), além de dietas concentradas, rentabilidade econômica e a otimização do tempo de confinamento (Barros *et al.*, 2009; Fourie, Vos e Abiola, 2009; Gallo *et al.*, 2014).

Nesse contexto, as dietas de alto concentrado (DAC) constituem estratégia alimentar fundamental para os sistemas de terminação ovina (Arruda *et al.*, 2021; Carlis *et al.*, 2021; Majdoub-Mathlouthi *et al.*, 2013). Esse tipo de dieta é constituído basicamente por grãos, que incluem milho, aveia, cevada (Bernardes *et al.*, 2015; Wang *et al.*, 2022) e farelos, como a soja, milho e algodão (Beretta *et al.*, 2020; Lopes *et al.*, 2025; Nascimento *et al.*, 2020), além do pelete um complexo de proteína, minerais e vitaminas (Lin *et al.*, 2021; Trabi *et al.*, 2019; Xue *et al.*, 2021). Se constitui em formular e fornecer esses ingredientes dietéticos, ricos em nutrientes solúveis, buscando a melhoria da eficiência alimentar, otimização dos índices de produção, parâmetros quantitativos e qualitativos das carcaças, ganho de peso, conversão alimentar e aumento da gordura intramuscular (Beretta *et al.*, 2020; Pereira *et al.*, 2023; Wang *et al.*, 2022), além de melhorar as características da carne como pH, textura, cor e composição nutricional (Bezerra *et al.*, 2016; Mateo *et al.*, 2018).

Apesar dessas vantagens, o fornecimento da DAC merece cautela, uma vez que são conhecidas por alterar significativamente a composição da microbiota, fermentação ruminal devido à grande quantidade de carboidratos solúveis (Hall, 2013; Hall, Larson e Wilcox, 2010), que favorece principalmente a queda do pH ruminal, resultando em distúrbios metabólicos como acidose ruminal, timpanismo, cetose, lipidose hepática e laminite (Van Cleef *et al.*, 2009; Xue *et al.*, 2021). Adicionalmente a isso, esse tipo de dieta quando utilizda sem um devido controle pode causar lesões nas células da mucosa do tratogastrointestinal (Zhong *et al.*, 2022). Dessa forma, com vistas a reduzir os problemas metabólicos do animal e seu desempenho produtivo, recomenda-se seguir os protocolos de adaptação a dieta (Morais, Camargo e Morais, 2024).

A DAC pode ser caracterizada de três maneiras distintas, dietas com baixa inclusão de volumoso, dieta com inclusão de 100% de concentrado e dieta de alto grão associada ao núcleo mineralizado peletizado. Por outro lado, a apresentação dessa dieta ocorre da seguinte forma: DAC tipo 1: baixa proporção volumoso: concentrado, 20:80; DAC tipo 2: 100% da inclusão de concentrado e DAC tipo 3: dieta de alto grão na forma padrão: pélete + grão inteiro (Rogério *et al.*, 2018).

Esse tipo de dieta é uma estratégia de apoio no período de confinamento, pois permite ganho médio diário de peso de 0,284 kg, com escore de condição corporal de 3,30, maior índice de produtividade, aliado a eficiência alimentar, uniformidade de desempenho, reduz o tempo de permanência do animal em confinamento, com maior desempenho de carcaça (Araújo Filho *et al.*, 2019; Gallo *et al.*, 2014; Pereira *et al.*, 2023). A DAC também promove maior rendimento de carcaça fria (54,28% e 52,72%), melhoria na eficiência alimentar (0,22 e 0,18), além de maior deposição de gordura (4,31 mm e 3,74 mm) e área de olho de lombo (18,04 cm^2 e 18,17 cm^2) quando comparado ao grupo de animais submetido a dieta convencional (Vicente *et al.*, 2022). Para esses autores dietas ricas em concentrado quando bem manejada, especialmente se adicionada um tamponante como bicarbonato de sódio podem ser utilizadas sem maiores prejuízos à saúde ruminal.

Considerando os fatores que influenciam o consumo de matéria seca em ovinos ao longo do confinamento, deve-se considerar os fatores físicos, neuroendócrino, hormonais, tamanho de partícula e consumo e a relação volumoso/concentrado (Miranda *et al.*, 2024). Dentre estes, uma atenção deve ser dada à regulação do consumo influenciada pelos hormônios neuropeptídeo y e leptina. Especialmente pelo fato de a leptina ser um hormônio produzido pelos adipócitos, com o aumento do peso e do escore de condição corporal ao longo do período de terminação ocorre uma redução da ingestão de alimentos (Altmann, Sauerwein e Von Borell, 2006; Ingvartsen e Boisclair, 2001).

Ao investigar a relação entre o escore de condição corporal e a produção do hormônio Leptina Catunda *et al*. (2013) e Młynek e Głowińska, (2020) encontraram uma correlação positiva tanto para ovinos quanto bovinos, onde maior o escore de condição corporal desses animais maior é a produção da leptina. Esses achados reforçam a importância de se conhecer os mecanismos regulatórios desse hormônio.

2.4 Características de carcaça de ovinos terminados em confinamento

A carcaça demanda pelo mercado e indústria da carne ovina é aquela que em sua composição, apresenta maior proporção de músculo, máximo rendimento, melhor grau de acabamento, conformação e rendimento dos cortes (Vicente *et al.*, 2022). O cordeiro que produz esse tipo de cacaça apresenta um peso corporal ao abate igual ou superior à 38,0 kg, carcaça acima de 17,0 kg e rendimentos de carcaças superiores a 45% (Cartaxo *et al.*, 2021). Em países como a África do Sul esse tipo de carcaça é classificada como A2, sendo muito valorizada pela indústria da carne (Brand *et al*., 2018; Van Der Merwe; Brand; Hoffman, 2020b).

Entretanto, para conseguir esse tipo de carcaça, estratégias de manejo e nutrição devem ser utilizadas para otimização da eficiência produtiva dos ovinos (Ferreira *et al.*, 2011). Além disso, a escolha do sistema de produção é um fator decisivo para otimizar a viabilidade econômica (Van Der Merwe *et al*., 2020; Pereira *et al*., 2023). Entre as opções existem o confinamento, os sistemas semi-intensivo e o extensivo, cada um com suas particularidades e impactos no manejo, custos e produtividade (Barros *et al.*, 2009; Pereira-Junior *et al.*, 2024; Silva *et al.*, 2021).

Com foco em orientar o produtor sobre quanto tempo devem engordar seus cordeiros para atingir a maior rentabilidade da carcaça de três raças ovinas, Brand *et al*. (2017), verificaram aumento significativo de gordura na carcaça com aumento da idade e com isso reduziu a porcentagem de músculo e osso em todas as raças, a classificação da carcaça mudou ao longo do confinamento. Por exemplo, as carcaças de cordeiros Merino começaram a ser classificada como obesa após 77 dias, os cordeiros Dorper apresentaram altos níveis de gordura subcutânea após 42 dias, atingindo 5,6 mm de gordura, devido sobretudo a maturação precoce da raça (Brand *et al*., 2017). Esse estudo mostra que o tempo de confinamento influência fortemente a composição da carcaça e que as raças apresentam padrões diferentes de deposição de gordura na carcaça.

Em sistema de terminação em confinamento, Pereira *et al*. (2019), obtiveram o peso médio de carcaça quente de 17,3 kg, carcaça fria de 17,1 kg, rendimento de carcaça comercial de 43,1%, além de maiores rendimento dos cortes comerciais como a paleta, pernil e lombo à medida que aumentou o nível de inclusão da quitosana (modulador da fermentação ruminal) na dieta de cordeiros ½ Dorper x ½ Santa Inês.

Os rendimentos das carcaças são fundamentais em um sistema de terminação de cordeiros, uma vez que são responsáveis por aumentar a produtividade e a lucratividade do produtor (Cartaxo *et al.*, 2021; Pereira *et al.*, 2023). Entretanto, sua rentabilidade perpassa por fatores fundamentais, que incluem o nível de musculosidade, gordura visceral, renal e subcutânea na carcaça. Nesse sentido, é fundamental conhecer as características de crescimento e a capacidade de deposição de gordura de cada raça, a fim de determinar o período e o peso ideal para abate (Brand *et al*., 2017). Adicionalmente a isso, para indústria frigorífica uma carcaça bem acabada é classificada como A2, com peso aproximado de 17,2 kg, sendo mais valorizada financeiramente pelo mercado (Brand *et al.*, 2018).

A indústria ovina é composta por diversas raças e suas aptidões, sejam elas voltadas para produção de carne, lã, dupla aptidão de maturidade precoce ou tardia (Brand *et al*., 2018; Van der Merwe *et al*., 2020). A raça Dorper especializada na produção de carne, exibe boas características de crescimento com uma conformação mais arredondada e maturidade precoce, além de adaptar-se bem em diferentes regiões (Van Der Merwe, Brand e Hoffman, 2020; Ocak, Ogun e Yilmaz, 2016). Por sua vez, a raça Santa Inês apresenta boa habilidade materna, maior taxa produtiva, reprodutiva, sem anestro sazonal e é considerada uma raça para linha materna (Ribeiro e González-García, 2016).

Além dessas raças, outra alternativa para produzir cordeiros de forma produtiva e eficiente que atenda as demandas da agroindústria é o cruzamento entre raças localmente adaptadas com reprodutores especializado para produção de carne, pois favorece a precocidade e o desempenho produtivo (Dias Junior *et al.*, 2022; Pereira *et al.*, 2022). Nesse sentido, mestiços de Dorper com Santa Inês são os mais utilizados, pois alcançam maior escore de condição corporal final, sendo suas carcaças as que apresentaram maiores rendimentos dos cortes comerciais, conformação de carcaça, acabamento e área de olho de lombo (Brant *et al.*, 2021; Cartaxo *et al.*, 2017).

Cordeiros com carcaças mais pesadas tendem a ser mais valorizados no mercado, devido sua maior deposição de músculo e acúmulo de gordura intramuscular (Brand *et al*., 2018). Porém o peso por si só não é determinante da qualidade da carne, o ganho de peso na terminação não se restringe somente ao fator financeiro, ele otimiza a musculatura, distribuição de gordura, ofertando assim, carne de melhor qualidade em termos de sabor e maciez (Nascimento *et al.*, 2018; Sousa *et al.*, 2024).

No aspecto rendimento de carcaça para a espécie ovina, a agroindústria tem identificado uma grande variação no rendimento, 40% a próximo de 51% do peso da carcaça (Abouheif *et al.*, 2013; Sousa *et al.*, 2024). Contudo, o desejado é que os rendimentos sejam superiores a 46% (Silva Filho *et al.*, 2021), porém isso é influenciado por fatores como grupo genético, idade, condição corporal, manejo nutricional, sexo, sistemas explorados e conformação do animal (Dias Junior *et al.*, 2024; Pereira *et al.*, 2023; Silva Filho *et al.*, 2021).

Em relação as raças ovinas, a variabilidade no rendimento de carcaça acentua-se especialmente em função da diferença entre os grupos genéticos (Silva Filho *et al*., 2021; Pereira *et al*., 2023). Dessa forma, cordeiros F1 Dorper x Santa Inês alimentados com dietas de alto concentrado apresentam maiores valores médios para o peso de carcaça, maior deposição de músculo e acabamento de cacaça quando comparado a raça Santa Inês (Santos et al., 2020; Sousa et al., 2019).

O grau de acabamento está diretamente relacionado a deposição total de gordura e músculo na carcaça, sendo desejável uma faixa de peso para que se encontre maior grau de acabamento (Brand *et al*., 2018). Em cordeiros Ile de France por exemplo, esse peso foi de 32 kg de peso corporal, enquanto que para para a raça Santa Inês foi de 30 kg (Fernandes Júnior *et al.*, 2015; Moreno *et al.*, 2010), para cordeiros ½ Dorper x Santa Inês e ¾ Dorper x Santa Inês, esses foram abatidos quando atingiram o peso médio de 36,8, 36,7 kg de peso vivo com espessura de gordura subcutânea de 3,1 e 3,3 mm respectivamente (Souza *et al.*, 2016). Por sua vez, Santos *et al*. (2020), recomendaram o peso e a idade média ao abate de 42,81 kg de peso vivo e 159 dias para os cordeiros ½ Dorper x ½ Santa Inês para atingirem 3,0 mm de espessura de gordura.

O termo acabamento de carcaça refere-se à sua estrutura física, incluindo a musculosidade, osso e gordura, os quais desempenham um papel fundamental no peso médio da carcaça e rendimento dos cortes comerciais, especialmente da paleta, pernil e costilhar (Alves *et al.*, 2020). Em relação ao percentual de gordura na carcaça essa aumenta conforme a idade do cordeiro avança (Brand *et al*., 2017; Van Der Merwe *et al*., 2020), além de influenciar o perfil lipídico e o colesterol da carne (Lopes *et al.*, 2023). O grau de conformação é expresso em escores de 1 a 5, uma medida subjetiva que varia de ruim a excelente e tem impacto nas avaliações visuais da carcaça, por exemplo uma carcaça bem conformada aumenta as expectativas do consumidor de que há cortes nobres e com isso aumenta seu valor comercial, no entanto, o excesso de gordura deprecia a carcaça e reduz seu valor de mercado (Brand *et al*., 2017; Van Der Merwe *et al*., 2020).

O rendimento dos cortes comerciais é um fator fundamental na produção de cordeiros para abate e é fortemente influenciado pelo grupo genético (Silva *et al.*, 2023; Vicente *et al.*, 2022), condições climáticas e alimentação (Gois *et al.*, 2019; Polli *et al.*, 2019). Esse rendimento refere-se à proporção de carne de qualidade obtida a partir da carcaça do animal após desossa e varia conforme a idade do animal, peso e proporção de gordura (Carvalho *et al.*, 2016; Sousa *et al.*, 2024).

Carcaças bem conformadas tem melhor rendimento de cortes, especialmente pernil e paleta (Costa *et al.*, 2023). O grau de acabamento contribui com a suculência da carne, contudo, o excesso de gordura pode reduzir o rendimento de músculo (Brand *et al.*, 2017, 2018). A idade ao abate está relacionada com a maciez da carne (animais jovens tendem a ter carne mais macia e com menor deposição de gordura) (Brand *et al*., 2018). O peso ao abate é um indicativo de maior rendimento dos cortes, por exemplo, o músculo da paleta aumentou em cordeiros abatidos com pesos variando entre 16 a 25 kg em comparação à cordeiros abatidos com pesos entre 36 a 45 kg (Alves *et al.*, 2020). A padronização dos cortes e a técnica de desossa otimizam o aproveitamento da carcaça, o manejo pré-abate que inclui transporte, jejum e manipulação que afetam diretamente a qualidade da carne.

2.5 Análise de custos e rentabilidade do confinamento de ovinos

Em sistema de terminação intensiva é comum a utilização de dietas com elevada proporção de concentrado para garantir maior desempenho animal, entretanto, há um aumento significativo dos custos de produção, sobretudo dos preços dos insumos (Alves *et al*., 2024; Van Der Merwe, Brand e Hoffman, 2020).

Assim, conhecer os custos de produção, rentabilidade e a viabilidade econômico-financeira de um sistema de produção é crucial para analisar a composição dos custos através de indicadores econômicos e financeiros (Guiducci *et al.*, 2012).

Entre os indicadores econômicos comumente utilizados estão a Receita Total (RT), Custo Operacional Efetivo (COE), Custo Operacional Total (COT), Custo total (CT), Margem Bruta (MB), Margem Líquida (ML), Renda líquida (RL), Renda da família (RF), Ponto de nivelamento (PN), Taxa de retorno do empreendedor (TR) e Produtividade total dos fatores (PTF), por sua vez, os indicadores financeiros são representados pelo Valor presente líquido (VPL), Valor presente líquido anualizado (VPLa), *Pay back* descontado, Taxa interna de retorno (TIR), Taxa interna de retorno modificada (TIRM), Índice de lucratividade (IL) e Taxa de rentabilidade (TR) (Guiducci *et al*. 2012).

Aliados aos indices econômicos, os índices zootécnicos, permitem ajustar os melhores manejos nutricionais, sanitários, reprodutivos e a identificar os pontos de maiores desáfios na atividade. Entre os indicadores zootécnicos destacam-se número de crias por ano, intervalo entre partos, peso ao nascimento, peso e idade à desmama, peso de abate, idade de abate, peso à primeira monta e idade ao primeiro parto (Lima *et al.*, 2018). Essas Informações são fundamentais para o planejamento estratégico do produtor, pois permitem identificar os entraves técnicos e financeiros da propriedade (Rodrigues *et al.*, 2023). Além disso, contribuem diretamente para aprimorar o manejo nutricional e reprodutivo, promovendo um melhor desempenho produtivo, reprodutivo e econômico da atividade (Borges *et al.*, 2019; Rezende *et al.*, 2020), além de avaliar a eficiência produtiva das matrizes quanto ao tipo de parto (simples e múltiplos) e identificar a prolificidade da ovelha (Costa *et al.*, 2022).

Na intensificação do sistema de produção de ovinos, a terminação em confinamento é uma estratégia fundamental para aumentar a produtividade (Brand *et al*., 2017). Essa ferramenta reduz a pressão de pastejo, o tempo de confinamento, a ocorrência de verminose e aumenta os parâmetros qualitativos e quantitativos da carcaça (Cartaxo *et al.*, 2017, 2018), contudo, apresenta custos adicionais, como a construção de infraestrutura (galpão, comedouro, bebedouros, cercas e balanças), custos mão de obra, produção de volumoso, concentrados e sal mineralizado (Maia, 2024). Esses itens compõe os custos de produção e contribuem significativamente para o aumento das despesas. Dessa forma, o gerenciamento dos custos da atividade ovina, a análise dos indicadores econômicos e financeiros são estratégias importantes para aumentar a rentabilidade e o monitoramento da eficiência do sistema de produção (Alves *et al*., 2024; Silva *et al*., 2021).

Nesse sentido, Alves *et al*. (2024) avaliaram diferentes planos nutricionais, comparando dietas sem redução (D0) e com redução de 15% (D15) de nutrientes digestíveis totais e proteína bruta. Esses autores identificaram que os maiores custos estavam associados à alimentação, com uma participação de 31,20% para machos alimentados com a dieta reduzida, enquanto para fêmeas, a média foi de 28,85%. Além disso, destacaram que outros custos, especialmente relacionados à compra de animais, representaram mais de 36% dos gastos tanto para machos (36.43%) quanto para fêmeas (37.79%) submetidos às dietas com redução de nutrientes. Os resultados também indicaram que machos e fêmeas alimentados com a dieta sem redução de nutrientes (D0) resultaram em maior receita total quando comparados aos ovinos do mesmo sexo alimentados com a dieta reduzida (D15). No entanto, as dietas com redução de nutrientes (D15) resultaram em menores custos de alimentação e menores custos totais, enquanto o maior custo da dieta sem redução (D0) foi atribuído especialmente ao maior uso de concentrado (Alves *et al*., 2024).

Por sua vez, Santos et al. (2022) também avaliaram a viabilidade econômica do uso de dietas controle (100% da recomendação do NRC (2007)), alto nível energético (110% de energia metabolizável por kg de matéria seca ingerida associada ao propionato de cromo), baixo nível energético (90% de energia metabolizável por kg de matéria seca ingerida), gordura (dieta alto nível energético associada a sais de cálcio de óleo de palma) na dieta de ovelhas na fase final de gestação e final de lactação constataram que animais alimentados com dietas com baixo nível energético obtiveram o menor custo variável (U$$ 51.226,22), custo total (U$$ 54.567,02), e custo por kg/animal produzido (U$$ 1,32). Esses autores sugerem ainda que as ovelhas alimentadas com dietas de maior nível energético associado com propionato de cromo os custos variáveis foram equivalentes (U$$ 104,368.66 e U$$ 107,336.61), custos totais (U$$107,709.46 e 110,677.41) e custos médios (U$$ 1,64 e U$$ 1,54, respectivamente). Adicionalmente a disso, as dietas com maior nível energético combinado ao propionato de cromo obtiverem o melhor valor presente líquido (U$$ 104,902.05), taxa interna de retorno (13,65% ao ano) e payback simples (101º mês) e esta foi seguida da dieta com maior densidade energética, cujo o valor presente líquido correspondeu a U$$ 64,894.11, taxa interna de retorno de 9,03% ao ano com payback simples no 113º mês (Santos *et al.*, 2022).

A atividade pecuária assim como outras atividades está sujeita a instabilidade de mercado, porém, um planejamento estratégico pode otimizar os índices econômicos, produtivos e zootécnicos, contribuindo significativamente para diluir os custos aumentar a eficiência, lucratividade e a produção animal (Bóscollo *et al.*, 2022). O aumento das receitas totais permite investimentos adicionais por parte do produtor e pode otimizar os índices técnicos da propriedade (Gomes *et al.*, 2018).

Pesquisas tem discutido a viabilidade econômico-financeira da substituição parcial do milho por farelo de biscoito em dietas para cordeiros em confinamento, Silva *et al*. (2021a) observaram aumento no ganho de peso médio diário á medida que aumentou o nível de inclusão do farelo de biscoito na dieta de cordeiros, variando de 173 g/dia para 0% até 204 g/dia para 45% de inclusão. O consumo de matéria seca também foi maior com a adição do farelo de biscoito, além disso, o rendimento de carcaça não foi comprometido. Quando analisado os custos e as receitas verificou-se que a alimentação, aquisição dos animais e a mão de obra foram os itens de maior participação na composição dos custos. A dieta com 15% de inclusão do farelo de biscoito apresentou maior custo com alimentação (R$ 27.090,45/ano), entretanto, resultou em maior receita (R$ 103.194,00/ano) e a maior renda líquida (R$ 20.747,80/ano), adicionalmente a isso, os indicadores econômicos mostraram viabilidade econômico-financeira para todas as dietas e cenários avaliados, ou seja, em todos os cenários analisados as receitas foram superiores aos custos. Esse trabalho reforça a importância de se conhecer os itens de maior composição nos custos, além de verificar a viabilidade econômico-financeira do sistema de produção ovino.

A produção de ovinos em confinamento pode ser uma atividade rentável e sustentável, mas sua viabilidade econômica depende de vários fatores que devem ser cuidadosamente considerados (Rojas-Moreno *et al.*, 2022). A rentabilidade da ovinocultura em confinamento está associada especialmente a aspectos como preço da carne pago ao produtor e pelo consumidor, hábito de consumir carne ovina, alimentação e manejo nutricional do rebanho, custo de produção, especialmente custo do cordeiro à desmama e tempo de confinamento (Alves *et al*., 2024; Van Der Merwe, Brand e Hoffman, 2020; Tupy, Esteves e Brito, 2018).

A otimização do desempenho econômico na produção cordeiros envolve a integração de fatores como genótipos, custos e sistemas de produção (Rojas-Moreno *et al.*, 2022; Silva Filho *et al.,* 2021). Nesse contexto, o cruzamento da raça Dorper com Santa Inês melhora a conversão alimentar e aumenta a margem de lucro do sistema de produção quando comparado o cruzamento da raça Santa Inês com animais sem um padrão racial definido e alimentado com dietas com baixa densidade energética (2,40 Mcal de energia metabolizável por kg de matéria seca). Por sua vez, dietas com maior densidade energética (2,90 Mcal) são indicadas para terminação de cordeiros em confinamento, pois resulta em maior ganho de peso corporal, aumenta a condição corporal e reduz o tempo de permanência dos animais em confinamento (Sousa *et al.*, 2012). Esses resultados destacam a importância de considerar tanto o genótipo, custo de produção, quanto a dieta em sistemas de produção visando otimizar o desempenho econômico na produção de cordeiros.

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CAPÍTULO II

(Small Ruminant Research)

Performance and Carcass Characteristics of Lambs Fed Finishing Diets

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Abstract

The objective of this study was to evaluate the growth performance and carcass yield of meat sheep fed high-concentrate finishing diets, aiming to meet agribusiness quality standards. Diet had a significant effect on final body weight (FBW), total average weight gain (TAWG), and total weight gain (TWG), with the CD and NRCD diets outperforming the HGD diet, while not differing from each other. Males showed superior performance compared to females, except for initial body condition score (IBCS) and final body condition score (FBCS). A significant effect of genotype × sex interaction was observed on estimated body condition score (BCS), with females presenting higher final scores. Regarding estimated weight gain, animals fed the CD and NRCD diets achieved greater gains than those fed HGD; males also outperformed females. For average daily weight gain (ADG), both diet and sex effects were observed, with higher values recorded for animals receiving CD and NRCD and for males. Adjusted means for BCS revealed a significant effect of diet × time interaction, with sheep fed CD and NRCD exhibiting higher BCS. Concerning genotype, F1 Dorper × Santa Inês animals showed higher BCS values. The CD diet did not differ from HGD in terms of hot carcass yield (HCY) and cold carcass yield (CCY), but was superior to NRCD for these variables. Males had higher slaughter body weight (SBW), hot carcass weight (HCW), and cold carcass weight (CCW), whereas females exhibited higher HCY and CCY. It can be concluded that Santa Inês and F1 Dorper × Santa Inês sheep fed the CD diet, regardless of sex, demonstrate performance and carcass yield consistent with agribusiness standards.

Keywords: Body Condition Score; Weight Gain; Slaughter Weight; Carcass Yield.

Introduction

Sheep production has faced multiple challenges with direct impacts on supply, productivity, and the quality of meat products derived from this chain. Market informality and the lack of strategic planning among producers remain major constraints to the sector (Monteiro et al., 2021; Sorio and Rasi, 2010).

These limitations are even more pronounced when considering lambs originating from traditional ewe-lamb and growing systems in Northeastern Brazil, particularly during the dry season (Moura et al., 2023). The primary feed resource, native pasture from the Caatinga biome, becomes scarce, and strategic forage reserves are generally not adopted (Voltolini et al., 2019). As a result, lambs often exhibit low weaning weights (below the minimum required for commercial finishing), reduced efficiency, and low carcass quality (Albuquerque et al., 2009).

High-concentrate diets, which provide nutrients at greater density and quality, represent an effective strategy to enhance average body weight gain, including the exploitation of compensatory growth to shorten the feedlot period (Bernardes et al., 2015). In addition, the use of genetic groups specialized for meat production and responsive to such diets is essential. This approach enables producers to achieve market standards for meat and carcass traits while maintaining economic viability (Albuquerque et al., 2009; Cartaxo et al., 2011; Oliveira et al., 2018; Venturini et al., 2016).

The feedlot finishing of ewe lambs also represents a viable zootechnical and economic alternative (H. P. Santos et al., 2020). Among strategies to optimize herd utilization, the use of ewe lambs not retained for replacement has gained attention, as these animals can be directed toward meat production (Lopes et al., 2025). In many production systems, the replacement rate of breeding females is lower than the number of weaned females, generating a surplus that, when properly managed, can become an additional source of revenue (Silva, 2023). Furthermore, slaughtering ewe lambs can yield carcasses comparable in quality to those of ram lambs, characterized by tender meat and mild (Bonacina et al., 2011a; Homem Junior et al., 2015), traits highly valued by consumers.

Feedlot systems provide conditions conducive to rapid and efficient weight gain by ensuring balanced diets and environmental control, thereby minimizing the effects of climatic variability and nutritional limitations typical of extensive systems (Gallo et al., 2014). Confinement also facilitates consignment standardization for slaughter, improving sales planning and enabling consistent delivery of carcasses that meet agribusiness specifications

(Cartaxo et al., 2021; Van Der Merwe et al., 2020a). Industry standards typically require a "standard lamb" with a body weight ≥ 38.0 kg, average cold carcass weight > 17.0 kg, and minimum carcass yield of 45%, with optimal yields approaching 50% for crossbred animals such as F1 Dorper × Santa Inês (Alves et al., 2024; Cartaxo et al., 2021; Lima et al., 2013). For ewe lambs, the recommended final body weight is ≥ 35.0 kg, with a minimum carcass weight of 16.0 kg and average carcass yield above 45% (Homem Junior et al., 2015; Wildeus et al., 2021).

Several factors influence the success of sheep finishing in feedlot systems, particularly genotype, nutritional and health management practices, body condition score, and age at slaughter (Van Der Merwe et al., 2020b). In this context, meat-specialized breeds such as Dorper and its crosses, as well as Santa Inês, have demonstrated favorable productive performance and carcass yield (Homem Junior et al., 2015; Santos et al., 2020).

Therefore, the objective of this study was to evaluate the growth performance and carcass yield of lambs from meat-specialized genetic groups finished in feedlot systems and fed high-performance diets, aiming to meet the standards required by the agribusiness sector.

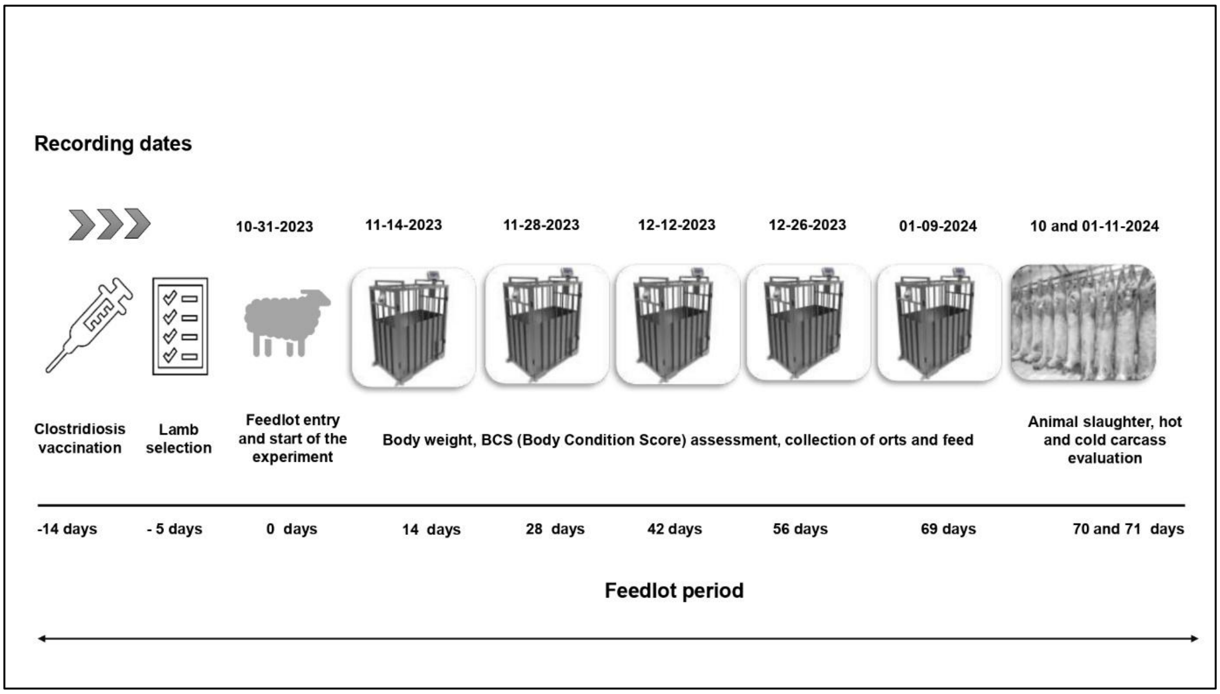
Material and Methods

Ethics Committee Approval, Location, and Experimental Period

The experiment was approved by the Ethics Animal Committee on the Use of Animals of Embrapa Goats and Sheep (CEUA/CNPC), under Protocol Nº. 003/2023.

The study was conducted at Guaiuba Agropecuária S/A, located in the town of Guaiuba, Ceará, Brazil (4°02’23” S, 38°38’14” W). The region is characterized by a tropical climate, classified as hot sub-humid to hot humid, with a mean annual temperature of 27.6 °C. The rainy season extends from January to June, and the average annual rainfall is 962.9 mm (FUNCEME, 2025).

Figure 1 Experimental activities for sheep finishing developed at Guaiuba Agropecuária during the research.

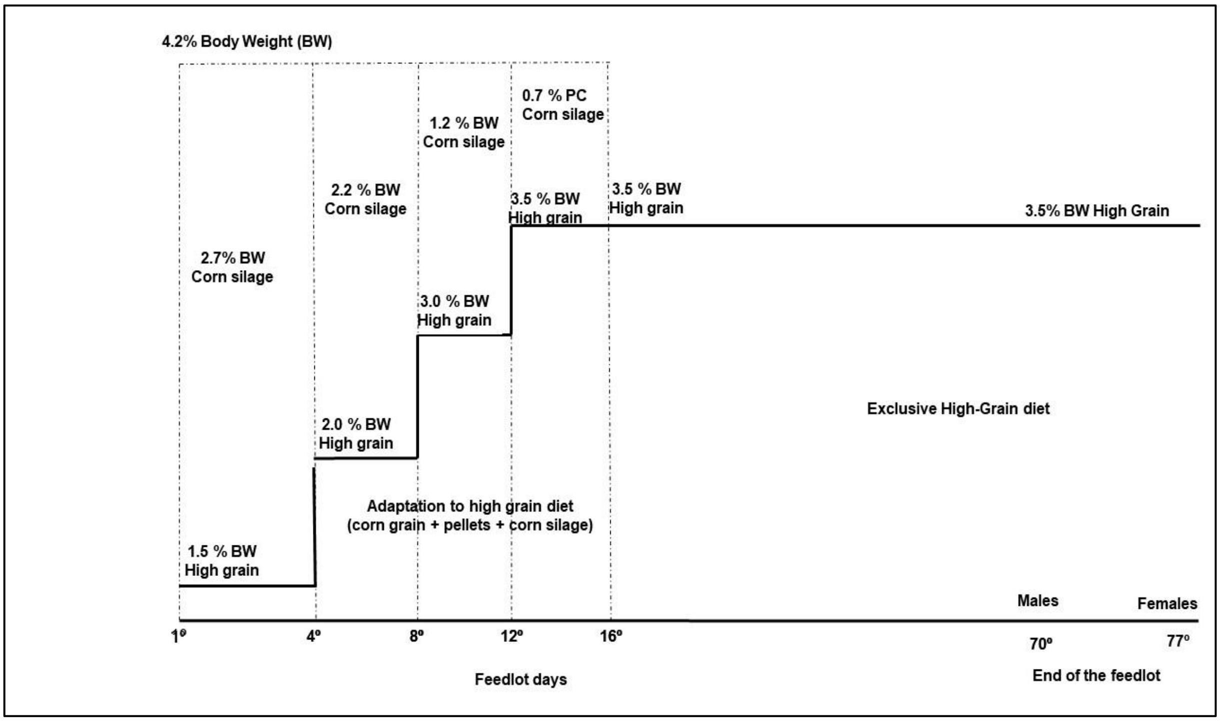


Experimental Diets

Three high-performance finishing diets were evaluated (Table 2): Control Diet (CD) – formulated with a forage-to-concentrate ratio of 40:60, and containing soybean meal, ground sorghum, mineral premix, sodium chloride, sodium bicarbonate, and corn silage. This diet was routinely used by Guaiuba Agropecuária S/A prior to the study; NRC Diet (NRCD) - formulated according to the recommendations of the National Research Council (2007) for lambs with an initial body weight of 20 kg and a targeted average daily gain of 300 g/day. The forage-to-concentrate ratio was 36.5:63.5, containing soybean meal, ground sorghum, soybean oil, mineral premix, sodium bicarbonate, and corn silage; and a High-Grain Diet (HGD) - composed of 15% commercial pelleted concentrate and 85% whole corn grain, acquired and supplied according to the technical recommendations of the manufacturer. The forage-to-concentrate ratio was 15:85 during the first 15 days and 0:100 after the adaptation period.

Animals underwent a 15-day dietary adaptation period. For the HGD treatment, a specific adaptation protocol was implemented: during the first 15 days, animals received whole corn grain, mineral premix, and corn silage. From day 16 until slaughter (70 days for males and 77 days for females), corn silage was completely withdrawn, and animals were fed exclusively whole corn grain and pelleted concentrate (Figure 2).

Figure 2 Provision of the whole grain corn, pelleted concentrate, and corn silage mixture in the sheep diet, according to the percentage of body weight during adaptation to the High Grain Diet.



Diets were offered three times daily at 07:30, 10:30, and 16:30 h. For CD and NRCD, feed was supplied to allow 5-10% leftovers (as-fed basis) per day. Water and mineral salt were provided *ad libitum*.

After each weighing, the HGD diet was adjusted to provide an average intake equivalent to 3.5% of body weight, as recommended by the manufacturer. No feed refusals were recorded for this treatment.

Animals and Experimental Design

A total of 72 weaned lambs were used, including 36 males and 36 females (18 Dorper × Santa Inês F1 crossbred and 18 Santa Inês per sex). Lambs were weaned at approximately three months of age, with an average initial body weight of 21.80 ± 0.26 kg for males and 20.68 ± 0.75 kg for females. Animals were assigned to twelve treatments with six replications per treatment, totaling 72 experimental units. A completely randomized design was adopted in a 3 × 2 × 2 factorial arrangement, consisting of three diets (CD, NRCD, and HGD), two genetic groups (Santa Inês and F1 Dorper × Santa Inês), and two sexes (male and female). All animals were individually identified with numbered ear tags, dewormed prior to the experimental period, and housed in collective pens equipped with feeders, drinkers, and mineral salt troughs.

Nutrient Intake and Physical-Chemical Analyses

To determine nutrient intake, approximately 500-g-samples of the diets offered and leftovers were collected every 14 days, except for HGD, for which no refusals occurred because feed allowance was adjusted according to body weight. Samples were identified, weighed, placed in transparent plastic bags, and stored at -10 °C until analysis.

Chemical analyses (Table 1) began with pre-drying the samples at 55 °C in a forced-air oven for 72 h. Subsequently, samples were ground in a Wiley mill to pass through a 1-mm sieve and stored in plastic containers. The following analyses were performed: dry matter (DM; AOAC, 2005, method 930.15); ash (AOAC, 2005, method 942.05); crude protein (CP; AOAC, 2005, method 984.13); and ether extract (EE), determined using a semi-automatic ANKOM XT15® extractor (ANKOM Technology Corporation, Fairport, NY, USA) according to the (OACS, 2004) procedures and Galvani and Martins (2015). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to Van Soest et al. (1991), using an autoclave procedure as described by Barbosa et al. (2015). Cellulose (CEL), hemicellulose (HCEL), and lignin (LIG) were determined following Van Soest et al. (1991). *In vitro* dry matter digestibility (IVDMD) was assessed according to Silva and Queiroz (2002). Total digestible nutrients (TDN) were estimated following Cappelle et al. (2001).

To determine physically effective fiber, the mean particle size (MPS) of feed and leftovers samples (both forage and concentrate fractions) collected during the experimental period was evaluated. Particle size distribution was assessed using the Penn State University Particle Size Separator (PSPSS; University Park, PA, USA), according to the methodology proposed by Lammers et al. (1996). The separator consists of four sieves with distinct mesh sizes: >19 mm; 19-8 mm; 8-1.18 mm; and a bottom pan (<1.18 mm). The MPS of each diet was estimated by multiplying the proportional inclusion of each ingredient in the diet by the respective particle size distribution of that ingredient and summing these values.

Intake of dry matter, organic matter, crude protein, ether extract, neutral detergent fiber, acid detergent fiber, hemicellulose, and total digestible nutrients was calculated as the difference between feed offered and leftovers. Therefore, intake data were analyzed descriptively. No inferential statistical analysis was performed because pens were not replicated, and intake was measured at the group level rather than individually.

Description of the ingredient proportion (g/kg) and chemical composition of the high-concentrate diets used for finishing lambs (Table 2).

Table 1. Chemical composition (g/kg) of ingredients used in high-concentrate diets for finishing lambs

Nutrientes	DM**	OM	CP	EE	NDF	Pef	peNDF	ADF	HCEL	CEL	IVDMD	LIG	TDN
Corn silage 1[1]	342.0	937.0	42.0	29.0	524.0	0.9	471.6	283.0	242.0	254.0	654.0	18.0	574.0
Corn silage 2[2]	270.0	942.0	72.0	37.0	582.0	0.9	523.8	351.0	228.0	274.0	719.0	46.0	620.0
Corn grain	891.0	986.0	102.0	74.0	449.0	0.4	179.6	42.0	407.0	35.0	940.0	2.0	876.0
Ground sorghum grain	903.0	989.0	96.0	22.0	252.0	0.3	75.6	34.0	218.0	1.0	900.0	1.0	843.0
Pelleted Concentrate Premix	889.0	848.0	294.0	20.0	372.0	1.0	372.0	130.0	242.0	65.0	881.0	32.0	827.0
Soybean meal	893.0	937.0	453.0	51.0	314.0	0.1	31.4	104.0	210.0	84.0	979.0	0.0	908.0
Soybean oil	1000.0	-	-	997.0	-	-	-	-	-	-	-	-	1770.0
Sodium bicarbonate[§]	990.0	136.0	-	-	-	-	-	-	-	-	-	-	-
Sodium Chloride	1000.0	-	-	-	-	-	-	-	-	-	-	-	-
Mineral Premix Containing Monensin[†]	980.0	-	-	-	-	-	-	-	-	-	-	-	-

** DM = Dry Matter; OM = Organic Matter; CP = Crude Protein; EE = Ether Extract; NDF = Neutral Detergent Fiber; Pef = Physical Effectiveness Factor; peNDF = Physically Effective Neutral Detergent Fiber; ADF = Acid Detergent Fiber; HCEL = Hemicellulose; CEL = Cellulose; LIG = Lignin; IVDMD = *In Vitro* Dry Matter Digestibility; TDN = Total Digestible Nutrients. [1] Corn silage used from October 31, 2023, to December 6, 2023. [2] Corn silage used from December 7, 2023, to January 8, 2024. [§]Cqbal 4.0. [†]Mineral premix containing monensin. Guaranteed analysis: Calcium (min/max) 200.00/250.00 g/kg; Phosphorus (min) 45.00 g/kg; Magnesium (min) 9,000 mg/kg; Potassium (min) 5,000.00 mg/kg; Sodium (min) 70.00 g/kg; Sulfur (min) 12.00 g/kg; Iron (min) 1,200.00 mg/kg; Zinc (min) 2,500.00 mg/kg; Manganese (min) 900.00 mg/kg; Iodine (min) 45.00 mg/kg; Selenium (min) 10.00 mg/kg; Cobalt (min) 50.00 mg/kg; Vitamin A (min) 100,000.00 IU/kg; Vitamin D_3 (min) 25,000.00 IU/kg; Vitamin E (min) 750.00 IU/kg; Sodium Monensin 700.00 mg/kg.

Table 2. Ingredient proportion (g/kg of feed) and chemical composition (g/kg DM) of the high-concentrate diets used for finishing lambs

Ingredient proportion (g/kg of feed)	Diets			
Ingredients	CD[1]	NRCD[2]	HGD[3]	HGD[4]
Corn silage	400.0	365.0	390.0	-
Corn grain	-	-	518.0	850.0
Ground sorghum grain	444.0	502.0	-	-
Soybean meal	123.0	92.0	-	-
Soybean oil	-	22.0	-	-
Sodium bicarbonate	6.0	9.5	-	-
Pelleted Concentrate Premix	-	-	92.0	150.0
Mineral Premix Containing Monensin	24.0	9.5	-	-
Sodium Chloride	3.0	-	-	-
Total	1000	1000	1000	1000
Chemical composition (g/kg DM)	CD	NRCD	HGD	HGD
Dry matter	667.0	689.0	664.0	891.0
Organic matter	931.0	927.0	957.0	968.0
Crude protein	122.0	111.0	103.0	131.0
Ether extract	30.0	50.0	26.0	22.0
Neutral detergent fiber	364.0	350.0	475.0	437.0
peNDF[5]	230.0	215.0	320.0	208.0
fNDF[6]	210.0	191.0	204.0	0.0
Acid detergent fiber	148.0	136.0	147.0	48.0
Hemicellulose	216.0	214.0	328.0	389.0
Cellulose	115.0	103.0	108.0	11.0
Lignin	12.0	11.0	14.0	6.0
Total carbohydrates	780.0	766.0	828.0	815.0
Total digestible nutrients*	828.5	792.0	0.0	754.0
IVDMD**	793.0	791.0	834.0	931.0

[1]CD - Control Diet; [2]NRCD - Diet formulated according to NRC (2007); [3]HGD - Commercial High-Grain Diet (corn grain plus pelleted concentrate premix) - adaptation period; [4]HGD - Commercial High-Grain Diet (corn grain plus pelleted concentrate premix) - post-adaptation period; [5]peNDF - Physically effective neutral detergent fiber; [6] fNDF - Forage neutral detergent fiber. *Experimental data; **IVDMD - *In vitro* dry matter digestibility.

Animal Evaluation and Growth Performance

The lambs evaluated in this study originated from the breeding herd of Guaiuba Agropecuária S/A. After weaning, animals were selected based on body weight homogeneity within each genotype. Individuals considered extremely heavy or extremely light relative to the contemporary group mean were excluded to ensure experimental uniformity.

To monitor growth performance, animals were weighed every 14 days after a 17-h solid-feed withdrawal using a mechanical scale (maximum capacity 300 kg; minimum 2 kg;

100 g precision; digital indicator). At each weighing, body condition score (BCS) was assessed by a trained evaluator and classified as follows: thin (scores 1.0 and 2.0), intermediate (scores 2.5 and 3.5), and fat (scores 4.0 and 5.0), according to the methodology described by Osório and Osório (2003). In addition, animals were evaluated using the FAMACHA© system (scores 1 to 5) to monitor anemia status and determine the need for anthelmintic treatment, following Molento et al. (2004).

Slaughter Procedures and Carcass Yield Evaluation

The slaughter criterion established for males was the attainment of an average body weight of 38.0 kg. After a feedlot period of 70 days for males and 77 days for females, animals were slaughtered to evaluate carcass weight and yield parameters.

Slaughter procedures were carried out at Frigorífico Guaiuba (SIE 203-CE). Prior to slaughter, lambs were subjected to a 17-h solid-feed withdrawal. At the end of this fasting period, slaughter body weight (SBW) was recorded.

Slaughter procedures followed Ordinance Nº. 365, issued on July 16, 2021, which regulates humane slaughter and authorized stunning methods by the Brazilian Ministry of Agriculture and Livestock. Animals were humanely slaughtered using prior electrical stunning, followed by exsanguination through severance of the jugular vein and carotid artery. Subsequently, skinning, removal of the head, feet, and genital organs, evisceration, and carcass trimming were performed. Carcasses were then weighed to obtain hot carcass weight (HCW), and the hot carcass yield (HCY) was calculated as follows: HCY (%) = (HCW / SBW) × 100, where HCY = hot carcass yield; HCW = hot carcass weight; and SBW = slaughter body weight.

Carcasses were subsequently transferred to a cold chamber at ±4 °C for 24 h, suspended by the gastrocnemius tendons using appropriate hooks. After chilling, carcasses were weighed to determine cold carcass weight (CCW), and the cold carcass yield (CCY) was calculated as: CCY (%) = (CCW / SBW) × 100, where CCY = cold carcass yield; CCW = cold carcass weight; and SBW = slaughter body weight.

Statistical analysis

All statistical analyses were performed using the R statistical computing environment (R Core Team, 2025), version 4.5.1.

Growth and Carcass Variables

The response variables analyzed included growth traits (initial body weight, final body weight, total average weight gain, total weight gain, and slaughter body weight) and carcass traits (hot carcass weight, hot carcass yield, cold carcass weight, and cold carcass yield).

The experimental factors (independent variables) evaluated were Genetic Group (Santa Inês - SI; F1 Dorper × Santa Inês - F1), Sex, and Diet. The objective of the statistical analyses was to determine the individual and/or combined effects of these factors on each response variable. Analysis of variance (ANOVA) was employed to partition the total observed variability into components attributable to the different sources of variation and to random residual variability.

All analyses were performed in the R environment using the lm() function. The full additive linear model included all main effects (Genetic Group, Sex, and Diet) as well as their interactions at all levels.

Model selection for each variable was conducted using the step() function from the *stats* package in R, applying a backward elimination procedure. This approach generally resulted in more parsimonious models by excluding non-significant interaction terms.

Assumptions of ANOVA were evaluated for each selected model. Residual normality was assessed using the Shapiro-Wilk test, and homogeneity of variances (homoscedasticity) was verified using Levene’s test.

When significant effects were detected, mean comparisons were performed using Tukey’s post-hoc test.

Repeated Measures Over Time

To better understand the temporal dynamics of individual performance throughout the experimental period, repeated-measures analyses were conducted for Body Weight (BW), Average Daily Gain (ADG), and Body Condition Score (BCS).

Analyses of BW and ADG were performed using Linear Mixed-Effects Models (LMMs) fitted with the *lme4* package in R. The modeling strategy accounted for the repeated-measures structure over time (Days on Feed), including Animal as a random effect. Fixed effects comprised Genetic Group (GG), Sex, Diet, and their interactions. To model the temporal trend, the variable Day was included as a natural cubic spline with three degrees of freedom, along with the interactions Sex × Day and Diet × Day, in order to evaluate potential differences in growth trajectories among factor levels.

The significance of fixed effects was assessed by Type III Analysis of Variance using Satterthwaite's approximation for degrees of freedom (package *lmerTest*). Model assumptions were evaluated through simulation-based diagnostic procedures implemented in the *DHARMa* package, and goodness-of-fit was quantified by calculating marginal and conditional R^2 values (package *performance*). When significant effects were identified, estimated marginal means (EMMs) were computed and compared at specific time points using pairwise post-hoc tests (package *emmeans*).

Body Condition Score (BCS), an ordinal variable, was analyzed using a Cumulative Link Mixed Model (CLMM) fitted with the *ordinal* package in R. This approach accommodated the repeated-measures structure over time (Days on Feed) by including Animal as a random effect. A probit link function was specified. The final model incorporated the fixed effects of Genetic Group, Sex, Diet, nonlinear time effects modeled through a natural cubic spline, and significant interactions involving time (GG × Sex, GG × Day, Diet × Day, GG × Diet × Day, and GG × Sex × Day). Model comparisons were conducted using goodness-of-fit metrics (package *performance*) and likelihood ratio tests. The significance of fixed effects and interactions was evaluated using chi-square tests.

To compare significant factor levels over time, estimated marginal means (EMMs) of BCS were calculated. Predicted probabilities for each BCS category were used to estimate mean scores at specific time points. Multiple comparisons among factor levels within each day were performed using Tukey-adjusted pairwise post-hoc tests (package *emmeans*), and results were presented using a Compact Letter Display (CLD) to indicate statistical differences (package *multcompView*).

Health Status

During the experimental period, metabolic disturbances (acidosis) were observed, which negatively affected animal performance. Based on these observations, an additional analysis was conducted to investigate the possible association between the experimental factors, Genetic Group (GG), Sex, and Diet, and the binary outcome variable *disease occurrence*. To address potential bias due to small sample size or separation issues, Firth's penalized logistic regression (Firth, 1993) was applied using the *logistf* package in R (Heinze et al., 2025). This approach provides more robust coefficient estimates and more reliable confidence intervals compared with conventional maximum likelihood logistic regression. The initial model included GG, Sex, Diet, and their interactions as predictors. Model selection was guided by parsimony criteria, likelihood ratio tests (LRT), and comparison of model fit statistics. The final model for the outcome variable (*disease occurrence*) retained the main effects (GG, Sex, and Diet) and the GG × Sex interaction. From the final model, Odds Ratios (OR) and their corresponding 95% confidence intervals (CI) were estimated to quantify the magnitude and direction of the associations.

Results

Nutrient Intake During Finishing of Santa Inês and F1 Dorper × Santa Inês Lambs

The CD and NRCD diets numerically resulted in greater average intake of dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose, cellulose, and total digestible nutrients (TDN) compared with the HGD diet. In contrast, crude protein (CP) and ether extract (EE) intake were similar among diets (Table 3). Regarding genetic group, F1 Dorper × Santa Inês lambs showed numerically lower intake of DM, OM, NDF, ADF, cellulose, and TDN compared with purebred Santa Inês lambs. However, CP and EE intake were equivalent between genotypes (Table 3).

Table 3 Average daily nutrient intake (kg/lamb/day) per animal according to finishing diets for F1 Dorper × Santa Inês and Santa Inês lambs

Intake	Diet			SEM*	Genotype		SEM
	CD[1]	NRCD[2]	HGD[3]		F1DOxSI[4]	Santa Inês	
Dry Matter	1.25	1.19	0.92	0.10	1.12	1.14	0.01
Organic Matter	1.19	1.12	0.86	0.10	1.05	1.07	0.01
Crude Protein	0.14	0.11	0.14	0.01	0.13	0.13	0.00
Ether Extract	0.04	0.04	0.04	0.00	0.04	0.04	0.00
Neutral Detergent Fiber	0.52	0.46	0.29	0.07	0.42	0.43	0.01
Acid Detergent Fiber	0.20	0.17	0.07	0.04	0.14	0.15	0.00
Hemicellulose	0.32	0.29	0.22	0.03	0.28	0.28	0.00
Cellulose	0.18	0.14	0.07	0.03	0.12	0.14	0.01
Total Digestible Nutrients	1.05	0.95	0.70	0.10	0.89	0.91	0.01

*SEM - Standard Error of the Mean; [1]CD - Control Diet; [2]NRCD - Diet formulated according to NRC (2007) using ingredients available on the farm; [3]HGD - Commercial High-Grain Diet (whole corn grain plus pelleted concentrate premix); [4]F1 DO × SI - Cross between Dorper and Santa Inês breeds.

Nutrient Intake During Finishing of Santa Inês and F1 Dorper × Santa Inês Ewe Lambs

The CD and NRCD diets numerically resulted in greater average intake of DM, OM, NDF, ADF, hemicellulose, cellulose, and TDN compared with the HGD diet. In contrast, CP and EE intake were similar among the three diets (Table 4). Regarding genetic group, F1 Dorper × Santa Inês ewe lambs showed numerically greater intake of DM, OM, NDF, hemicellulose, cellulose, and TDN compared with purebred Santa Inês ewe lambs. However, CP, EE, and ADF intake were similar between genetic groups (Table 4).

Table 4. Average daily nutrient intake (kg/ewe lamb/day) per animal according to finishing diets for F1 Dorper × Santa Inês and Santa Inês ewe lambs

Intake	Diet			SEM*	Genotype		SEM
	CD[1]	NRCD[2]	HGD[3]		F1DOxSI [4]	Santa Inês	
Dry matter	1.15	1.12	0.87	0.23	1.08	1.04	0.02
Orgânic Matter	1.06	1.03	0.80	0.20	0.98	0.96	0.01
Crude Protein	0.13	0.10	0.13	0.15	0.12	0.12	0.00
Ether Extract	0.04	0.04	0.04	0.16	0.04	0.04	0.00
Neutral Detergent Fiber	0.45	0.41	0.27	0.16	0.38	0.37	0.01
Acid Detergent Fiber	0.17	0.14	0.07	0.18	0.13	0.13	0.00
Hemicellulose	0.28	0.27	0.20	0.19	0.25	0.24	0.01
Cellulose	0.15	0.13	0.07	0.23	0.12	0.11	0.01
Total Digestible Nutrients	0.94	0.88	0.65	0.09	0.83	0.82	0.01

*SEM - Standard Error of the Mean; [1]CD - Control Diet; [2]NRCD - Diet formulated according to NRC (2007) using ingredients available on the farm; [3]HGD - Commercial High-Grain Diet (whole corn grain plus pelleted concentrate premix); [4]F1 DO × SI - Cross between Dorper and Santa Inês breeds.

Performance and finishing data of Santa Inês and F1 Dorper × Santa Inês lambs

The analysis of finishing performance showed a significant effect ($P < 0.05$) of both diet and sex (Table 5). The diet factor influenced ($P < 0.05$) the variables FBW (Final Body Weight), TAWG (Total Average Weight Gain), and TWG (Total Weight Gain) (Table 5). The CD and NRCD diets did not differ ($P > 0.05$) from each other and showed superior performance ($P < 0.05$) compared to HGD regarding FBW. Furthermore, these diets differed ($P < 0.05$) for TAWG and TWG, with CD standing out in comparison to the others (Table 5). Regarding the sex factor, males showed superior performance for all analyzed variables compared to females, except for IBCS (Initial Body Condition Score) and FBCS (Final Body Condition Score), in which females outperformed ($P < 0.05$) males (Table 5).

Table 5. Performance (kg) of F1 Dorper × Santa Inês and Santa Inês lambs finished on high-concentrate diets

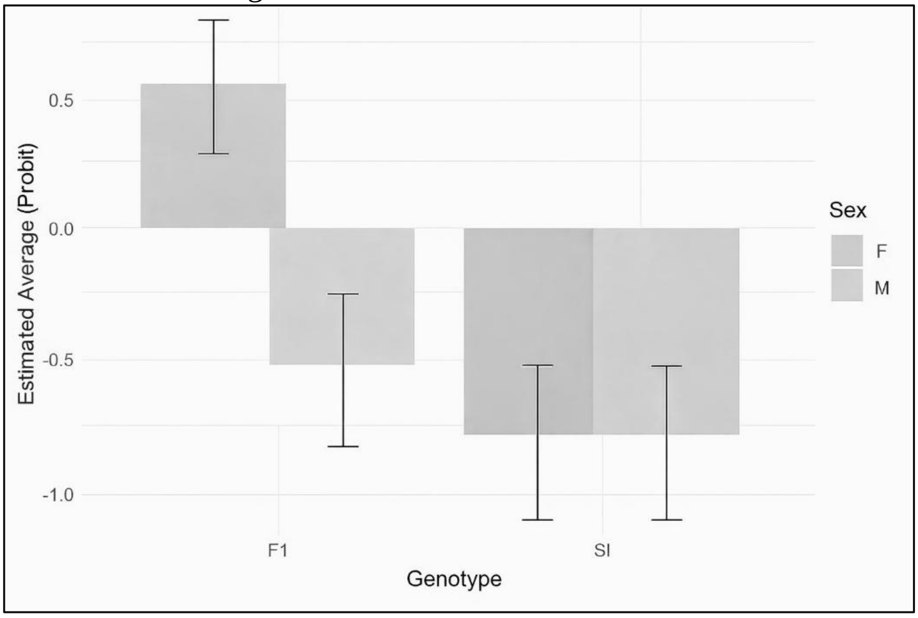
Variável	Diets			P-Value	Sex		P-Value
	CD	NRCD	HGD		Males Mean ± SEM*	Females Média ± SEM	
IBW**	21,1±0,49	21,3±0,43	21,3±0,46	0,935	21,8 ±0,36[a]	20,7 ±0,36[b]	0,033
FBW	38,8±0,67[a]	38,1±0,67[a]	36,8±0,70[b]	0,001	40,1±0,57[a]	35,7 ±0,54[b]	0,001
TAWG	0,253±0,006[a]	0,239±0,006[b]	0,222±0,006[c]	0,005	0,263±0,005[a]	0,213±0,005[b]	0,001
TWG	17,7±0,435[a]	16,7±0,435[b]	15,6±0,458[b]	0,005	18,4±0,37[a]	14,9±0,353[b]	0,001
IBCS	2,6±0,08	2,6±0,09	2,7±0,07	0,417	2,6±0,06[b]	2,7±0,07[a]	0,039
FBCS	3,9±0,001	3,9±0,104	4,0±0,104	0,143	3,7±0,08[b]	4,2±0,06[a]	0,003

*Standard error of the mean; **IBW = Initial Body Weight; FBW = Final Body Weight; TAWG = Total Average Weight Gain; TWG = Total Average Weight Gain; IBCS = Initial Body Condition Score; FBCS = Final Body Condition Score. Means followed by different lowercase letters within the same row differ (P < 0.05) according to Tukey's test.

Estimated marginal means of initial and final body condition score by genetic group and sex in the finishing Santa Inês and F1 Dorper × Santa Inês lambs

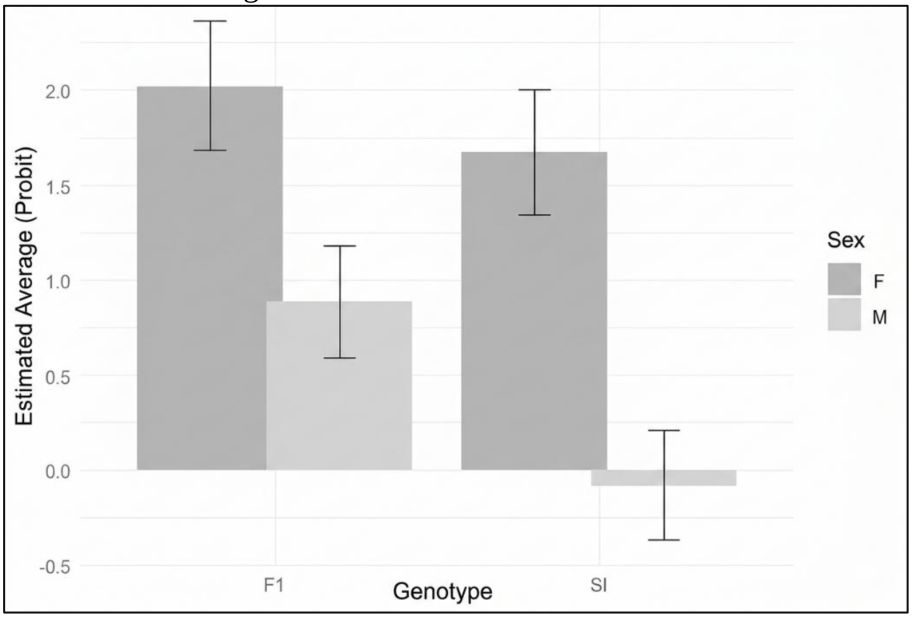
A significant interaction (P < 0.05) was observed between Genetic Group (GG) and Sex for the estimated marginal means of Initial Body Condition Score (IBCS) (Figure 3). In the F1 Dorper × Santa Inês genotype, the estimated mean IBCS was higher and positive (+0.6) for females compared to males (-0.5) (Figure 3). For the Santa Inês genotype, the estimated mean IBCS values for both females and males were negative and similar, approximately -0.7 (Figure 3).

Figure 3 Estimated marginal means of initial BCS by genetic group and sex in lambs fed high-concentrate diets



A significant effect (P < 0.05) of the interaction between GG and sex was observed for the estimated marginal means of FBCS (Figure 4). In the F1 Dorper × Santa Inês genotype, the mean FBCS for females was higher (P < 0.05) than that of males (Figure 4). For the Santa Inês genotype, the mean FBCS for females also exceeded (P < 0.05) that of males, with the latter showing a negative mean value (Figure 4). Considering the sex factor, female lambs of the F1 Dorper × Santa Inês genotype exhibited higher FBCS (P < 0.05) compared to those of the Santa Inês genotype (Figure 4).

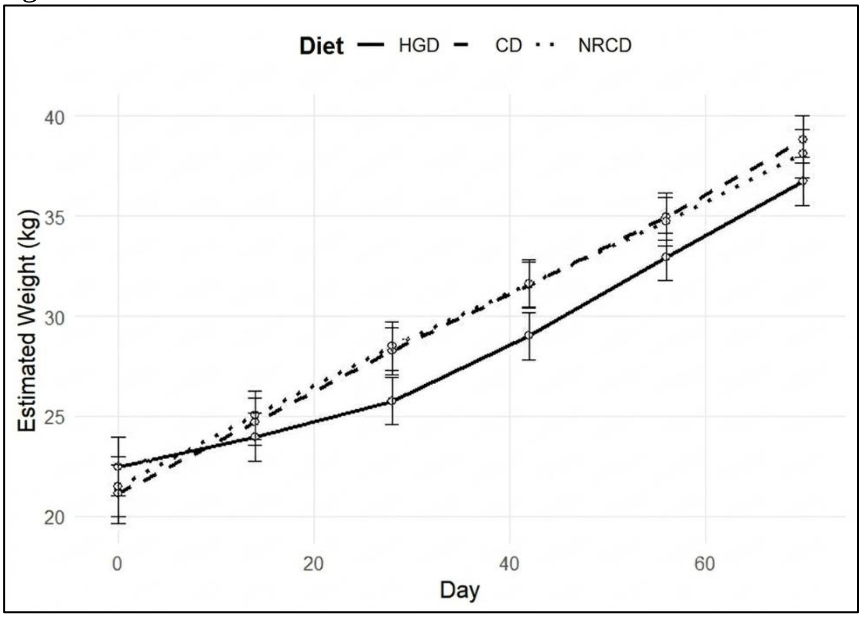
Figure 4 Estimated marginal means of final BCS by genetic group and sex in lambs fed high-concentrate diets



Repeated measures over time during the finishing of Santa Inês and F1 Dorper × Santa Inês lambs

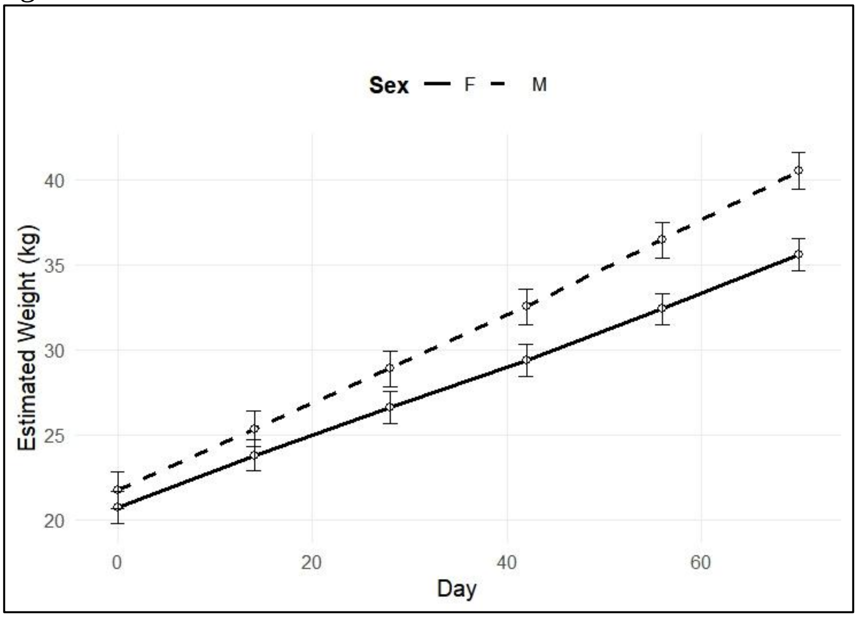
A significant effect of interaction among diets ($P < 0.05$) was observed for adjusted body weight means over time (Figure 5). The CD and NRCD diets showed similar weight gains throughout the feedlot period ($P > 0.05$). In contrast, the HGD diet resulted in lower body weight ($P < 0.05$) compared to the other diets (Figure 5). The difference ($P < 0.05$) in body weight between HGD and the other diets increased as the confinement period progressed, particularly at 42 days (Figure 5).

Figure 5 Adjusted mean body weight by diet over time in lambs fed high-concentrate diets



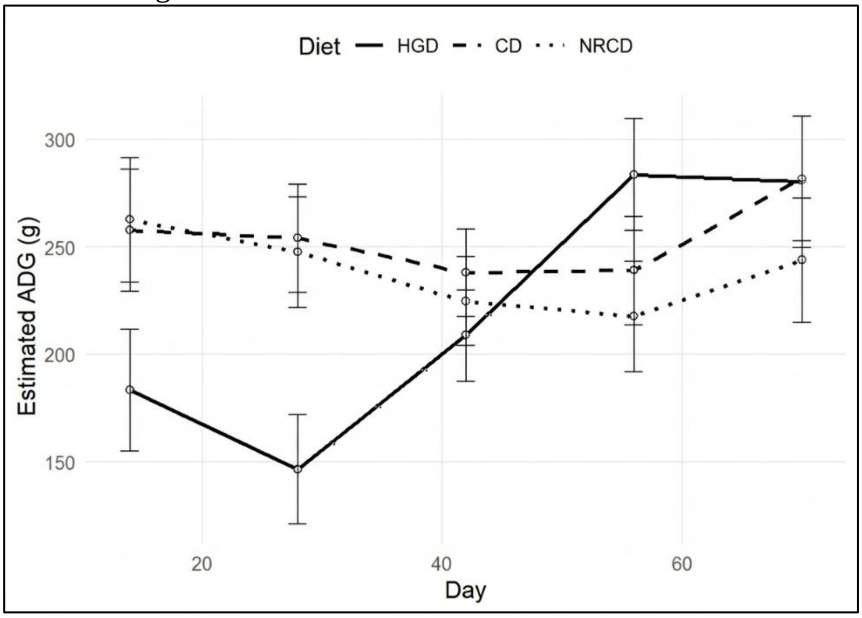
For the adjusted mean body weight by sex over time, significant effects ($P < 0.05$) of both sex and time were observed (Figure 6). Males exhibited higher ($P < 0.05$) average weight gain compared to females, with this difference becoming more pronounced after 42 days (Figure 6).

Figure 6 Adjusted mean body weight by sex over time in lambs fed high-concentrate diets



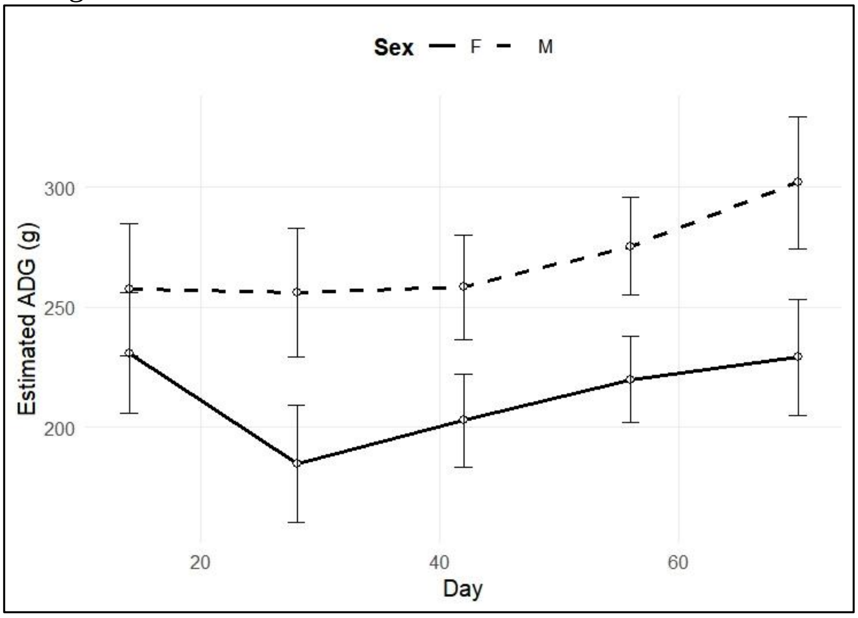
For the adjusted mean average daily gain (ADG) over time, a significant effect of interaction ($P < 0.05$) was observed between diet and time (Figure 7). The CD and NRCD diets showed higher ADG ($P < 0.05$) compared to HGD up to 42 days. The HGD diet exhibited lower ADG ($P < 0.05$) up to 28 days, followed by recovery thereafter, and did not differ ($P > 0.05$) from CD at the end of the experiment (Figure 7).

Figure 7 Adjusted mean average daily gain by diet over time in lambs fed high-concentrate diets



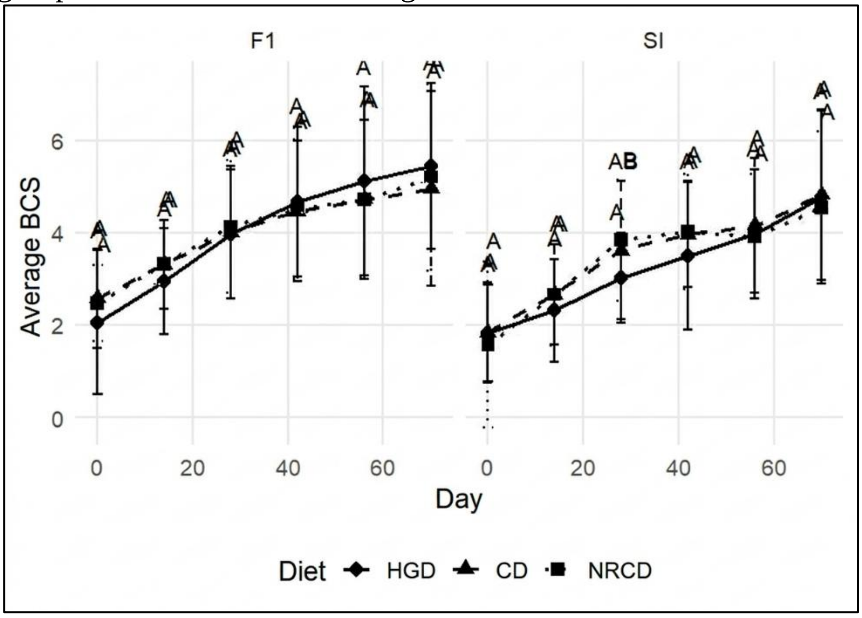
For the adjusted mean average daily gain (ADG) by sex, a significant effect of interaction (P < 0.05) was observed between sex and time (Figure 8). Males consistently exhibited higher ADG compared to females (Figure 8). Females showed the lowest ADG at 28 days, followed by recovery throughout the remainder of the feedlot period.

Figure 8 Adjusted mean average daily gain by sex over time in lambs fed high-concentrate diets



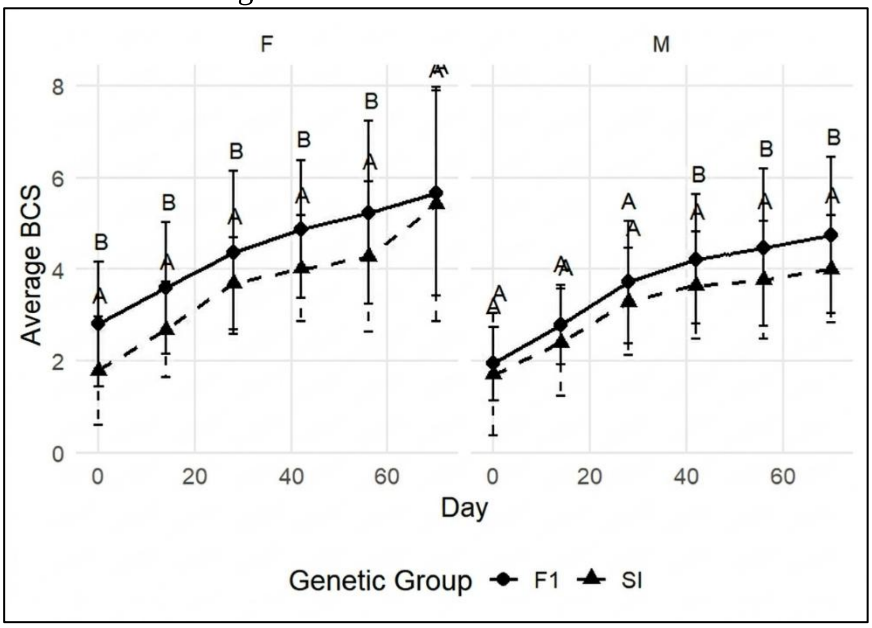
No significant effect (P > 0.05) of the interaction between diet and time was observed for BCS over time in the F1 Dorper × Santa Inês genotype (Figure 9). In contrast, for the Santa Inês genotype, a significant effect of interaction (P < 0.05) between diet and confinement time was detected, with a progressive increase in BCS as the days advanced (Figure 9). Lambs fed the CD and NRCD diets showed higher (P < 0.05) BCS compared to those receiving the HGD diet. The latter resulted in the lowest BCS values, remaining inferior to the other diets up to 42 days of confinement.

Figure 9 Adjusted mean body condition score (BCS) by genetic group over time in lambs fed high-concentrate diets



A significant effect of interaction (P < 0.05) among sex, confinement time, and GG was observed for BCS (Figure 10). Regarding the sex factor, F1 Dorper × Santa Inês females exhibited higher (P < 0.05) BCS compared to Santa Inês females up to 56 days of confinement (Figure 10). For males, BCS was similar (P > 0.05) between the F1 Dorper × Santa Inês and Santa Inês genotypes up to 28 days of confinement. However, by the end of the experimental period, F1 Dorper × Santa Inês males showed higher BCS (P < 0.05) (Figure 10).

Figure 10 Adjusted mean body condition score (BCS) by sex over time in lambs fed high-concentrate diets



Performance and slaughter data related to the finishing of Santa Inês and F1 Dorper × Santa Inês lambs

The analysis of finishing performance and carcass yield showed significant effects ($P < 0.05$) of diet and sex (Table 6). For the diet factor, CD had a marginal effect ($P = 0.077$ and $P = 0.080$) compared to NRCD and did not differ from HGD for HCY and CCY (Table 6). Males showed higher values than females for absolute weights, particularly SBW, HCW, and CCW (Table 6), except for CCY, in which females outperformed males.

Table 6. Performance (kg) and carcass yields (%) of F1 Dorper × Santa Inês and Santa Inês lambs finished on high-concentrate diets

Variable	Diets			P-Value	Sex		P-Value
	CD	NRCD	HGD		Males Mean ± SEM*	Females Mean ± SEM	
SBW**	39,1±0,84	38,8±0,79	37,9±0,79	0,2611	40,2 ±0,61[a]	36,7 ±0,58[b]	0,001
HCW	18,3±0,42	17,7±0,39	17,3±0,37	0,215	18,3 ± 0,32[a]	17,2 ± 0,30[b]	0,012
HCY	46,7±0,0033[a]	45,7±0,0033[b]	46,3±0,0035[ab]	0,077	45,6 ±0,0028[b]	46,9±0,0027[a]	0,001
CCW	18,1±0,42	17,5±0,38	17,1±0,37	0,219	18,1±0,31[a]	17,1 ± 0,30[b]	0,0097
CCY	46,2 ±0,0033[a]	45,1±0,0033[b]	45,8±0,0035[a]	0,080	45,1 ±0,0028[b]	46,3 ±0,0027[a]	0,0016

*Standard error of the mean; **SBW = Slaughter Body Weight; HCW = Hot Carcass Weight; HCY = Hot Carcass Yield; CCW = Cold Carcass Weight; CCY = Cold Carcass Yield. Means followed by different lowercase letters within the same row differ ($P < 0.07$) according to Tukey's test.

Health data during the finishing of Santa Inês and F1 Dorper × Santa Inês lambs

Regarding health data, F1 Dorper × Santa Inês lambs exhibited a lower incidence of metabolic disorders compared to Santa Inês lambs (Table 7). Regardless of the diet, F1 Dorper × Santa Inês lambs did not present any metabolic disturbances.

In contrast, Santa Inês lambs showed a higher incidence ($P < 0.05$) of metabolic disorders. Those fed the CD and NRCD diets had a 16.7% probability of occurrence, whereas lambs on the HGD diet had an 83.3% probability (Table 7). Furthermore, it was observed that females of both F1 Dorper × Santa Inês and Santa Inês genotypes maintained on the HGD diet had a 16.7% probability of developing metabolic disorders (Table 7).

Table 7. Incidence of metabolic disorders in F1 Dorper × Santa Inês and Santa Inês lambs by genetic group (GG), sex, and diet under feedlot conditions

GG	Sex	Diet	Total de animals	Presence of disorder	Absence of disorder	Probability of disorder (%)
F1 DO x SI[1]	M[2]	1	6	0	6	0.0
F1 DO x SI	M	2	6	0	6	0.0
F1 DO x SI	M	3	6	0	6	0.0
Santa Inês	M	1	6	1	5	16.7
Santa Inês	M	2	6	1	5	16.7
Santa Inês	M	3	6	5	1	83.3
F1 DO x SI	F[3]	1	6	0	6	0.0
F1 DO x SI	F	2	6	0	6	0.0
F1 DO x SI	F	3	6	1	5	16.7
Santa Inês	F	1	6	0	6	0.0
Santa Inês	F	2	6	1	5	16.7
Santa Inês	F	3	6	0	6	0.0

[1]F1 DO x SI - Dorper x Santa Inês; [2]Male; [3]Female

Discussion

Nutrient intake during the finishing of Santa Inês and F1 Dorper × Santa Inês lambs

The numerical increase in intake of DM, OM, NDF, ADF, hemicellulose, cellulose, and TDN can be explained by the higher levels of NDF, peNDF, fNDF, and TDN in the CD and NRCD diets compared to the HGD diet (Table 2). Higher intake of fiber components can limit total DM intake due to rumen fill, thereby restricting the expression of the animals' genetic potential (Alves et al., 2016). Nevertheless, the intake observed in the CD and NRCD diets met the nutritional requirements of these animals.

The reduced intake of DM, OM, NDF, ADF, peNDF, fNDF, and TDN by lambs fed the HGD diet likely increased their risk of metabolic disorders (Tables 1, 2, and 3) (Mertens, 1997). This effect was primarily due to the composition of the diet ingredients, particularly whole corn, which had a low physically effective fiber factor (0.4).

The physically effective fiber (Pef) factor represents the ability of fiber to stimulate chewing and salivation in ruminants, ranging from 0 (ineffective) to 1 (fully effective) (Armentano and Pereira, 1997; Mertens, 1997). peNDF is calculated as the product of NDF concentration and the physically effective fiber factor. In this context, whole corn in the HGD diet was insufficient to maintain rumen health, whereas the pelletized concentrate provided adequate fiber effectiveness (1.0) (Mertens, 1997).

Considering peNDF and fNDF, which relate to fiber’s physical characteristics, particularly particle size, influencing chewing activity and the biphasic structure of rumen contents (Mertens, 1997; Zebeli et al., 2012), the intake in the CD and NRCD diets was higher than in the HGD diet. This indicates that lambs on the HGD diet had limited performance due to reduced intake of these nutrients. The HGD diet followed the adaptation protocol recommended by the feed supplier, which gradually increased the intake from 1.5% of body weight (days 1-3) to 2% (days 4-7), 3% (days 8-11), and 3.5% (days 12-15). From day 16 until slaughter (day 70 for males and day 77 for females), silage was completely removed, and animals received only a mixture of whole corn grain and commercial pelleted concentrate. This adaptation protocol likely contributed to the reduced performance observed in lambs fed the HGD diet.

Diet composition and physical characteristics strongly influence animal performance and diet utilization. Insufficient fiber in the diet can trigger a cascade of effects that impair performance, including reduced chewing activity, lower salivary buffer secretion, decreased rumen pH, altered fermentation patterns, shifts in the acetate-to-propionate ratio, modified metabolism, and reduced milk fat in dairy cattle (Mertens, 1997).

The lower intake of DM, OM, NDF, ADF, cellulose, and TDN in F1 Dorper × Santa Inês lambs compared to Santa Inês lambs was likely due to nutrient intake below the NRC (2007) recommendations for this animal category. Although Santa Inês lambs showed numerically higher intake than F1 Dorper × Santa Inês lambs for DM and NDF, their intake still fell below NRC (2007) recommendations. These intakes were also lower than those reported by Cartaxo et al. (2017), who evaluated Santa Inês, ½ Dorper × ½ Santa Inês, and ¾ Dorper × ¾ Santa Inês lambs under feedlot conditions.

Nutrient intake during the finishing of Santa Inês and F1 Dorper × Santa Inês ewe lambs

O The higher average daily intake of DM, OM, NDF, ADF, hemicellulose, cellulose, and TDN observed in the CD and NRCD diets compared to the HGD diet can be attributed to the higher concentrations of these nutrients in the former diets (Table 2), which supports animal performance and productivity. However, increased intake of fiber components such as NDF, ADF, hemicellulose, and cellulose, although essential in the diet, may lead to rumen fill, imposing a physical intake limitation (Alves et al., 2016; Ferreira et al., 2021). Although the intake of these nutrients was numerically higher in the CD and NRCD diets than in HGD, it remained below the NRC (2007) recommendations, particularly for DM and TDN, potentially limiting the animals' performance. Similarly, crude protein intake, although similar across the three diets, did not meet the minimum requirement of 142 g/day established by the NRC (2007) for small ruminants.

The chemical composition of CD and NRCD diets showed higher levels peNDF, fNDF, and TDN compared to HGD, highlighting the limitations of the latter diet. While chemical analysis of fiber components is important in animal production systems, it may be insufficient as a sole measure due to variability in the effectiveness of different physical forms of forage (Mertens, 1997).

Despite fiber components intake being below NRC (2007) recommendations, ewe lambs were less susceptible than males to metabolic disorders (Table 7), likely due to physiological adaptations that allow them to regulate intake of diets with higher energy density (Altmann et al., 2006; Kowalski et al., 2014).

The higher intake of DM, OM, NDF, hemicellulose, cellulose, and peNDF in F1 Dorper × Santa Inês lambs compared to Santa Inês lambs may reflect a compensatory increase in feed intake to meet nutritional requirements. In addition, the digestibility of these diets may also have contributed to increased nutrient intake.

Failure to meet the nutritional requirements of lambs can be a critical limitation in feedlot operations, strongly reducing the expression of genetic potential. This was observed in Santa Inês lambs fed the HGD diet, especially during the first weeks of the experiment. Conversely, animals achieve higher productive performance when their nutritional requirements are met, particularly during the first six months of life (Sousa et al., 2012).

Similar results for DM intake have been reported by Sousa et al. (2012) and Araújo Filho et al. (2010), who evaluated the performance of Santa Inês lambs and Dorper × Santa Inês crossbreds.

Performance and finishing data of Santa Inês and F1 Dorper × Santa Inês sheep

Possibly, the superior FBW observed in lambs fed the CD and NRCD diets can be attributed to higher intake of key nutrients such as DM, CP, and TDN (Table 3), as well as the inclusion of the ionophore monensin in these diet formulations (Table 2). According to NRC (2007), the CD and NRCD diets met the nutritional requirements for DM, CP, and TDN. Therefore, the knowledge of nutrient intake and requirements is essential for effective diet formulation and optimal animal performance (Cartaxo et al., 2017; Galvani et al., 2018).

Differences in TAWG and TWG among the three diets may be explained by the presence of monensin in the CD and NRCD diets (Benatti et al., 2017; G. H. G. Polizel et al., 2021). The monensin concentration in the CD diet was more than double that in the NRCD diet. This ionophore primarily improves rumen fermentation, maintains rumen health, and enhances animal performance, particularly weight gain (Benatti et al., 2017).

The greater performance observed in males compared to females for IBW, FBW, TAWG, and TWG is expected and is likely due to sexual dimorphism (Homem Junior et al., 2015; Macedo Junior et al., 2019). Males generally exhibit superior performance due to differences in morphometric characteristics and muscle mass, particularly body weight (Cartaxo et al., 2017; Homem Junior et al., 2015) and allometric growth patterns (Sousa et al., 2019).

Conversely, the higher IBCS and FBCS observed in females compared to males may be attributed to the precocity of ewe lambs in depositing subcutaneous and internal fat (Homem Junior et al., 2015; Kenyon et al., 2014). According to Homem Junior et al. (2015), females slaughtered at the same age and weight as males are more likely to deposit fat, explaining the observed differences in body condition.

Estimated marginal means of initial and final body condition scores by genetic group and sex in the finishing of Santa Inês and F1 Dorper × Santa Inês sheep

The higher IBCS observed in F1 Dorper × Santa Inês females compared to males is likely explained by the precocity of ewe lambs, greater subcutaneous fat deposition, and hormonal factors (Brandão et al., 2024; Costa et al., 2022). Males generally deposit more muscle, whereas females tend to deposit fat at a faster rate (Pereira et al., 2023; Soares et al., 2012). From a meat production perspective, finishing only females may be less advantageous due to higher fat accumulation relative to muscle and lower yields of commercial cuts.

The lack of difference in IBCS between males and females of the Santa Inês genotype suggests a reduced sexual dimorphism in this breed. Another possible explanation is the contemporaneity of the animals and the fact that Dorper × Santa Inês crossbreds tend to deposit more subcutaneous fat compared to pure Santa Inês animals (Souza et al., 2016). Studies by Pereira et al. (2023) and Cartaxo et al. (2017) also reported higher subcutaneous fat content in F1 Dorper × Santa Inês lambs compared to Santa Inês lambs, supporting the additive effect observed in crossbred F1 animals.

Males typically exhibit greater musculature and lower carcass fat content (Rocha et al., 2010), which translates into higher hot carcass weight. The higher fat deposition in females may be advantageous for carcass yield, as it provides thermal insulation and reduces cooling losses (Araújo Filho et al., 2010; Cartaxo et al., 2011), explaining the superior CCY observed in females.

The higher FBCS observed in F1 Dorper × Santa Inês ram and ewe lambs compared to Santa Inês is likely due to the additive effects of this cross (Cartaxo et al., 2011; Cloete et al., 2000). Crossbred animals tend to deposit more adipose tissue (Bonacina et al., 2011b; Cartaxo et al., 2011), consistent with previous literature (Cartaxo et al., 2017; Souza et al., 2016).

Repeated measures over time in the finishing of Santa Inês and F1 Dorper × Santa Inês sheep

Possibly, the similar body weight observed in animals fed the CD and NRCD diets is likely due to their higher nutrient intake compared to the HGD diet. According to NRC (2007) recommendations, the CD and NRCD diets met the requirements for DM, CP, and NDF (Tables 3 and 4), whereas nutrient intake in HGD was below NRC (2007) recommendations. Additionally, the inclusion of the ionophore monensin in the CD and NRCD diets may have contributed to the higher performance observed (Benatti et al., 2017; Polizel et al., 2021). The lower body weight observed in HGD-fed sheep can also be attributed to the fifteen-day adaptation period, which may have limited final body weight.

Formulating diets that meet the nutritional requirements for each category and sex of sheep is of paramount importance (Brandão et al., 2024; Homem Junior et al., 2015). The lower weight observed in HGD-fed animals may reflect the extended adaptation protocol to this diet, which gradually increased concentrate proportion over 15 days (Figure 2), possibly limiting early growth.

The higher body weight of males compared to females is explained by sexual dimorphism, with males exhibiting greater SBW, HCW, and CCW (Costa Júnior et al., 2006; Rocha et al., 2010). Conversely, females are generally more precocious and deposit greater subcutaneous fat, while males deposit more muscle (Bonacina et al., 2011a).

The higher initial ADG observed for CD- and NRCD-fed sheep may be attributed to previous nutritional management under creep feeding, which maintained nutrient intake (Tables 3 and 4) compared to HGD-fed sheep.

The reduced ADG observed in CD and NRCD-fed lambs after 42 days coincides with a change in silage, where variation in dry matter content likely limited intake (Table 2). Such variations can be critical in confinement systems, as they constrain intake and reduce growth rate, with effects depending on genetic group (Souza et al., 2016; Van de Vyver et al., 2013; Van Der Merwe et al., 2020).

Males exhibited higher ADG than females, consistent with greater allometric growth (Rosa et al., 2005), larger thoracic perimeter (Rosa e Paula et al., 2022), increased muscling, and higher morphometric measurements (Cartaxo et al., 2017), which also contribute to higher nutrient intake (Table 4) and weight gain.

The lower ADG of females at 28 days is likely due to lower nutrient intake in this period (Table 4), combined with smaller morphometric dimensions (Costa Júnior et al., 2006; Rosa e Paula et al., 2022) and lower absolute growth, although females still show higher cold carcass yield.

Costa Júnior et al. (2006) characterized Santa Inês animals morphometrically and reported that differences between males and females of that breed for body weight and morphometric traits increase with age.

The lack of dietary effects in F1 Dorper × Santa Inês animals was expected, given the strong additive effects in crossbred animals (Araújo Filho et al., 2010). Although females were expected to deposit more subcutaneous fat than males, this was not observed.

Dietary effects on Santa Inês sheep are likely explained by higher nutrient intake in CD- and NRCD-fed animals, along with monensin, which may have improved rumen fermentation. The lower BCS observed in HGD-fed Santa Inês lambs may reflect the breed’s adaptation to higher-concentrate diets (Cartaxo et al., 2008; Lira et al., 2017).

In addition, due to the additive effect of the Dorper breed (Cartaxo et al., 2008; Cloete et al., 2000), F1 Dorper × Santa Inês animals have higher adipose tissue content than purebred Santa Inês (Sousa et al., 2024). Santa Inês sheep, adapted to forage-based diets, tend to have greater muscling and lower fat proportion (Oliveira et al., 2020; Sousa et al., 2024).

The higher BCS in F1 Dorper × Santa Inês females compared to Santa Inês aligns with previous studies (Cartaxo et al., 2017; Rosa e Paula et al., 2022). Crossbreeding aims to exploit additive effects, with Dorper used for its superior growth potential (Cartaxo et al., 2011; Cloete et al., 2000). Santa Inês females, with lower subcutaneous fat than F1 Dorper × Santa Inês ewes, reinforce the notion that crossbreds are more efficient in muscle deposition (Cartaxo et al., 2011; Sousa et al., 2012).

Finally, the higher BCS observed in F1 Dorper × Santa Inês lambs can be attributed to additive genetic effects, consistently exceeding pure Santa Inês sheep (Cartaxo et al., 2011; Cloete et al., 2000; Sousa et al., 2024). On the other hand, the Santa Inês animals used in the farm were heavier and more muscular (Lira et al., 2017; Oliveira et al., 2020; Sousa et al., 2024), which contributed to lower BCS.

Differences in BCS between genotypes have been previously reported by Garcia et al. (2010) and Cartaxo et al. (2011) in studies with feedlot finished F1 Dorper x Santa Inês lambs, confirming that incorporating Dorper genetics improves carcass performance and subcutaneous fat thickness in crossbreds.

Performance and carcass data in the finishing of Santa Inês and F1 Dorper × Santa Inês sheep

Probably, the effect of the CD on HCY and CCY is likely associated with higher intake of CP and TDN by the sheep (Tables 3 and 4). Additionally, the monensin content in the CD diet was more than double that in NRCD, which may have further enhanced animal performance. Notably, the HCY and CCY values observed in this study fall within the typical range for sheep carcass yield, which varies between 40 and 50% (Gastaldello Junior et al., 2010; Lira et al., 2017). For both Santa Inês and F1 Dorper × Santa Inês genotypes, the carcass yields obtained can be considered satisfactory.

The superiority of males for most carcass performance variables was expected, as they consistently exhibit higher growth than females (Costa Júnior et al., 2006; Homem Junior et al., 2015). Males, particularly non-castrated rams, tend to accumulate more lean muscle mass (Gois et al., 2018; Rocha et al., 2010), whereas females are generally more efficient at depositing fat (Homem Junior et al., 2015).

Higher HCY and CCY in females can be explained by greater fat deposition (Gois et al., 2018; Kenyon et al., 2014). Ewes deposit more subcutaneous and internal fat (Carvalho et al., 2015; Homem Junior et al., 2015), which increases carcass weight relative to body weight. Fat also serves as a protective layer, reducing water losses during carcass cooling (Lima et al., 2013).

Males tend to have proportionally larger internal organs relative to body weight, such as testes and visceral mass, which reduces the carcass yield percentage. In contrast, females have lighter internal organs, which contributes to their higher carcass yield.

Health data in the finishing of Santa Inês and F1 Dorper × Santa Inês sheep

The lower probability of metabolic disorders observed in F1 Dorper × Santa Inês lambs reflects the superior adaptive capacity of this crossbreed (Cloete et al., 2000; Costa et al., 2012; Van Der Merwe et al., 2020). Crossbred animals benefit from heterosis derived from the Dorper breed, resulting in greater productive and adaptive capacity to consume high-concentrate diets (Sousa et al., 2012; Van Der Merwe et al., 2020).

In contrast, Santa Inês lambs exhibited higher susceptibility to metabolic disorders, mainly because this breed is not adapted to consume large amounts of concentrated feed (Oliveira et al., 2018; Sena et al., 2021). Furthermore, males tend to consume feed faster and in greater quantities when the diet is energy-dense and highly digestible.

Males also have higher energy and protein requirements for weight gain and muscle deposition (Galvani et al., 2018, 2014), which may overload the rumen and related organs, such as the liver. Rapidly fermentable carbohydrates, such as corn grain, can lead to accumulation of short-chain fatty acids, particularly lactic acid (Araújo Filho et al., 2019; Paulino et al., 2013).

The lower incidence of metabolic disorders in F1 Dorper × Santa Inês and Santa Inês females may be explained by several key factors, including neurohormonal regulation, additive breed effects, and physiological differences between sexes.

Regarding neurohormonal factors, leptin, a hormone produced by adipocytes, is known to regulate feed intake and satiety. Leptin production is directly correlated with body fat stores (Kowalski et al., 2014). Therefore, animals with higher body condition scores (BCS) produce more leptin (Altmann et al., 2006; Ingvartsen and Boisclair, 2001), which in turn enhances feed intake regulation.

This mechanism is supported by the present data (Figures 3 and 4; Table 6), where females exhibited higher BCS compared to males.

These findings align with previous studies that reported a positive correlation between BCS and leptin production in ruminant animals (Altmann et al., 2006; Ingvartsen and Boisclair, 2001; Lents et al., 2005).

Regarding additive breed effects, the Dorper breed has been selected for higher efficiency in intensive production systems (Cloete et al., 2000), whereas Santa Inês has not been adapted for such systems (Oliveira et al., 2024). Consequently, crossbred animals outperform the pure breeds from which they originate (Cartaxo et al., 2011; Souza et al., 2013).

Conclusion

Sheep genotypes Santa Inês and F1 Dorper × Santa Inês finished with the control diet exhibited superior body weight performance and carcass yields compared to those fed the high-grain diet, reaching the standards required by the meat industry.

Santa Inês lambs subjected to finishing with the high-grain diet showed a higher incidence of metabolic disorders.

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CAPÍTULO III

(Pesquisa Agropecuária Brasileira -PAB)

Economic-financial feasibility of lambs finished in feedlots and fed high-performance diets

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Abstract - This study evaluated the economic-financial feasibility of finishing meat specialized sheep genetic groups (Santa Inês and F1 Dorper x Santa Inês) in feedlots, using high-concentrate diets to meet the standards of the meat industry. The experiment was conducted in Guaiuba, Ceará, using 72 animals (36 males and 36 females). Three diets were tested: Control (CD; 40:60 forage-to-concentrate ratio), NRC 2007-based diet (NRCD; 36.5:63.5 forage-to-concentrate ratio), and High Grain diet (HGD; 15:85 forage-to-concentrate ratio). Twelve scenarios were simulated for a commercial module with a static capacity of 517 animals.

Financial indicators included Net Present Value (NPV), Internal Rate of Return (IRR), Payback period, and Total Factor Productivity (TFP). Animal acquisition was the primary cost component (52.23% to 56.09%), followed by feeding. For males, all scenarios were economically viable, with the highest profitability observed when the Control diet was used (C1 and C4), yielding IRR of 130.54% and 127.23%, respectively. For females, scenario C9 (F1 Dorper x Santa Inês fed HGD) proved unfeasible, showing negative net income and a negative rate of return (-3.04%). HGD diet was associated with a high incidence of metabolic disorders (acidosis), affecting 83.3% of Santa Inês lambs in scenario C6, which increased health costs and reduced efficiency. Finishing Santa Inês and F1 Dorper x Santa Inês sheep in feedlots is economically viable when using CD or NRCD diets. The Control diet is the most efficient for meeting industrial standards. Conversely, HGD is financially unfeasible for ewes and poses significant metabolic risks for lambs. Animal acquisition and feeding remain the most critical factors impacting production costs.

Index terms: lamb finishing, production cost, high-concentrate diets, genetic groups.

Introduction

Cost management in sheep production is essential to ensure financial sustainability, competitiveness, and strategic planning of the activity (Barros et al., 2009; Theodoridis et al., 2021; Salinas-Martínez et al., 2022). This management tool enables the identification of the main components of production costs, operational bottlenecks, and business feasibility in the medium and long term (Barros et al., 2009; Silva et al., 2021; Sá et al., 2024). The absence of such analysis increases uncertainty and may result in elevated production costs and low performance indices, sometimes leading producers to abandon the activity (Stivari et al., 2013; Belanche et al., 2021).

On the other hand, economic and financial analysis supports the careful selection of animals and diets, aligning production with agro-industrial requirements regarding supply consistency and carcass standardization (Monteiro et al., 2021). Although corn silage is recommended due to its high yield and nutritional value (Vyver, Van de et al., 2013; Ferraretto et al., 2018), its adoption requires rigorous assessment of the economic feasibility of the associated production factors (Souza et al., 2020; Demircan et al., 2021).

In this context, evaluating the feasibility of finishing systems for ram and ewe lambs becomes essential to ensure compliance with the standards required by the agro-industrial chain (Viana & Silveira, 2008; Santos et al., 2020; Landim et al., 2022). Given the need to test high-performance diets, the hypothesis of this study is that the production of sheep from specialized meat breeds is economically viable for meeting slaughterhouse market demands.

The objective of this study was to evaluate the economic and financial feasibility of feedlot finishing systems for specialized genetic groups of meat-type sheep, subjected to high-performance diets, aiming to meet the standards required by the meat-processing industry.

Material and Methods

Location and experimental period

Zootechnical data were collected between October 31, 2023, and January 16, 2024, at Sítio São Gregório (Guaiuba Agropecuária S/A), located in Guaiuba, Ceará, Brazil.

Animals

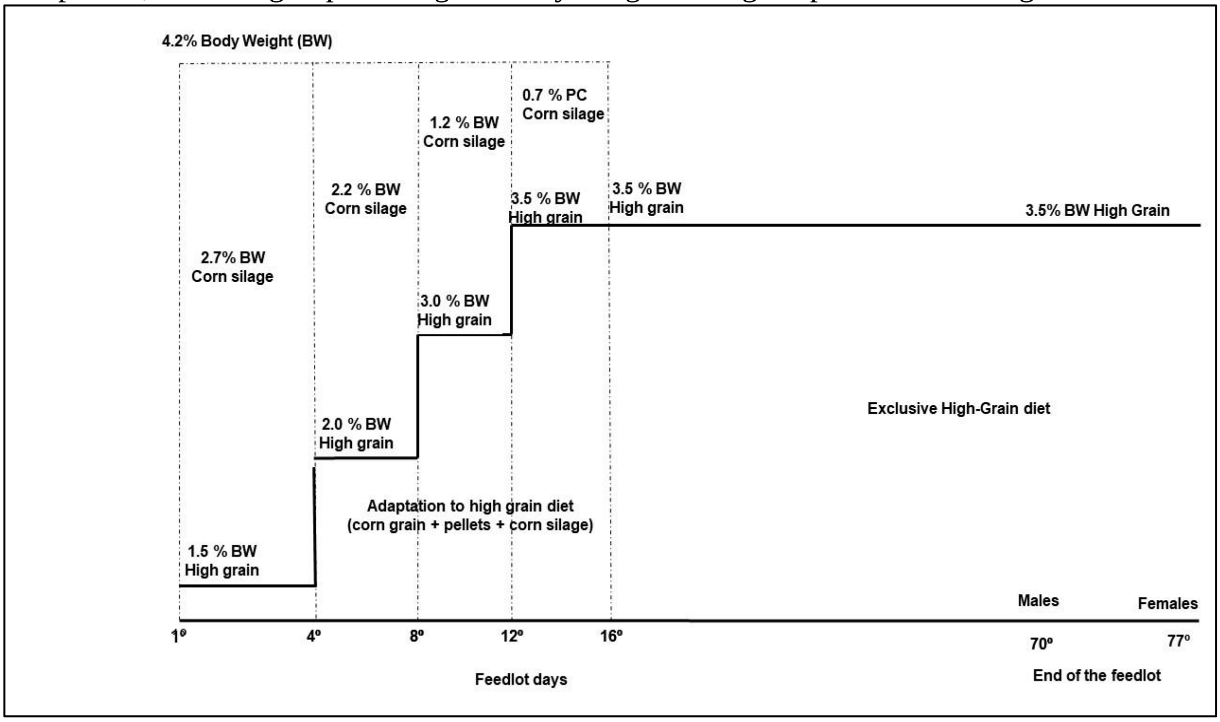
A total of 72 animals were used, including 36 males and 36 females (18 Santa Inês and 18 F1 Dorper × Santa Inês), which were weaned at approximately three months of age, with an average body weight of 21.80 ± 0.26 kg and 20.68 ± 0.75 kg for males and females, respectively. Prior to the experimental period, all animals were dewormed, vaccinated against clostridial diseases, and identified with electronic ear tags. The animals were housed in a masonry shed covered with ceramic tiles and allocated to collective pens equipped with outdoor access areas (solariums), feed bunks, plastic drum feeders, automatic drinkers, and plastic mineral feeders.

Experimental diets

Three high-performance finishing diets for sheep were evaluated (Table 1): Control Diet (CD): Roughage-to-concentrate ratio of 40:60, consisting of soybean meal, ground sorghum, mineral premix, sodium bicarbonate, and corn silage. This diet was already in use at Guaiuba Agropecuária S/A; NRC-Based Diet (NRCD): Formulated according to NRC (2007) recommendations for 20-kg lambs targeting an average daily gain of 300 g/day, with a roughage-to-concentrate ratio of 36.5:63.5, consisting of soybean meal, ground sorghum, soybean oil, mineral premix, sodium bicarbonate, and corn silage; and High-Grain Diet (HGD): Composed of 15% commercial pelleted concentrate and 85% whole corn grain, acquired and supplied according to the technical recommendations of the feed manufacturer. The roughage-to-concentrate ratio was 15:85 during the first 15 days and 0:100 after day 15.

The adaptation period to the experimental diets lasted 15 days. For the HGD, a specific adaptation protocol was adopted: during the first 15 days, animals received corn grain, mineral premix, and corn silage. From day 16 until slaughter (70 days for males and 77 days for females), corn silage was completely withdrawn, and animals were fed exclusively a mixture of whole corn grain and pelleted concentrate (Figure 1).

Figure 11 Provision of the whole corn grain, pelleted concentrate, and corn silage mixture in sheep diets, according to percentage of body weight during adaptation to the High-Grain Diet.



Economic-Financial Analysis and Performance Parameters

Economic feasibility was assessed using AVETEC software (Embrapa) and Excel®, following the methodology described by Guiducci et al. (2012). The performance parameters (Table 2) included: Initial Body Weight (IBW) and Final Body Weight (FBW), measured at feedlot entry and exit; Total Weight Gain (TWG), calculated as FBW minus IBW; Average Daily Gain (ADG), obtained by dividing TWG by the length of the finishing period; and Dry Matter Intake (DMI), estimated as the average total intake divided by the number of animals per treatment. The results were extrapolated to a commercial production module with a static capacity of 517 lambs to allow for economies-of-scale analysis. For males, a 70-day finishing cycle (5.2 cycles/year) was considered, totaling 2,696 animals/year. For females, a 77-day cycle (4.7 cycles/year) was considered, totaling 2,451 animals/year. A five-day interval between production cycles was assumed.

Fixed investments included a masonry sheep barn (1,072.50 m²), consisting of 50% covered area and 50% outdoor space. The facility design followed technical welfare criteria

(Averós et al., 2014; Santana, 2016): 20 pens accommodating 25 lambs each; space allowance of 1.80 m^2/animal (total area) and 0.30 linear meters of feeder space per animal; polyethylene feeders and drinkers; a feed mixer; and a mechanical scale. The mean performance parameters of F1 Dorper × Santa Inês and Santa Inês lambs finished under high-concentrate diets are presented in Table 2.

Cost Composition and Economic Indicators

Production costs were calculated as the sum of all operational inputs and services (Guiducci et al., 2012), based on 2023 price quotations from Guaiuba Agropecuária S/A. Variable costs included animal acquisition (US$ 2.40/kg BW), health management (vaccines, anthelmintics, and medications), equipment maintenance, and feed expenses (diet ingredients plus 24.0 - 24.5 g of mineral salt/day). Labor and related charges included one manager, one full-time employee (2023 minimum wage plus 13th salary and paid vacation), and technical assistance (two monthly visits at US$ 65.87 each), with an additional 20% allocated for social charges. Other costs included electricity, land taxes (ITR and INCRA), zootechnical recordkeeping, depreciation, and opportunity costs (Guiducci et al., 2012). Total revenue was calculated by multiplying average final body weight by the sale price of US$ 2.59/kg BW. The following indicators were calculated to assess economic viability (Guiducci et al., 2012): Economic indicators: Total Revenue (TR), Gross Margin (GM), Net Margin (NM), Net Income (NI), and Family Income (FI). Operational indicators: Effective Operational Cost (EOC), Total Operational Cost (TOC), and Total Cost (TC). Efficiency indicators: Break-Even Point (BEP), Entrepreneur's Rate of Return (ERR), and Total Factor Productivity (TFP).

Financial indicators included Net Present Value (NPV), Annualized Net Present Value (ANPV), Discounted Payback, Internal Rate of Return (IRR), and Modified Internal Rate of Return (MIRR), calculated according to Guiducci et al. (2012).

The six diets combined with the simulated purchase price (US$ 2.40/kg BW) and sale price (US$ 2.59/kg BW) generated 12 scenarios for economic-financial analysis. These values correspond to those applied by Guaiuba Agropecuária S/A in 2023 during both the rainy and dry seasons. Scenarios were defined according to sex, genetic group, and diet:

Males (Ram Lambs): C1, C2, and C3: F1 Dorper × Santa Inês, fed CD, NRCD, and HGD, respectively. C4, C5, and C6: Santa Inês, fed CD, NRCD, and HGD, respectively.

Females (Ewe Lambs): C7, C8, and C9: F1 Dorper × Santa Inês, fed CD, NRCD, and HGD, respectively. C10, C11, and C12: Santa Inês, fed CD, NRCD, and HGD, respectively.

During the experimental phase, metabolic disorders (rumen metabolic acidosis) were observed, negatively affecting animal performance and production costs. These effects were particularly pronounced in Santa Inês lambs fed the HGD diet (Table 3).

Results and Discussion

Economic-Financial Feasibility Analysis of Male Lambs Finishing

Animal acquisition represented the main component of production costs, accounting for 53.63% to 56.09% of the total (Table 4), with the lowest nominal values recorded in scenarios C6, C1, C2, and C5. The predominance of acquisition costs over feed expenses and opportunity costs is associated with initial body weight and prevailing market prices (Batista et al., 2018; Alves et al., 2024). Entry weight is a determining variable, as it influences feedlot duration, age at slaughter, carcass yield, and growth rate (Lima et al., 2017; Merwe, Van der et al., 2020).

The purchase of lighter animals during periods of feed scarcity may favor compensatory growth (Batista et al., 2018). In the present study, lower costs observed in scenarios C6, C1, C2, and C5 (males) and C10, C12, and C11 (females) directly reflected lower initial body weights (19.9 to 21.7 kg; Table 2).

Profit margins were sensitive to purchase and sale prices, carcass yield, and growth efficiency (Lima et al., 2017). Market requirements vary regionally: the South African market prefers heavier animals, whereas the European market demands lighter carcasses (Merwe, Van der et al., 2020; Pereira et al., 2023).

Feed represented the second most impactful cost component, particularly in scenarios C3 and C6, with costs of US$ 27.91 and US$ 26.49 per lamb, respectively. The substantial contribution of feed to annual production costs (Stivari et al., 2014; Lima et al., 2017; Urbano et al., 2017) can be mitigated through strategic input purchasing during peak supply periods or by incorporating agro-industrial by-products (Rogério et al., 2016). Higher expenditures in scenarios C3 and C6 (males) and C7, C9, and C12 (females) resulted from the high inclusion of whole corn grain, pelleted concentrate, and silages. Pelleted diets have higher market value due to industrial processing and the requirement for specialized equipment (Nilsson et al., 2011; Muramatsu et al., 2015; Cathcart et al., 2021).

The High-Grain Diet (HGD) presented a high risk of metabolic acidosis. In scenario C6, 83.3% of animals exhibited metabolic disorders (Table 3), resulting in the lowest Total Factor Productivity (TFP) among scenarios, although still above the sustainability threshold (TFP $\geq$ 1) (Guiducci et al., 2012).

Labor was the third most significant cost factor, with fixed costs of US$ 3.76 (males) and US$ 4.14 (females) per animal (3.83% to 4.06% of total costs). Personnel expenses (operational and management) represented 85.71% of total fixed costs. Labor is critical for operational management (Guiducci et al., 2012), and profitability may be improved through the use of family or temporary labor, thereby reducing fixed expenditures (Silva et al., 2021; Landim et al., 2022).

Labor, composed in this project of two employees and one part-time manager, is essential for managing daily production activities (Guiducci et al., 2012). Although its relative share varies according to the total cost structure of each scenario, labor consistently ranked as the third most impactful cost component (Silva et al., 2018; Silva et al., 2021; Alves et al., 2024). Strategies such as the use of family or temporary labor may enhance profitability by reducing fixed expenditures (Silva et al., 2021; Landim et al., 2022), thereby helping to mitigate the current labor shortage faced by the sector (Soares, 2023; Spanevello et al., 2023).

Animal acquisition, feeding, and labor were the primary determinants of economic-financial feasibility, corroborating previous findings in sheep finishing systems (Batista et al., 2018; Silva et al., 2018; Alves et al., 2024). Maintenance and depreciation were constant across scenarios, averaging 2.85% of total costs.

The opportunity cost of invested capital (10% rate) was positive across all treatments, ranging from US$ 25,015.19 to US$ 26,545.26, with higher values in C3 and C6. Accordingly, these scenarios, F1 Dorper × Santa Inês (C3) and Santa Inês (C6), both fed HGD, presented the highest production costs per kilogram of body weight (US$ 2.46 and US$ 2.43, respectively). Opportunity cost represents the implicit remuneration of production factors (Goulart, 2002; Stivari et al., 2014). In scenarios C3 and C6 (males), the higher values were associated with lower body weight and reduced net income. In scenario C9 (females), the opportunity cost exceeded financial returns (negative net income), indicating that capital would yield higher returns in alternative investments. Nevertheless, overall positive indicators confirm that finishing Santa Inês and F1 Dorper × Santa Inês ewe lambs is economically viable, returning the production factors.

Production cost per animal in scenarios C3, C9, C7, C8, C12, and C10 was primarily driven by expenditures on animal acquisition, feed, and health management (Tables 4 and 9). In scenario C6, the lower acquisition cost was offset by elevated health-related expenses: 83.3% of the animals developed metabolic acidosis associated with the High-Grain Diet. Although high-energy-density diets may enhance performance, they also increase the risk of metabolic disorders (Lima et al., 2013; Paulino et al., 2013; Xue et al., 2021).

Production cost per kilogram of body weight (notably in C3, C6, C9, and C12) is a key indicator for market projections (Ziguer et al., 2011). Minimum sale prices required to ensure profitability were estimated at US$ 2.27 for males and US$ 2.46 for females; prices below these thresholds would compromise economic viability in the evaluated scenarios.

The highest expenditures observed in scenarios C3, C4, C8, and C11 (Tables 4 and 9) were associated with higher average initial body weights (20.2 to 22.3 kg) and the prevailing market price (US$ 2.40/kg body weight). Animal acquisition is frequently the most impactful component of feedlot production costs (Lima et al., 2017; Romão et al., 2017; Batista et al., 2018; Landim et al., 2022).

Animal acquisition and feeding were the primary components of the Effective Operational Cost (EOC), jointly accounting for 92.14% of the total (Table 5). The highest acquisition expenditure occurred in scenario C3 (US$ 144,111.69; ~61.08% of EOC), followed by C4 (US$ 140,773.17; ~61.53% of EOC), whereas the lowest value was recorded in C6. Feed costs ranged from 29.63% to 31.89% of EOC, with higher expenses in scenarios C3, C2, C6, and C4. To reduce EOC, strategies such as purchasing lighter animals or acquiring them during the dry season, when forage scarcity and lower rainfall tend to reduce both livestock and commodity prices, have proven effective (Rogério et al., 2016; Merwe, Van der et al., 2020). Scenario C6 exemplifies this pattern, presenting lower acquisition expenditure due to reduced entry body weight (Table 2).

Diet cost in scenarios C3, C2, C6, and C4 (males) and C7 and C12 (females) was influenced by the inclusion of high-cost ingredients such as whole corn grain and pelleted mineral concentrate (US$ 0.27/kg and US$ 0.66/kg, respectively). In scenario C12, these ingredients accounted for 80.28% of the diet composition, while in C2 the inclusion of soybean oil further increased feed costs (Appendix B).

Although the literature reports that feed may represent 70 - 80% of total production costs (Lima et al., 2017; Romão et al., 2017; Alves et al., 2024), in the present study the averages were 30.60% for male lambs and 32.09% for female lambs. Feed planning, particularly the use of alternative feedstuffs and advance purchasing during periods of greater supply, is essential to improve profitability (Vyver, Van de et al., 2013; Rogério et al., 2016; Merwe, Van der et al., 2020).

Scenarios C3 and C6 (males) and C9 and C12 (females) exhibited the highest annual production costs per animal, highlighting operational bottlenecks related to feeding and health management (Araújo Filho et al., 2019; Alves et al., 2024). High-Grain Diets, although widely used, increase system costs due to input prices and elevated metabolic risk, thereby requiring greater expenditures on health management (Gomes et al., 2018).

The financial sustainability of the activity depends on accurate knowledge of the cost per kilogram of body weight (Ziguer et al., 2011). To ensure profit margins and capital recovery, minimum selling prices of US$ 2.03/kg (males) and US$ 2.20/kg (females) were identified, as necessary. Considering the prevailing market price of US$ 2.59/kg, revenues were sufficient to cover production costs across all analyzed scenarios.

Regarding health expenditures, Santa Inês lambs (C6) exhibited the highest costs (US$ 5,709.49; 2.46% of EOC), suggesting greater health vulnerability associated with nutritional and genetic management. In contrast, the F1 Dorper × Santa Inês group showed moderate expenditures, with the highest value recorded in scenario C3 (US$ 1,420.65).

Labor (US$ 10,143.71) and other expenses (US$ 5,033.46) were fixed across all scenarios, accounting on average for 4.4% and 2.2% of the EOC, respectively. In terms of efficiency indicators, scenarios C3 and C6 were the costliest, presenting the highest cost per animal (US$ 87.52 and US$ 86.02, respectively) and per kilogram of body weight (US$ 2.19 and US$ 2.26, respectively). Scenarios C6 and C3, which adopted the HGD based on whole corn grain and pelleted concentrate, recorded the highest production costs (Table 6). For C6 and C3, respectively, the values were: EOC of US$ 2.26 and US$ 2.19; TOC of US$ 2.28 and US$ 2.22; and TC of US$ 2.54 and US$ 2.46.

The use of pelleted feeds justifies their higher purchase price due to industrial processing (grinding and pelleting) and the inclusion of high-nutrient-density ingredients (Nilsson et al., 2011; Muramatsu et al., 2015; Cathcart et al., 2021). Although costly, these diets enhance dry matter intake and weight gain (Buchanan et al., 2010; Zhong et al., 2018). However, increased feed and health expenditures raised TC, particularly in Santa Inês males, due to the incidence of metabolic disorders (Muramatsu et al., 2015; Maia, 2024).

All simulated scenarios (2,696 lambs; US$ 2.59/kg BW) demonstrated economic feasibility, with total revenues exceeding production costs (Table 7). The highest revenues were recorded in C4 (US$ 289,758.12) and C1 (US$ 284,840.20), whereas the lowest values occurred in C6 and C3. Slaughter weight is the primary determinant of revenue and profitability, influencing market acceptance across different regions (Merwe, Van der et al., 2020; Pereira et al., 2023). While the European market demands light carcasses (10-13 kg), the South African market requires heavier animals (18-22 kg) (Merwe, Van der et al., 2020; Prache et al., 2022). The performance of Santa Inês females (C10 and C11) was comparable to that of F1 Dorper × Santa Inês, contributing positively to total revenue and overall business viability (Silva et al., 2018).

Animal acquisition and feed costs are consistently the most impactful components of the production system (Silva et al., 2021; Silveira et al., 2022). Expenditures on animal purchase are determined by the combination of initial body weight and market price, whereas feed costs are largely driven by the prices of corn and pelleted concentrates (Rogério et al., 2019; Alves et al., 2024).

High-cost scenarios (C3, C6, C9, and C7) were primarily affected by feed expenses, accounting for up to 88.3% of EOC, as well as by health-related expenditures. In contrast, low-cost scenarios (C1 and C2) benefited from lower animal purchase costs and efficient dietary management (Table 4). Strategic planning, particularly regarding the timing of input and animal acquisition, is a key tool for reducing tied-up capital and optimizing profit margins (Rogério et al., 2016; Batista et al., 2018; Merwe, Van der et al., 2020).

In terms of total expenditures, C3 and C6 were the costliest, recording the highest EOC values (US$ 234,269.84 and US$ 230,213.25, respectively) as well as the highest Total Costs (TC). Conversely, C1 and C2 exhibited the most efficient cost structures. As a result, net income was higher in C1 (US$ 35,189.56), followed by C4 and C2. These scenarios also required lower production volumes to cover minimum costs, unlike C3 and C6, which required greater quantities of body weight (kg).

Positive Net Income (NI) in most scenarios indicates financial soundness and growth potential of the activity (NI ≥ 0), according to the criteria established by Guiducci et al. (2012). Scenarios C1, C4, C2, C11, and C7 achieved higher NI and rates of return (e.g., C1 at 14.10%), primarily due to greater final average body weight and higher total revenue (Lima et al., 2017). In contrast, F1 Dorper × Santa Inês ewe lambs (C9) exhibited negative NI and return rates, as total costs exceeded revenue. The lower returns observed in C3 and C6 were associated with reduced productive performance and the incidence of metabolic disorders (Table 3; Silva et al., 2021).

The break-even point was highest in scenarios C3, C6, C9, and C7, requiring a greater volume of meat production to cover total costs (Guiducci et al., 2012). Unlike the findings of Alves et al. (2024) and Landim et al. (2022), who associated lower break-even points with reduced nutritional levels or the use of purebred animals, the present results indicate that the highest break-even points coincided with the highest total costs (C3 and C6), reflecting more operationally challenging scenarios.

The rate of return and Total Factor Productivity (TFP) further confirm the superior profitability of C1 (14.10%), C4 (12.83%), and C2 (12.07%), generating returns of US$ 0.03, US$ 0.03, and US$ 0.02 per dollar invested, respectively. Scenarios C6 and C3 showed the lowest return rates (2.32% and 5.42%), ranking as the least efficient in terms of profitability. TFP exceeded one in all scenarios, indicating system sustainability (Guiducci et al., 2012). Although the TFP values for C1, C4, and C2 (ranging from US$ 0.21 to 0.23) were slightly lower than the US$ 0.24 reported by Andrade et al. (2018), the results reinforce the profitability of sheep finishing systems (Batista et al., 2018). Scenarios C6 and C12 were the least efficient, mainly due to therapeutic costs associated with metabolic disorders.

At a selling price of US$ 2.59/kg BW, all scenarios demonstrated financial viability (Table 8). Scenarios C1 and C4 achieved the highest profitability, reflecting lower production costs per kilogram and stronger cash flow generation. Under a discount rate of 11.25% per year, C1 and C4 were consolidated as the most attractive investment options, presenting the highest financial indicators: an Internal Rate of Return (IRR) of 130.54% for C1 and 127.23% for C4, and an annual Net Present Value (ANPV) of US$ 52,270.01 for C1 and US$ 50,747.57 for C4. These scenarios also exhibited the shortest capital payback periods.

Regarding financial feasibility, the key decision-making indicators for entrepreneurs (Guiducci et al., 2012) showed that, regardless of genetic group or sex, all scenarios are viable over a 10-year planning horizon, considering a Minimum Attractive Rate of Return (MARR) of 11.25%.

The superior profitability observed in scenarios C1, C4, C11, and C7 is attributable to lower production costs per kilogram of body weight (Tables 4 and 9), resulting in higher revenues and cash flows. The economic feasibility of the activity is further supported by the Net Present Value (NPV) and Internal Rate of Return (IRR) (Table 8). NPV, which discounts future cash flows by the MARR, benchmarked against the Selic rate (Jacomassi & Oliveira, 2022), was positive in all scenarios, confirming the sustainability of the investment (Guiducci et al., 2012; Barros et al., 2015).

The ANPV, which distributes returns over the project’s useful life (Guiducci et al., 2012; Bendin et al., 2023), was substantially higher in C1 (US$ 52,270.01) and C4 (US$ 295,756.94). This performance in Santa Inês lambs is attributed to their larger biotype (Oliveira et al., 2018) and to the use of the CD and NRCD. These diets, containing sodium monensin, optimize rumen fermentation and improve feed efficiency (Russell & Strobel, 1989; Martineau et al., 2007). In contrast, the lower ANPV observed in scenarios C3 and C6 (HGD) resulted from poorer body performance and a high incidence of metabolic disorders (Table 3).

The discounted payback period, an indicator of the time required to recover invested capital (Landim et al., 2022), further supports the robustness of scenarios C1, C4, C11, and C7 (Silva et al., 2021). In scenarios C1, C2, and C4, capital recovery occurred in approximately 10 months. In C3 and C6, as well as in the female scenarios (C11 and C7), the payback period was longer, yet remained under two years. The high Internal Rates of Return (IRR and MIRR) observed in the top-performing scenarios confirm that sheep production, under the experimental conditions evaluated, demonstrates strong economic potential and investment attractiveness (Guiducci et al., 2012).

Economic and Financial Feasibility Analysis of Female Lambs Finishing

Animal acquisition, feed, and opportunity cost were the most impactful components of the production structure (Table 9). Animal purchase represented the largest share (52.23% to 54.88%), with the lowest values observed for the Santa Inês breed (C10, C11, and C12). Feed ranked as the second highest cost, with greater impact in scenarios C7, C9, and C12. Regarding fixed costs, labor totaled US$ 10,143.71 (US$ 4.14 per animal), while maintenance and depreciation accounted, on average, for 3.17% of total costs. Opportunity cost (10%) ranged from US$ 22,122.82 to US$ 23,559.61 and exceeded net income in all scenarios, underscoring the attractiveness of the invested capital.

The highest annual cost per animal and per kilogram of body weight was observed in the F1 Dorper × Santa Inês group (C7, C8, and C9) and in the HGD scenarios (C12 and C9). Specifically, cost per kilogram reached its highest values in C12 (US$ 2.68) and C9 (US$ 2.58). Animal acquisition (58.71% to 61.66% of the EOC) and feed (average of 32.09% of EOC) were the primary determinants of operational costs (Table 10). The highest expenditures on animal purchase occurred in C8 and C11, while feed costs had a more pronounced impact in C7 and C12.

Health-related expenses were low across most treatments, indicating the absence of severe sanitary problems, except in scenarios C11 and C9. Labor and other expenses remained fixed, with labor accounting for up to 5.16% of EOC.

As a direct consequence of acquisition and feeding costs, scenarios C9 and C12 recorded the highest production costs, both per animal (US$ 85.44 and US$ 81.60, respectively) and per kilogram of body weight (US$ 2.38 and US$ 2.29, respectively).

Scenarios C9 (F1 Dorper × Santa Inês) and C12 (Santa Inês), both under the High-Grain Diet based on whole corn grain and pelleted concentrate, presented the highest production costs (Table 11). Scenario C9 recorded the maximum values across all indicators, with an EOC of US$ 2.38, a TOC of US$ 2.42, and a TC of US$ 2.68. For scenario C12, the corresponding values were US$ 2.29 (EOC), US$ 2.32 (TOC), and US$ 2.58 (TC).

The simulation for finishing 2,451 ewe lambs (selling price of US$ 2.59/kg BW) indicated economic feasibility in most scenarios, with the exception of C9. In this case, total cost exceeded revenue, resulting in negative net income (- US$ 7,146.77) and a negative rate of return (-3.04%) (Table 12).

The highest total revenues were recorded in scenarios C7 and C8 (F1 Dorper × Santa Inês) and C11 and C10 (Santa Inês). Conversely, the highest EOC and TC were concentrated in C9 and C7, followed by C12 and C10. NI was positive in all treatments except C9, with the greatest profitability observed in C11 (Santa Inês) and C7 (F1 Dorper × Santa Inês), reaching US$ 14,012.87 and US$ 11,809.23, respectively.

TFP confirmed profitability in most scenarios, with C11 and C7 standing out for their higher efficiency and returns of US$ 0.01 per dollar invested, respectively. In contrast, scenarios C9 and C7 required a greater production volume (break-even point) to cover total costs (Table 12). The highest rates of return were observed in C11 (6.34%) and C7 (5.06%), whereas C6 and C9 recorded the lowest values.

From an investment perspective (10-year horizon, discount rate of 11.25% per year), scenarios C11 and C7 proved to be the most attractive due to their lower production costs and stronger cash flow generation (Table 13). These scenarios presented the following indicators: IRR of 78.10% (C11) and 75.95% (C7); ANPV of US$ 28,200.95 (C11) and US$ 27,221.51 (C7); and discounted payback periods of 1.47 and 1.51 years, respectively. These results, further supported by the superior performance of the NRCD (C11) and CD (C7), confirm the economic viability and financial soundness of the activity across the evaluated scenarios.

Conclusion

Feedlot finishing of Santa Inês and F1 Dorper × Santa Inês sheep is economically viable when associated with the Control and NRC diets. Among these, the control diet stands out for providing greater financial efficiency in meeting the standards required by the meat processing industry. In contrast, the use of high-grain diet for females is economically unfeasible from a financial perspective. Regardless of genetic group or diet, animal acquisition and feeding consistently represent the most impactful components of both operational and total system costs.

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Tables

Table 1 Proximate composition (g/kg of feed) and chemical composition (g/kg DM) of the high-concentrate diets used in sheep finishing.

Proximate composition (g/kg DM)	Diets			
Ingredients	CD[1]	NRCD[2]	HGD[3]	HGD[4]
Corn silage	400.0	365.0	390.0	-
Corn grain	-	-	518.0	850.0
Ground sorghum grain	444.0	502.0	-	-
Soybean meal	123.0	92.0	-	-
Soybean oil	-	22.0	-	-
Sodium Bicarbonate	6.0	9.5	-	-
Pelleted concentrate premix	-	-	92.0	150.0
Mineral premix containing monensin	24.0	9.5	-	-
Sodium chloride	3.0	-	-	-
Total	1000	1000	1000	1000
Chemical composition (g/kg DM)	CD	NRCD	HGD	HGD
Dry matter	667.0	689.0	664.0	891.0
Organic matter	931.0	927.0	957.0	968.0
Crude protein	122.0	111.0	103.0	131.0
Ether extract	30.0	50.0	26.0	22.0
Neutral Detergent Fiber	364.0	350.0	475.0	437.0
peNDF[5]	230.0	215.0	320.0	208.0
fNDF[6]	210.0	191.0	204.0	0.0
Acid Detergent Fiber	148.0	136.0	147.0	48.0
Hemicellulose	21.6	21.4	32.8	38.9
Cellulose	115.0	103.0	108.0	11.0
Lignin	12.0	11.0	14.0	6.0
Total Carbohydrates	780.0	766.0	828.0	815.0
Total Digestible Nutrients*	828.5	792.0	-	754.0
IVDMD**	793.0	791.0	834.0	931.0

[1]CD - Control Diet; [2]NRCD - Diet formulated according to NRC (2007); [3]HGD - Commercial High-Grain Diet (whole corn grain plus pelleted concentrate premix) - adaptation period; [4]HGD - Commercial High-Grain Diet (whole corn grain plus pelleted concentrate premix) - post-adaptation period; [5]peNDF = physically effective neutral detergent fiber; [6]fNDF = forage neutral detergent fiber; *Experimental data; **IVDMD - *In vitro* dry matter digestibility.

Table 2 Mean values of performance parameters of F1 Dorper × Santa Inês and Santa Inês sheep finished in feedlot with high-concentrate diets.

	TREATMENTS					
Male Average Indices	***F1 Dorper x Santa Inês**			**Santa Inês**		
	CD[1]	NRCD[2]	HGD[3]	CD	NRCD	HGD
Initial body weight (kg)	21.7	21.7	22.3	21.8	21.7	21.6
Final average weight (kg)	40.7	40.7	39.9	41.4	39.8	38.1
Feedlot duration (days)	70	70	70	70	70	70
Total weight gain (kg)	19.0	19.0	17.6	19.6	18.1	16.5
Average daily gain (kg day^{-1})	0.272	0.271	0.251	0.280	0.258	0.235
Dry matter intake (kg day^{-1})	1.2	1.2	0.9	1.3	1.2	0.9
Female Average Indices	***F1 Dorper x Santa Inês**			**Santa Inês**		
	CD	NRCD	HGD	CD	NRCD	HGD
Initial body weight (kg)	21.1	21.6	21.3	19.9	20.2	20.0
Final average weight (kg)	38.5	37.4	35.9	36.4	37.0	35.6
Feedlot duration (days)	77	77	77	77	77	77
Total weight gain (kg)	17.5	15.7	14.6	16.5	16.8	15.6
Average daily gain (kg day^{-1})	0.227	0.204	0.189	0.214	0.218	0.202
Dry matter intake (kg day^{-1})	1.2	1.1	0.9	1.1	1.1	0.9

*F1 Dorper x Santa Inês = Dorper x Santa Inês; [1]CD = Control diet; [2]NRCD = Diet formulated according to NRC 2007; [3]HGD = High Grain Diet.

Table 3 Incidence of metabolic disorders in F1 Dorper × Santa Inês and Santa Inês lambs by genetic group (GG), sex, and diet in a feedlot system.

GG	**Sex**	**Diet**	**Total of animals**	**Presence of disorder**	**Absence of disorder**	**Disorder Probability (%)**
F1 DO x SI[1]	M[2]	1	6	0	6	0.0
F1 DO x SI	M	2	6	0	6	0.0
F1 DO x SI	M	3	6	0	6	0.0
Santa Inês	M	1	6	1	5	16.7
Santa Inês	M	2	6	1	5	16.7
Santa Inês	M	3	6	5	1	83.3
F1 DO x SI	F	1	6	0	6	0.0
F1 DO x SI	F	2	6	0	6	0.0
F1 DO x SI	F	3	6	1	5	16.7
Santa Inês	F	1	6	0	6	0.0
Santa Inês	F	2	6	1	5	16.7
Santa Inês	F	3	6	0	6	0.0

[1]F1 DO x SI - Dorper x Santa Inês; [2]Male; [3]Female

Table 4 Annual production costs for finishing F1 Dorper × Santa Inês and Santa Inês lambs fed high-concentrate diets, according to the economic and financial evaluation scenarios.

Average Indices (U$$ and %)	**C1***	**C2**	**C3**	**C4**	**C5**	**C6**
Feeding	65,892.44	69,673.21	75,248.39	69,478.58	68,493.68	71,423.20
	(26.39%)	*(27.45%)*	*(28.42%)*	*(27.05%)*	*(26.83%)*	*(27.44%)*
Health	1,269.97	1,269.97	1,420.65	3,368.65	3,750.72	5,709.49
	(0.51%)	*(0.50%)*	*(0.54%)*	*(1.31%)*	*(1.47%)*	*(2.19%)*
Labor	10,143.71	10,143.71	10,143.71	10,143.71	10,143.71	10,143.71
	(4.06%)	*(4.00%)*	*(3.83%)*	*(3.95%)*	*(3.97%)*	*(3.90%)*
Animal acquisition	140,017.65	140,017.65	144,111.69	140,773.17	140,017.65	139,591.45
	(56.09%)	*(55.16%)*	*(54.43%)*	*(54.81%)*	*(54.84%)*	*(53.63%)*
Other costs	5,033.46	5,033.46	5,033.46	5,033.46	5,033.46	5,033.46
	(2.02%)	*(1.98%)*	*(1.90%)*	*(1.96%)*	*(1.97%)*	*(1.93%)*
Maintenance	1,152.26	1,152.26	1,152.26	1,152.26	1,152.26	1,152.26
	(0.46%)	*(0.45%)*	*(0.44%)*	*(0.45%)*	*(0.45%)*	*(0.44%)*
Depreciation	1,125.97	1,125.97	1,125.97	1,125.97	1,125.97	1,125.97
	(0.45%)	*(0.44%)*	*(0.43%)*	*(0.44%)*	*(0.44%)*	*(0.43%)*
Opportunity cost	25,015.19	25,440.52	26,545.26	25,739.73	25,586.91	26,088.90
	(10.02%)	*(10.02%)*	*(10.03%)*	*(10.02%)*	*(10.02%)*	*(10.02%)*
Total cost (TC)	249,650.65	253,856.76	264,781.39	256,815.54	255,304.36	260,268.45
	(100%)	*(100%)*	*(100%)*	*(100%)*	*(100%)*	*(100%)*
Production cost (lamb/year)	92.60	94.16	98.21	95.26	94.70	96.54
Production cost (kg/live lamb)	2.27	2.32	2.46	2.30	2.38	2.54

*The six evaluated scenarios refer to feedlot finishing systems with purchase and selling prices fixed at US$ 2.40 and US$ 2.59 per kilogram of BW, respectively. Scenarios C1, C2, and C3 used the F1 Dorper × Santa Inês genotype, whereas C4, C5, and C6 used the Santa Inês breed, both subjected successively to the Control (CD), NRCD, and High-Grain (HGD) diets.

Table 5 Effective Operational Cost (EOC) of finishing F1 Dorper × Santa Inês and Santa Inês lambs fed high-concentrate diets, under different economic and financial scenarios including animal acquisition.

Average Indices (U$$ and %)	**C1**[1]	**C2**	**C3**	**C4**	**C5**	**C6**
Animal acquisition	140,017.65	140,017.65	144,111.69	140,773.17	140,017.65	139,591.45
	(62.97%)	*(61.92%)*	*(61.08%)*	*(61.53%)*	*(61.56%)*	*(60.19%)*
Feeding	65,892.44	69,673.21	75,248.39	69,478.58	68,493.68	71,423.20
	(29.63%)	*(30.81%)*	*(31.89%)*	*(30.37%)*	*(30.12%)*	*(30.80%)*
Health	1,269.97	1,269.97	1,420.65	3,368.65	3,750.72	5,709.49
	(0.57%)	*(0.56%)*	*(0.60%)*	*(1.47%)*	*(1.65%)*	*(2.46%)*
Labor	10,143.71	10,143.71	10,143.71	10,143.71	10,143.71	10,143.71
	(4.56%)	*(4.49%)*	*(4.30%)*	*(4.43%)*	*(4.46%)*	*(4.37%)*
Other costs	5,033.46	5,033.46	5,033.46	5,033.46	5,033.46	5,033.46
	(2.26%)	*(2.23%)*	*(2.13%)*	*(2.20%)*	*(2.21%)*	*(2.17%)*
EOC with animal acquisition	222,357.22	226,138.00	235,957.89	228,797.58	227,439.22	231,901.31
	(100%)	*(100%)*	*(100%)*	*(100%)*	*(100%)*	*(100%)*
Production cost (lamb/year)	82.48	83.88	87.52	84.87	84.36	86.02
Production cost (kg/live lamb)	2.03	2.06	2.19	2.05	2.12	2.26

*The six evaluated scenarios refer to feedlot finishing systems with purchase and selling prices fixed at US$ 2.40 and US$ 2.59 per kilogram of BW, respectively. Scenarios C1, C2, and C3 used the F1 Dorper × Santa Inês genotype, whereas C4, C5, and C6 used the Santa Inês breed, both subjected successively to the Control (CD), NRCD, and High-Grain (HGD) diets.

Table 6 Effective Operational Cost (EOC), Total Operational Cost (TOC), and Total Cost (TC) of production (US$) for finishing F1 Dorper × Santa Inês and Santa Inês lambs fed high-concentrate diets.

Production Costs/kg BW[1]	**C1***	**C2**	**C3**	**C4****	**C5**	**C6**
EOC / kg BW[2]	2.03	2.06	2.19	2.05	2.12	2.26
TOC / kg BW[3]	2.05	2.08	2.22	2.07	2.14	2.28
TC / kg BW[4]	2.27	2.32	2.46	2.30	2.38	2.54

[1]Production cost per kilogram of body weight; [2]Effective Operational Cost per kilogram of body weight gain; [3]Total Operational Cost per kilogram of body weight; [4]Total Cost per kilogram of body weight. *The six evaluated scenarios refer to feedlot finishing systems with purchase and selling prices fixed at US$ 2.40 and US$ 2.59 per kilogram of BW, respectively. Scenarios C1, C2, and C3 used the F1 Dorper × Santa Inês genotype, whereas C4, C5, and C6 used the Santa Inês breed, both subjected successively to the Control (CD), NRCD, and High-Grain (HGD) diets.

Table 7 Economic indicators of the feedlot finishing system for F1 Dorper × Santa Inês and Santa Inês lambs fed high-concentrate diets, according to the economic and financial evaluation scenarios.

Economic Indicators	**C1***	**C2**	**C3**	**C4**	**C5**	**C6**
Total Revenue (US$)	284,840.20	284,490.42	279,124.79	289,758.12	278,075.45	266,301.84
Effective Operational Cost (EOC) (US$)	220,669.16	224,449.94	234,269.84	227,109.52	225,751.16	230,213.25
Total Operational Cost (TOC) (US$)	224,635.46	228,416.23	238,236.13	231,075.81	229,717.45	234,179.55
Total Cost (U$$)	249,650.64	253,856.76	264,781.39	256,815.54	255,304.36	260,268.44
Gross Margin (US$)	64,171.04	60,040.48	44,854.95	62,648.60	52,324.29	36,088.59
Net Margin (US$)	60,204.75	56,074.19	40,888.66	58,682.31	48,358.00	32,122.29
Net Income (US$)	35,189.56	30,633.66	14,343.40	32,942.58	22,771.09	6,033.40
Family Income (US$)	70,348.46	66,217.90	51,032.37	68,826.02	58,501.71	42,266.01
Break-even Point (kg/meat)	96,211.52	97,832.49	102,042.68	98,972.76	98,390.37	100,303.45
Entrepreneur’s Rate of Return (%)	14.10	12.07	5.42	12.83	8.92	2.32
Total Factor Productivity (US$:US$)	0.23	0.22	0.21	0.23	0.22	0.20

*The six evaluated scenarios refer to feedlot finishing systems with purchase and selling prices fixed at US$ 2.40 and US$ 2.59 per kilogram of BW, respectively. Scenarios C1, C2, and C3 used the F1 Dorper × Santa Inês genotype, whereas C4, C5, and C6 used the Santa Inês breed, both subjected successively to the Control (CD), NRCD, and High-Grain (HGD) diets.

Table 8 Financial indicators of the feedlot finishing system for F1 Dorper × Santa Inês and Santa Inês lambs fed high-concentrate diets, according to the economic and financial evaluation scenarios.

Financial indicators	**C1***	**C2**	**C3**	**C4**	**C5**	**C6**
Net Present Value (U$$)	304,629.74	280,556.84	192,055.55	295,756.94	235,586.87	140,965.14
Annualized Net Present Value (U$$)	52,270.01	48,139.46	32,953.93	50,747.57	40,423.27	24,187.56
Discounted *Payback* (years)	0.85	0.91	1.28	0.87	1.07	1.66
Internal Rate of Return (% year)	130.54%	121.56%	88.50%	127.23%	104.78%	69.28%
Modified Internal Rate of Return (% year)	36.28%	35.32%	31.11%	35.93%	33.33%	27.98%

*The six evaluated scenarios refer to feedlot finishing systems with purchase and selling prices fixed at US$ 2.40 and US$ 2.59 per kilogram of BW, respectively. Scenarios C1, C2, and C3 used the F1 Dorper × Santa Inês genotype, whereas C4, C5, and C6 used the Santa Inês breed, both subjected successively to the Control (CD), NRCD, and High-Grain (HGD) diets.

Table 9 Annual production costs for finishing F1 Dorper × Santa Inês and Santa Inês ewe lambs fed high-concentrate diets, according to the economic and financial evaluation scenarios.

Average indices (U$$ **and %)**	**C7***	**C8**	**C9**	**C10**	**C11**	**C12**
Feeding	67,610.60	62,729.14	67,530.72	65,671.13	60,991.90	66,347.18
	(29.00%)	*(27.11%)*	*(28.71%)*	*(29.42%)*	*(27.59%)*	*(29.52%)*
Health	1,154.56	1,154.56	1,756.31	1,188.81	1,981.35	1,154.56
	(0.50%)	*(0.50%)*	*(0.75%)*	*(0.53%)*	*(0.90%)*	*(0.51%)*
Labor	10,143.71	10,143.71	10,143.71	10,143.71	10,143.71	10,143.71
	(4.35%)	*(4.38%)*	*(4.31%)*	*(4.54%)*	*(4.59%)*	*(4.51%)*
Animal acquisition	123,677.17	126,999.96	125,045.03	116,632.38	118,587.31	117,413.17
	(53.05%)	*(54.88%)*	*(53.15%)*	*(52.26%)*	*(53.65%)*	*(52.23%)*
Other costs	4,942.99	4,942.99	4,942.99	4,942.99	4,942.99	4,942.99
	(2.12%)	*(2.14%)*	*(2.10%)*	*(2.21%)*	*(2.24%)*	*(2.20%)*
Maintenance	1,152.26	1,152.26	1,152.26	1,152.26	1,152.26	1,152.26
	(0.49%)	*(0.50%)*	*(0.49%)*	*(0.52%)*	*(0.52%)*	*(0.51%)*
Depreciation	1,125.97	1,125.97	1,125.97	1,125.97	1,125.97	1,125.97
	(0.48%)	*(0.49%)*	*(0.48%)*	*(0.50%)*	*(0.51%)*	*(0.50%)*
Opportunity cost	23,347.02	23,171.67	23,559.61	22,340.14	22,122.82	22,500.18
	(10.01%)	*(10.01%)*	*(10.01%)*	*(10.01%)*	*(10.01%)*	*(10.01%)*
Total cost (TC)	233,154.28	231,420.27	235,256.59	223,197.38	221,048.31	224,780.03
	(100%)	*(100%)*	*(100%)*	*(100%)*	*(100%)*	*(100%)*
Production cost (R$/ewe lamb)	95.13	94.42	95.98	91.06	90.19	91.71
Production cost (R$/kg ewe lamb)	2.47	2.52	2.67	2.50	2.44	2.58

*The six evaluated scenarios refer to feedlot finishing systems with purchase and selling prices fixed at US$ 2.40 and US$ 2.59 per kilogram of BW, respectively. Scenarios C1, C2, and C3 used the F1 Dorper × Santa Inês genotype, whereas C4, C5, and C6 used the Santa Inês breed, both subjected successively to the Control (CD), NRCD, and High-Grain (HGD) diets.

Table 10 Effective Operational Cost (EOC) of finishing F1 Dorper × Santa Inês and Santa Inês ewe lambs fed high-concentrate diets, under different economic and financial scenarios including animal acquisition.

Average indices (U$$ **and %)**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
Animal acquisition	123,677.17	126,999.96	125,045.03	116,632.38	118,587.31	117,413.17
	59.60%	61.66%	59.71%	58.73%	60.30%	58.71%
Feeding	67,610.60	62,729.14	67,530.72	65,671.13	60,991.90	66,347.18
	32.58%	*30.46%*	*32.25%*	*33.07%*	*31.02%*	*33.17%*
Health	1,154.56	1,154.56	1,756.31	1,188.81	1,981.35	1,154.56
	0.56%	*0.56%*	*0.84%*	*0.60%*	*1.01%*	*0.58%*
Labor	10,143.71	10,143.71	10,143.71	10,143.71	10,143.71	10,143.71
	4.89%	*4.92%*	*4.84%*	*5.11%*	*5.16%*	*5.07%*
Other costs	4,942.99	4,942.99	4,942.99	4,942.99	4,942.99	4,942.99
	2.38%	*2.40%*	*2.36%*	*2.49%*	*2.51%*	*2.47%*
EOC with animal acquisition	207,529.03	205,970.36	209,418.75	198,579.01	196,647.26	200,001.61
	100.00%	*100.00%*	*100.00%*	*100.00%*	*100.00%*	*100.00%*
Production cost (R$/ewe lamb/year)	84.67	84.04	85.44	81.02	80.23	81.60
Production cost (R$/kg of ewe lamb)	2.20	2.25	2.38	2.23	2.17	2.29

*The six evaluated scenarios refer to feedlot finishing systems with purchase and selling prices fixed at US$ 2.40 and US$ 2.59 per kilogram of BW, respectively. Scenarios C1, C2, and C3 used the F1 Dorper × Santa Inês genotype, whereas C4, C5, and C6 used the Santa Inês breed, both subjected successively to the Control (CD), NRCD, and High-Grain (HGD) diets.

Table 11 Effective Operational Cost (EOC), Total Operational Cost (TOC), and Total Cost (TC) of production (US$) for finishing F1 Dorper × Santa Inês and Santa Inês ewe lambs fed high-concentrate diets.

Production Costs/kg BW[1]	**C7***	**C8**	**C9**	**C10****	**C11**	**C12**
EOC/kg BW[2]	2.20	2.25	2.38	2.23	2.17	2.29
TOC/ kg BW[3]	2.22	2.27	2.41	2.25	2.20	2.32
TC /kg BW[4]	2.47	2.53	2.68	2.50	2.44	2.58

[1]Production cost per kilogram of body weight; [2]Effective Operational Cost per kilogram of body weight gain; [3]Total Operational Cost per kilogram of body weight; [4]Total Cost per kilogram of body weight. *The six evaluated scenarios refer to feedlot finishing systems with purchase and selling prices fixed at US$ 2.40 and US$ 2.59 per kilogram of BW, respectively. Scenarios C1, C2, and C3 used the F1 Dorper × Santa Inês genotype, whereas C4, C5, and C6 used the Santa Inês breed, both subjected successively to the Control (CD), NRCD, and High-Grain (HGD) diets.

Table 12 Economic indicators of the feedlot finishing system for F1 Dorper × Santa Inês and Santa Inês ewe lambs fed high-concentrate diets, according to the economic and financial evaluation scenarios.

Economic indicators	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**
Total Revenue (US$)	244,963.51	237,649.64	228,109.82	231,391.52	235,061.17	226,201.86
Effective Operational Cost (EOC) (US$)	205,840.97	204,282.30	207,730.69	196,890.95	194,959.20	198,313.55
Total Operational Cost (TOC) (US$)	209,807.26	208,248.60	211,696.99	200,857.25	198,925.49	202,279.85
Total Cost (U$$)	233,154.28	231,420.26	235,256.59	223,197.38	221,048.31	224,780.03
Gross Margin (US$)	39,122.54	33,367.34	20,379.13	34,500.57	40,101.98	27,888.31
Net Margin (US$)	35,156.24	29,401.05	16,412.84	30,534.28	36,135.68	23,922.01
Net Income (US$)	11,809.23	6,229.38	-7,146.77	8,194.14	14,012.87	1,421.83
Family Income (US$)	45,299.96	39,544.76	26,556.55	40,677.99	46,279.40	34,065.72
Break-even Point (kg/meat)	89,854.07	89,185.81	90,664.27	86,016.84	85,188.62	86,626.77
Entrepreneur's Rate of Return (%)	5.06	2.69	-3.04	3.67	6.34	0.63
Total Factor Productivity (US$:US$)	0.21	0.21	0.19	0.21	0.21	0.20

*The six evaluated scenarios refer to feedlot finishing systems with purchase and selling prices fixed at US$ 2.40 and US$ 2.59 per kilogram of BW, respectively. Scenarios C1, C2, and C3 used the F1 Dorper × Santa Inês genotype, whereas C4, C5, and C6 used the Santa Inês breed, both subjected successively to the Control (CD), NRCD, and High-Grain (HGD) diets.

Table 13 Financial indicators of the feedlot finishing system for F1 Dorper × Santa Inês and Santa Inês ewe lambs fed high-concentrate diets, according to the economic and financial evaluation scenarios.

Financial indicators	**C7***	**C8**	**C9**	**C10**	**C11**	**C12**
Net Present Value (U$$)	158,647.01	125,105.72	49,410.41	131,710.19	164,355.19	93,173.89
Annualized Net Present Value (U$$)	27,221.51	21,466.31	8,478.10	22,599.54	28,200.95	15,987.28
Discounted *Payback* (years)	1.51	1.83	3.58	1.76	1.47	2.31
Internal Rate of Return (% year)	75.95%	63.26%	33.59%	65.77%	78.10%	51.00%
Modified Internal Rate of Return (% year)	29.14%	26.85%	19.66%	27.33%	29.49%	24.26%

*The six evaluated scenarios refer to feedlot finishing systems with purchase and selling prices fixed at US$ 2.40 and US$ 2.59 per kilogram of BW, respectively. Scenarios C1, C2, and C3 used the F1 Dorper × Santa Inês genotype, whereas C4, C5, and C6 used the Santa Inês breed, both subjected successively to the Control (CD), NRCD, and High-Grain (HGD) diets.

CONSIDERAÇÕES FINAIS

A interpretação dos resultados dos capítulos II e III nos permite fazer algumas sugestões buscando melhorias significativas nos processos do sistema de terminação de cordeiros da Guaiuba Agropecuária S/A.

Dentre as sugestões pode-se incluir a recomendação da destinação das cordeiras excedentes da reposição para terminação em confinamento, tanto do genótipo Santa Inês quanto as F1 Dorper x Santa Inês, uma vez que apresentaram desempenhos ponderais, rendimentos de carcaças e viabilidade econômico-financeira adequados nos cenários avaliados.

Quanto aos machos jovens utilizados para terminação no confinamento da Agropecuária Guaiuba S/A, tanto para os animais do genótipo Santa Inês quanto os F1 Dorper x Santa Inês, a recomendação é a utilização da dieta controle como primeira opção, uma vez que neste tratamento os cordeiros apresentaram maiores desempenhos ponderais, rendimentos de carcaças e viabilidade econômico-financeira. Sendo a dieta NRC (2007) uma segunda alternativa.

Do ponto de vista da formação dos lotes para a terminação, uma das sugestões é que seja realizada a separação dos cordeiros na entrada do confinamento, especialmente lotes separados em função do genótipo e do sexo, uma vez que esses cordeiros vêm de duas raças e de dois sexos diferentes e por conseguinte possuem exigências nutricionais para energia e proteína distintos. Esta estratégia, permite o produtor alcançar o ponto ótimo de abate para cada um desses quatro grupos avaliados.

A utilização do escore de condição corporal (ECC) deve ser uma ferramenta adotada para auxiliar o alcance do ponto ótimo de abate, produtivo e econômico. Nesse sentido, deve ser uma ferramenta utilizada pela equipe técnica no confinamento e se possível realizada a cada quinze dias, com vistas a melhorar a eficiência produtiva. O uso do ECC pode otimizar o tempo de confinamento e por conseguinte minimizar os custos de produção.

Outro fator relevante observado foi a mudança da silagem durante o ciclo de terminação dos cordeiros, em função de sua variação na composição nutricional, o que alterou o desempenho dos cordeiros após cada mudança. Percebeu-se ao longo da terminação a oscilação na composição química da silagem adquirida de fonte externa à propriedade. A principal alteração foi a composição de matéria seca (MS). Nesse contexto, uma alternativa para minimizar esse impacto é a avaliação do teor de MS antes de cada troca de silagem, o que pode ser realizado na própria fazenda a partir de métodos simples que utilizam o forno micro-ondas ou air fryer.

Quanto aos resultados encontrados para a dieta alto grão, após as suas interpretações, conclui-se a necessidade de estudos mais detalhados, especialmente, quanto a duração do período de adaptação e ao ponto de abate dos cordeiros, em função dos riscos de alterações metabólicas e de possibilidades de aumento da eficiência econômico-financeira.

ANEXO

ANEXO A: Inversões sobre os materiais utilizados na construção do galpão de alvenaria para confinamento de cordeiros terminados no semiárido do nordeste brasileiro

Inversões Totais	Área (m²)	Quant.	Valor unitário (R$)	Valor total (R$)	%
1. Cobertura					
1.1 Área coberta	727,50	1,0	160,00	116.400,00	55,62%
2. Colunas					
2.1 Colunas de alvenaria	3,56	88	76,50	6.752,63	3,23%
3. Piso área coberta					
3.1 Cimentado	727,50	1,0	83,00	60.382,50	28,85%
4. Cercamentos e divisões					
4.1 Tela campestre + mão de obra	276,00	5,50	450,00	3.864,00	1,85%
4.2 Estacas	276,00	138,0	3,00	414,00	0,20%
4.3 Cancelas - tela + madeira		24,0	80,00	1.920,00	0,92%
5. Canzil					
5.1 Arame Liso + mão de obra	150,00	450,0	0,80	1.110,00	0,53%
5.2 Caibros	150,00	150,0	4,30	645,00	0,31%
5.3 Estacas	150,00	60,0	3,00	180,00	0,09%
6. Cochos e bebedouros					
6.1 Comedouros (Bombona)	150,00	150,0	60,00	9.000,00	4,30%
6.2 Saleiro (Bombona)		20,0	35,00	700,00	0,33%
6.3 Bebedouros (Bombona)		20,0	40,00	800,00	0,38%
6.4 Caixa d'água 2.500l		1,0	2.500,00	2.500,00	1,19%
6.5 Rede hidráulica para bebedouros	270,00	45,0	25,00	1.125,00	0,54%
7. Curral de manejo					
7.11 Brete	8,00	16,0	45,00	720,00	0,34%
7.2 Currais		60,0	30,00	1.800,00	0,86%
7.3 Cancelas		12,0	80,00	960,00	0,46%
8. TOTAL				**209.273,13**	**100**
Equipamentos					
Balança mecânica (300 kg)		1	7.500,00	7.500,00	
Misturador de ração 1000 kg		1	13.750,00	13.750,00	
Total				**21.250,00**	

ANEXO B: Custos de dietas de alto concentrado usadas na alimentação de cordeiros F1 Dorper x Santa e Santa Inês para terminação em confinamento

Ingredientes	R$/Kg	Quant. Kg	R$ total	Participação (%)
		F1 DORPER DC*		
Silagem de milho	0,27	388.493,60	104.893,27	31,77
Sorgo Grão moído	0,97	106.435,38	103.242,32	31,27
Farelo de soja	2,38	29.485,48	70.175,44	21,26
Núcleo mineralizado na dieta	4,01	5.753,26	23.070,59	6,99
Bicarbonato de sódio	8,00	1.438,32	11.506,53	3,49
Cloreto de sódio	0,51	719,16	366,77	0,11
Sal mineralizado a vontade	7,82	2.156,80	16.866,18	5,11
Total	**1,53**	**534.482,00**	**330.121,10**	**100**
		F1 DORPER DNRC		
Silagem de milho	0,27	351.558,40	94.920,77	27,19
Sorgo grão moído	0,97	113.648,26	110.238,81	31,58
Farelo de soja	2,38	20.859,49	49.645,59	14,22
Óleo de soja	5,45	5.035,05	27.441,02	7,86
Núcleo mineralizado na dieta	4,01	2.157,88	8.653,09	2,48
Bicarbonato de sódio	8,00	2.157,88	17.263,03	4,95
Sal mineralizado a vontade	7,82	5.230,24	40.900,48	11,72
Total	**1,86**	**500.647,20**	**349.062,79**	**100**
		F1 DORPER DAG		
Silagem de milho	0,27	92.742,40	25.040,45	6,64
Milho grão inteiro	1,36	151.245,60	205.694,02	54,56
Núcleo concentrado paletizado	3,30	26.690,40	88.071,65	23,36
Sal mineralizado a vontade	7,82	7.440,96	58.188,31	15,43
Total	**1,81**	**278.119,36**	**376.994,42**	**100**
		SIDC		
Silagem de milho	0,27	422.535,99	114.084,72	32,77
Sorgo grão moído	0,97	113.777,13	110.363,82	31,71
Farelo de soja	2,38	315.19,34	75.016,03	21,55
Núcleo mineralizado na dieta	2,38	6.150,12	14.637,27	4,21
Bicarbonato de sódio	8,00	1.537,53	12.300,23	3,53
Cloreto de sódio		7.68,76	392,07	0,11
Sal mineralizado a vontade	7,82	2.722,96	21.293,55	6,21
Total	**1,38**	**579.011,83**	**348.087,69**	**100**
		SIDNRC		
Silagem de milho	0,27	366.345,96	98.913,41	28,82
Sorgo grão moído	0,97	115.927,19	112.449,38	32,77
Farelo de soja	2,38	21.277,78	50.641,11	14,76
Óleo de soja	5,45	5.136,01	27.991,28	8,16

Núcleo mineralizado na dieta	4,01	2.201,15	8.826,61	2,57
Bicarbonato de sódio	8,00	2.201,15	17.609,19	5,13
Sal mineralizado a vontade	7,82	3.417,18	26.722,35	7,79
Total	**1,85**	**516.506,42**	**343.153,32**	**100**
		SIDAG		
Silagem de milho	0,27	91.259,60	24.640,09	6,89
Milho grão inteiro	1,36	146.607,40	199.386,07	55,72
Núcleo concentrado paletizado	3,30	25.871,89	85.370,78	23,86
Sal mineralizado a vontade	7,82	6.193,51	48.433,28	13,54
Total	**1,81**	**269.932,41**	**357.830,22**	**100**

*F1 DORPER DC = F1 Dorper x Santa Inês alimentados com dieta controle; F1 DORPER DNRC = F1 Dorper x Santa Inês alimentados com dieta formulada de acordo com NRC 2007; F1 DORPER DAG = F1 Dorper x Santa Inês alimentados com Dieta Alto Grão; SID1= Santa Inês alimentados com dieta controle, SIDNRC = Santa Inês alimentados com dieta formulada de acordo com NRC 2007; SIDAG = Santa Inês alimentadas com Dieta Alto Grão.

ANEXO C: Custos de dietas de alto concentrado utilizadas na alimentação de cordeiras F1 Dorper x Santa e Santa Inês para terminação em confinamento

Ingredientes	**R$/kg**	**Quant. Kg**	**R$ total**	**Participação (%)**
		F1 DORPER DC*		
Silagem de milho	0,27	359.292,09	97.008,86	28,64
Sorgo grão moído	0,97	107.337,13	104.117,02	30,74
Farelo de soja	2,38	297.35,29	70.769,98	20,89
Núcleo mineralizado na dieta	4,01	5.802,01	23.266,05	6,87
Bicarbonato de sódio	8,00	1.450,50	11.604,01	3,43
Cloreto de sódio	0,51	725,25	369,88	0,11
Sal mineralizado a vontade	7,82	4.040,07	31.593,31	9,33
Total	**1,57**	**508.382,34**	**338.729,12**	**100**
		F1 DORPER DNRC		
Silagem de milho	0,27	318.973,14	86.122,75	27,40
Sorgo grão moído	0,97	107.667,41	104.437,38	33,23
Farelo de soja	2,38	19.761,74	47.032,94	14,97
Óleo de soja	5,45	4.770,07	25.996,91	8,27
Núcleo mineralizado na dieta	4,01	2.044,32	8.197,71	2,61
Bicarbonato de sódio	8,00	2.044,32	16.354,54	5,20
Sal mineralizado a vontade	7,82	3.341,53	26.130,76	8,31
Total	**1,88**	**458.602,53**	**314.273,00**	**100**
		F1 DORPER DAG		
Silagem de milho	0,27	8.0637,90	21.772,23	6,44
Milho grão inteiro	1,36	142.824,06	194.240,72	57,41
Núcleo concentrado paletizado	3,30	25.204,25	83.167,71	24,58
Sal mineralizado a vontade	7,82	5.006,17	39.148,23	11,57
Total	**1,82**	**253.672,37**	**338.328,89**	**100**
		SIDC		
Silagem de milho	0,27	338813,99	91.479,78	27,80
Sorgo grão moído	0,97	100408,65	97.396,39	29,60
Farelo de soja	2,38	27815,91	66.201,86	20,12
Núcleo mineralizado na dieta	4,01	5427,49	21.764,25	6,62
Bicarbonato de sódio	8,00	1356,87	10.854,99	3,30
Cloreto de sódio	0,51	678,44	346,00	0,11
Sal mineralizado a vontade	7,82	5239,01	40.969,08	12,45
Total	**1,57**	**479.740,36**	**329.012,35**	**100**
		SIDNRC		
Silagem de milho	0,27	321.257,47	86.739,52	28,39
Sorgo grão moído	0,97	116.626,62	113.127,82	37,02
Farelo de soja	2,38	21.406,15	50.946,64	16,67
Óleo de soja	5,45	5.167,00	28.160,16	9,22
Núcleo mineralizado na dieta	4,01	2.214,43	8.879,86	2,91
Bicarbonato de sódio	8,00	2.214,43	17.715,44	5,80
Sal mineralizado a vontade	7,82	4.389,17	34.323,29	11,23
Total	**1,92**	**473.275,27**	**305.569,44**	**100**
		SIDAG		
Silagem de milho	0,27	75.490,80	20.382,52	6,13
Milho grão inteiro	1,36	137.386,52	186.845,66	56,21

Núcleo concentrado paletizado	3,30	24.244,68	80.001,38	24,07
Sal mineralizado a vontade	7,82	5.776,19	45.169,81	13,59
Total	**1,82**	**242.898,19**	**332.399,36**	**100**

*F1 DORPER DC = F1 Dorper x Santa Inês alimentados com dieta controle; F1 DORPER DNRC = F1 Dorper x Santa Inês alimentados com dieta formulada de acordo com NRC 2007; F1 DORPER DAG = F1 Dorper x Santa Inês alimentados com Dieta Alto Grão; SID1= Santa Inês alimentados com dieta controle, SIDNRC = Santa Inês alimentados com dieta formulada de acordo com NRC 2007; SIDAG = Santa Inês alimentadas com Dieta Alto Grão.