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Economic performance of high-energy diets and supplementation with chromium propionate or calcium salts of palm oil in ewes' production

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ABSTRACT - The experiment aimed to analyze the economic viability of using high-energy diets and the supplementation of chromium propionate or calcium salts of palm oil in the diet of ewes from the late gestation until the end of lactation. Seventy-two ewes of Santa Ines × Dorper crossbreeds were allocated to five treatments: CTL (n = 14) with 100% of NRC recommendation for metabolizable energy per kg dry matter intake (ME/kg DMI), LOW (n = 14) with 90% ME/kg DMI, HIGH (n = 15) with 110% ME/kg DMI, Cr (n = 15) HIGH diet plus chromium propionate, and FAT (n = 14) HIGH diet plus calcium salts of palm oil. Based on the performance data, a short-term analysis was performed for a module of 1000 ewes, evaluating costs, revenues, and profitability, and long-term analysis was performed by an additional cash flow of 120 months. The CTL and FAT treatments were not viable due to higher costs and lower revenues, and they also had a negative net present value (NPV) and internal rate of return (IRR). The LOW treatment, despite lower costs and positive profitability, had a negative NPV (-$872.90) and IRR (1.85%) that was below the discount rate, making it unprofitable in the long run. The HIGH and Cr treatments were considered feasible because they had lower unit costs and higher profitability, in addition to a high NPV ($64,894.11 and 104,902.05, respectively) and a higher IRR (9.03% and 13.65%, respectively) than the discount rate. The use of high-energy diets, with added chromium propionate, promoted better performance and, consequently, better economic return.

Keywords: economy, palm oil, profitability, reproduction, sheep

1. Introduction

The Brazilian sheep livestock trade is small compared to the large ruminants, but the herd has been growing since 2010 (FAOSTAT, 2021). However, for the national herd to become economically viable, it must overcome challenges such as low pregnancy indices, high lamb mortality rates, health problems, and inadequate nutrition, resulting in high production costs (Raineri et al., 2015b).

Strategic use of feed can increase productivity and maximize the economic profitability of lamb production (Ermias et al., 2013). Studies demonstrate the importance of updating sheep nutrient requirement tables, considering the tropical climate and the exclusive grazing system of sheep raised only on pasture (Dove, 2010; Pereira et al., 2017).

Energy intakes above the NRC (2007) can be beneficial during pregnancy and lactation by improving the behavior of the ewe with the lamb in the first hours after birth, a greater amount of colostrum, and the ewe's weight and body condition score at weaning (Campion et al., 2017; McGovern et al., 2015a; McGovern et al., 2015b). Similarly, increasing the energy content of the diet confers productive benefits, such as higher ovulation rate, a shorter interval between births, earlier pubertal age, and lower embryo loss (Rae et al., 2002; Scaramuzzi et al., 2006; Donnem et al., 2020), better fetal growth, and higher birth weaning, and slaughter weights (Kenyon and Blair, 2014; McGregor, 2017). However, a high-energy diet during pregnancy may result in obese ewes, which is also not advisable. However, it is possible to properly increase the energy content of the diet by adding starch, calcium salts of palm oil, or chromium propionate (Leiva et al., 2018).

Starch fermentation increases the amount of propionate produced in the rumen, which increases the availability of glucose in the blood through hepatic gluconeogenesis (Klevenhusen, 2019). The inclusion of fat in the diet of ruminants improves energy efficiency by directly supplying long-chain fatty acids for fatty acid synthesis (Bhatt et al., 2013). Chromium increases tissue sensitivity to insulin, improving energy efficiency (Leiva et al., 2017).

Nutritional management is an important variable influencing the success of a production system; therefore, it is important to determine the amount of energy and viable feed sources (Santos et al., 2018). To assess whether the implementation of a feed strategy is economically viable, a profitability analysis must be conducted. This will help determine whether the project can meet the expectations and requirements of investors so that the decision to invest and obtain higher returns can be made (Ojeda Rojas, 2015).

In this paper, it is hypothesized that although investments in high-energy diets can increase production costs, this value is offset by higher productivity at the end of a production cycle. The objective was to analyze the economic viability of using high-energy diets and adding chromium propionate or calcium salts of palm oil in the diet of ewes from the late gestation to the end of lactation.

2. Material and Methods

Research on animals was conducted according to the institutional committee on animal use (2700201218).

2.1. Data collection

The experiment was conducted in Pirassununga, São Paulo, Brazil, and the experimental data were used for the economic analysis. Seventy-two Dorper × Santa Ines ewes, 59.65±10 kg body weight (BW), aged two to four years, were divided into five treatments: CTL (n = 14) with 100% of NRC (2007) recommendation for metabolizable energy per kg dry matter intake (ME/kg DMI), LOW (n = 14) with 90% ME/kg DMI, HIGH (n = 15) with 110% ME/kg DMI, Cr (n = 15) HIGH diet plus chromium propionate, and FAT (n = 14) HIGH diet plus calcium salts of palm oil (Table 1). Ewes were fed the experimental diet twice a day, from 100 days of gestation to 80 days of lactation.

Table 1 - Chemical composition of feed used in experimental diets of sheep during gestation and lactation

Nutrient	Corn silage	Corn grain	Soybean meal	Calcium salts of palm oil
Dry matter (%)	26	88	91	98
Crude protein (% of DM)	7.0	9.0	40	
NDF (% of DM)	70	9	15	
ADF (% of DM)	44	3	10	
ME (Mcal/kg)	1.98	3.2	3.0	5.41
EE (% of DM)	1.3	4.3	1.6	84.5
MM (% of DM)	7	2	7	15
Calcium (% of DM)	0.35	0.02	0.38	12
Phosphorus (% of DM)	0.19	0.3	0.71	

NDF - neutral detergent fiber; ADF - acid detergent fiber; ME - metabolizable energy; EE - ether extract; MM - mineral matter.

In total, 102 lambs were born, fifty-two females and fifty males. From 10 days of age, the offspring had access to concentrates (creep feeding with 22% CP, 3.200 Mcal ME) and was weaned at 80 days of age. Ewes and lambs were vaccinated against *Clostridium* sp.

Male lambs went to the feedlot on the same day of weaning and were fed the same diet (NRC, 2007) for 56 days and slaughtered. The nutrition consisted of hay, ground corn, soybean meal, and minerals. The feed consisted of 15% hay and 85% concentrate (68% ground corn, 25% soybean meal, 5% minerals, 2% limestone, on a dry matter basis) containing 14% crude protein, 3,200 Mcal ME, and 30% NDF. The diet was controlled individually and daily.

Ewe offspring were housed in communal pens until eight months of age and fed the same diet (NRC, 2007), as this age was considered appropriate for the onset of reproductive activity. Nutrition consisted of corn silage, ground corn, soybean meal, and minerals. The total diet had 12% CP, 2.400 Mcal ME, 35% NDF, 6% minerals, and 3% ethereal extract. The body condition score, Famacha® score, and health status of the herd were monitored monthly, and the use of medication was made according to the need for each treatment. The following reproductive data were analyzed: pregnancy rate (%), prolificity, mortality to weaning (%), lamb birth weight (kg), lamb weight at weaning (kg), lamb weight at slaughter (kg), ewe weight at 8 months of age (kg), and ewes suitable for breeding (%) (Table 2).

Table 2 - Productive data of ewes in diets with different levels and sources of energy

Performance	Treatment					SEM	P-value
	LOW	CTL	HIGH	Cr	FAT		
Birth weight (kg)	3.8b	4.4a	4.2a	4.3a	4.5a	0.11	0.0022
Weaning weight (kg)	18.71b	22.27a	21.17a	25.68a	22.82a	0.73	0.0191
Lamb slaughter weight (kg)	42.38	47.13	42.90	46.81	44.75	2.30	0.7891
Lamb weight at eight months (kg)	43.52b	53.15a	47.85a	52.57a	49.32a	1.17	0.0105
Pregnancy rate (%)	100	100	100	100	92.85	1.98	0.3396
Prolificity	1.43	1.36	1.53	1.53	1.23	0.06	0.5729
Mortality until weaning (%)	20c	0a	0a	4.4b	0a	1.58	0.0069
Ewe lambs suitable for breeding (%)	66.7c	100a	100a	100a	75b	0.77	0.007

LOW: 90% of predicted metabolizable energy (ME) requirement; CTL: 100% of predicted ME requirement; HIGH: 110% of predicted ME requirement with starch as the energy source; Cr: HIGH plus chromium propionate; FAT: HIGH plus calcium salts of palm oil.
a-b - Values within a row with different letters differ significantly at $P<0.05$.

2.2. Economic-financial analysis

An economic and financial analysis was conducted for each treatment with a short- and long-term focus, using performance data from ewes and progeny (Table 2). The short-term analyses included calculation of contribution margin (CM = total revenue − variable costs), contribution margin per kg (CMU = CM/total kg produced) (Padoveze, 2013), profit (P = total revenue − total costs), profit per kg (PU = profit/total kg produced) for the period of one year (Mankiw, 2014), representative of one production cycle. The production system started with 100 sheep and was considered stabilized when it reached a total number of 1000, a reasonable value for a flock for meat production. Therefore, the surplus of sheep was sold. For the long-term analysis, a monthly cash flow (HR) was elaborated until reaching 120 months. The experimental values obtained with the different feeds were used to calculate the evolution of the flock. The replacement was carried out only with lambs born in the flock, and after their stabilization, the surplus was sold. After the fifth year, a replacement rate of 20% per ewe per year was used. The rate of one male per 50 females was used during breeding (Stivari et al., 2013).

From the cash flow, the indicators of net present value (NPV), internal rate of return (IRR), and simple amortization were calculated according to Gitman et al. (2015), considering the annual discount rate of 2% (Selic) and the period for stabilization of the flock (PS), considered as the time in months to reach 1000 ewes, which was set as the endpoint of the study in this project. The Selic is the prime rate of the economy. It is the main monetary policy tool used by the Banco Central do Brasil (BCB) to control inflation. It affects all interest rates in the country, such as those on loans, financing, and financial investments (BCB, 2021). The initial investment was $27,778.00 for all treatments, considering the purchase of the first 100 ewes and the necessary equipment (tractor, fence, and other equipment). All animals in the flock were sold at the end of the 120th month for $0.92/kg body weight.

Production costs were divided into variable (feed and veterinary costs) and fixed (labor, depreciation, equipment maintenance and repair, taxes, capital, and land rent) costs. For more details on this calculation, see Raineri et al. (2015c).

Prices for hay ($0.005/kg), corn ($0.15/kg), soybean meal ($0.33/kg), limestone ($0.03/kg), and minerals ($1.04/kg) were obtained from the Instituto de Economia Agrícola (IEA, 2021), and prices for calcium salts of palm oil ($1.11/kg) and chromium propionate ($4.63/kg) in the feed industry (Kemin Industries Inc, Valinhos, São Paulo, Brazil). The price of giving milk to newborns ($0.26/kg) was obtained from the Center for Advanced Studies in Applied Economics database (CEPEA, 2021) for the São Paulo region. However, the values for the vaccine ($0.30/dose) and deworming ($0.014/dose) were obtained from an agricultural store in the state of São Paulo. The National Consumer Price Index (IGP - DI/FGV) was used as a reference for the deflated values for September 2020.

Considering the sales value of the region of Pirassununga, SP, the proceeds were calculated with the sale of live lambs ($1.75/kg BW) (CEPEA), the sale of animals for disposal ($0.74/kg BW) and the sale of an eight-month-old young female ($1.48/kg BW). The amount of $1.00 is equivalent to R$5.4 (Brazil). Excel® (Microsoft Corporation, 2010) was used for herd development and economic calculations, and results were compared using descriptive statistics.

3. Results

The LOW treatment had the lowest variable cost ($51,226.22), total cost ($54,567.02), and cost per kg/animal produced ($1.32). The HIGH and Cr treaments had similar variable costs ($104,368.66 and $107,336.61, respectively), total costs ($107,709.46 and $110,677.41, respectively), and average costs ($1.64 and $1.54, respectively). The CTL and FAT treaments were the most expensive, with the average cost of producing one kilogram of the animal from the CTL treatment being $2.11 and $1.97 for FAT (Table 3).

The total revenues of LOW were the lowest ($69,145.83), followed by FAT ($86,831.24), CTL ($110,066.20), HIGH ($117,354.84), and Cr with the highest revenues ($128,947.42).

In the short-term analysis for a module of 1000 ewes, CTL and FAT were negative, and their values were close to each other, so that the profit per unit (profit/total kg produced) was −$0.23 and −$0.27, respectively.

The contribution margin (CM = total revenue − variable cost) and profit (P = total revenue − total cost) of LOW were intermediate (CM = $17,919.60 and P = $14,578.80) between the HIGH (CM = $ 12,986.17 and P = $9,645.38) and Cr (CM = $21,610.81 and P = $18,270.00). The values per unit of kg produced were higher for LOW (CMU = $0.43 and PU = $0.36), followed by Cr (CMU = $0.30 and PU = $0.26) and HIGH (CMU = $0.20 and PU = $0.15).

In the incremental cash flow analysis, the NPV and IRR of CTL and FAT were negative, and there was no simple payback for the specified 120-month period. The LOW had a negative NPV and IRR lower than the rate of return (2%), and the payback did not occur until the end of the project when all the animals were sold. Therefore, they are not considered economically viable.

The Cr had the best NPV ($104,902.05), IRR (13.65% per year), and simple payback (101st month), followed by the HIGH treatment with an NPV of $64,894.11, IRR of 9.03% per year, and simple payback in the 113th month.

The herd period of stabilization (PS) was 45 months for the CTL and HIGH treatments, 53 months for Cr, 69 months for FAT, and 85 months for the lowest energy treatment (LOW).

Table 3 - Annual economic-financial ($/year) and long-term (120 months) analyses of ewes fed different levels and energy sources, for modules of 1000 ewes

	Treatment				
	LOW	CTL	HIGH	Cr	FAT
Expense ($)					
A - Variable costs	51,226.22	120.999.25	104,368.66	107,336.61	97,761.36
B - Fixed costs	3,340.80	3,340.80	3,340.80	3,340.80	3,340.80
C - Total cost (A + B)	54,567.02	124,340.05	107,709.46	110,677.41	101,102.16
D - Average cost ($)/kg BW	1.32	2.11	1.64	1.54	1.97
Revenue ($)					
Sale of live finished lambs	26,026.62	43,615.29	54,986.90	78,109.20	45,027.82
Sale of replacement ewes	30,813.35	60,895.36	56,812.38	45,393.77	31,069.59
Sale of discard animals	12,305.85	5,555.55	5,555.55	5,555.55	10,733.82
E - Total revenue	69,145.83	110,066.20	117,354.84	128,947.42	86,831.24
F - Average revenue ($)/kg BW	1.67	1.87	1.79	1.80	1.70
G - Total produced (kg)	7,674.34	10,908.44	12,161.12	13,266.19	9,479.39
Short-term viability (annual)					
H - Contribution margin (E – A) ($)	17,919.60	−10,933.05	12,986.17	21,610.81	−10,930.12
I - Contribution margin per unit (H/G) ($/kg)	0.43	−0.18	0.20	0.30	0.21
J - Profit (E – C) ($)	14,578.80	−14,273.85	9,645.38	18,270.00	−14,270.92
Profit per unit (J/G) ($/kg)	0.36	−0.23	0.15	0.26	−0.27
Long-term viability (120 mouths)					
NPV ($)	−872.90	−217,950.42	64,894.11	104,902.05	−269,623.72
IRR (per year) (%)	1.85%	−24.27%	9.03%	13.65%	−38.06%
Simple payback (months)	120	-	113	101	-
PS (months)	85	45	45	53	69

LOW: 90% of predicted metabolizable energy (ME) requirement; CTL: 100% of predicted ME requirement; HIGH: 110% of predicted ME requirement with starch as the energy source; Cr: HIGH plus chromium propionate; FAT: HIGH plus calcium salts of palm oil.
BW - body weight; NPV - net present value; IRR - internal rate of return; PS - herd stabilization period, considering the time, in months, to reach 1000 ewes.

4. Discussion

The PS of the herd, considered as the time in months required to reach 1000 ewes, takes into account performance indices. Because the LOW treatment had higher mortality (20%) and a lower percentage of lambs fit for breeding (66.7%), it took longer to reach 1000 ewes, almost twice as long as CTL and HIGH. Neonatal mortality has a major impact on herd profitability (Byrne et al., 2010; Reijers et al., 2019). The FAT treatment showed lower reproductive rates such as pregnancy rate (92.85%), prolificacy (1.23 lambs/sheep), and lambs able to reproduce (70%) and, therefore, had a higher PS. The treatments HIGH and Cr showed a higher prolificity rate and low mortality rate, resulting in more animals for slaughter and young ewes available for breeding.

As expected, the LOW treatment had lower variable costs, total costs, and costs per kg of animal produced due to the absence of investment in feed, representing 63.17% of the total costs of animal production (Raineri et al., 2015b). The similarity of costs between the HIGH and Cr treatments was also expected since the difference was only in the inclusion of chromium propionate in 0.1% of the concentrate feed.

No higher cost with feed was not expected for the CTL treatment. However, the higher intake of corn silage in the control treatment was the main reason for the increase in variable costs and consequently in total and average costs. Silage costs for the CTL treatment were $84,251.49, while for the HIGH, Cr, and FAT treatments they were $56,204.65, $56,938.88, and $59,227.72, respectively. For the FAT treatment, the highest cost was found to be the addition of calcium salts of palm oil, which increased the total cost of the diet by $2,400 per year. Chromium intake can also lower DMI (Domínguez-Vara et al., 2009), thereby reducing silage intake costs.

According to the Índice de Custo de Produção do Cordeiro Paulista (Lamb Production Cost Index of São Paulo), updated monthly by the Laboratório de Análises Socioeconômicas e Ciência Animal (Laboratory of Socioeconomic Analysis and Animal Science (LAE)) of the University of São Paulo, in September 2020, the average cost of lamb production in the state of São Paulo was $2.34/kg BW. In this experiment, all treatments had an average production cost per kg of live animal lower than the average for the state of São Paulo, probably due to differences in nutritional management. Feed cost is the main variable responsible for the total cost, not only in Brazilian production (Barros et al., 2009; Viana and Silveira, 2009; Lôbo et al., 2011; Paim et al., 2011; Ziguer et al., 2011; Raineri et al., 2015b; Romanzini et al., 2018; Santos et al., 2018; Reijers et al., 2019) but also in other countries (Stott et al., 2005; Hilali et al., 2011; Bohan et al., 2018; Demirhan, 2019). The price of lamb meat in Australia for the year 2020-2021 was 784 cents/kg, which corresponds to approximately $5.68/kg (Abares, 2021).

Few studies analyzed the profitability in sheep production and, the majority chose to disregard some production costs (opportunity cost of land, pasture, others) by option or ignorance (Raineri et al., 2015a). Viana and Silveira (2009) carried out an economic analysis of sheep farming (meat and wool) in the region of Rio Grande do Sul, Brazil, and concluded that it was a profitable activity due to the positive balance of operating income, but it does not compensate for the opportunity costs of the main factors of production (land and capital). Toro-Mujica et al. (2011) assessed the economic viability of dairy sheep properties in Spain and concluded that 45% of the properties were non-viable and needed a better balance between the use of feeding supplements and the sheep productive capacity. Barros et al. (2009) analyzed the profitability of sheep production in pasture and feedlot, with or without weaning, which showed a positive gross margin only when there was no use of feedlot, but did not obtain an economic return, NPV was negative, and IRR lower than the discount rate, concluding that none of the scenarios were viable, because the productive indices were unsatisfactory. This information, and our results, show the importance of fetal programming and of focusing on improving progeny production rates for economic success.

Lamb is a commodity and, therefore, producers cannot control the price of the product they sell, so they need to manage variables that are under their control, such as the opportunity to purchase supplies, genetic improvement, obtain better reproductive rates with correct management, use sanitary protocols for disease control, and reduction of mortality and production cost (Raineri et al., 2015b). Therefore, the implementation of new technologies, mainly nutritional, capable of reducing costs and increasing revenue are necessary (Santos et al., 2018). The HIGH and Cr treatments demonstrated that the supply of diets with a higher energy level and with chromium supplementation, not only decrease the total cost but also improves the economic return, due to higher productivity, e.g., higher indices of prolificity.

This positive result of nutritional supplementation on economic return was also described by Santos et al. (2018), who stated that nutritional supplementation of ewes and lambs promoted an increase in the animal stocking rate and had a positive economic return. Supplementation nutrition also provides a high level of ewe reproductive performance, which brings a significant economic return (Atsan et al., 2007), and profitability is mainly affected by revenues which, in turn, is mainly affected by productivity (Gazzarin and Benni, 2020). The increase in any performance indicator has a greater impact on production profitability than any increase in the prices of inputs used in the diet (Raineri et al., 2015b). The traits with higher economic importance are carcass yield, number of lambing per year, and lambing percentage (Kosgey et al., 2003; Lôbo et al., 2011).

For the investment to be considered viable, NPV has to be greater than zero, that is, the expected flow of revenues must be higher than the investment that generated it and the IRR should be higher than the savings account, for example (Pinheiro Rogério et al., 2019). In the short-term analysis, in a module with 1000 ewes, the LOW treatment seems viable, due to the positive unit profit. However, in the long-term analysis, the NPV is negative and the IRR is lower than the discount rate. The payback occurs only in the last month, with the sale of the entire remaining herd. Throughout the analyzed period (months 0-119), the accumulated cash flow is negative; therefore, it is not a promising project. Although the LOW treatment seems to be profitable, the accumulated losses until reaching 1000 ewes (PS = 85 months) can only be recovered with the sale of all animals in the last month, confirming that this treatment is not promising.

The CTL and FAT treatments were not economically viable either in the short or long term. In the short term, both have no contribution margin, that is, the revenues cannot pay the costs with feed and medicine (variable costs). The variable costs of these treatments were higher, while the total production of kg produced was not as big enough as the other treatments, so they did not reach the expected return. The high cost of CTL and FAT treatments is due to the high price of nutrition with return on the sale of female lambs and meat production similar to or worse than the HIGH and Cr treatment.

In contrast, both HIGH and Cr treatments were economically viable. The Cr treatment proved to be the most economically profitable, with a high NPV (4.6% higher than the HIGH treatment) and an IRR seven times higher than the Selic rate (2%), while the HIGH treatment showed an IRR of almost five times greater than Selic. These treatments produced more sheep to increase herd and meat production.

The simple payback was calculated considering the annual discount rate of 2% of Selic, and the period, in months, to reach 1000 sheep. Treatment with Cr had the fastest payback, with eight years to recover the amount invested. However, in the literature, simple payback is found above 10 years, as described by Pinheiro Rogério et al. (2019), with the Morada Nova breed supplemented with dairy residue, similarly as in the project by França et al. (2011) in a system involving agriculture, livestock, and wood production, called agroforestry.

5. Conclusions

The increase in the energy level in the diet of ewes has a positive response on the performance of ewes and their progeny, therefore, with the economic return. The use of chromium propionate in sheep supplementation presents better financial benefit in the long term because it presents better productive and reproductive indices. Non-supplementation, despite having low cost, is not feasible to the production system in the long term, as it results in a smaller amount of product for sales, such as live animals or meat production, therefore generating less profit.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: F.F. Santos and S.B. Gallo. Data curation: F.F. Santos. Formal analysis: F.F. Santos, R.A. Nacimento and A.H. Gameiro. Funding acquisition: F.F. Santos. Investigation: F.F. Santos, L. Brochine, F.M. Moreira and S.B. Gallo. Methodology: F.F. Santos and A.H. Gameiro. Project administration: F.F. Santos and S.B. Gallo. Resources: S.B. Gallo. Software: R.A. Nacimento and A.H. Gameiro. Writing – original draft: F.F. Santos, R.A. Nacimento, F.M. Moreira, A.H. Gameiro and S.B. Gallo. Writing – review & editing: F.F. Santos, A.H. Gameiro and S.B. Gallo.

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