Original Article

STOCHASTIC SIMULATION OF THE ECONOMIC VIABILITY OF FEEDLOT FINISHING STEERS SLAUGHTERED AT DIFFERENT WEIGHTS IN SOUTHERN BRAZIL

SIMULAÇÃO ESTOCÁSTICA DA VIABILIDADE ECONÔMICA DA TERMINAÇÃO DE NOVILHOS EM CONFINAMENTO ABATIDOS COM DIFERENTES PESOS NO SUL DO BRASIL

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ABSTRACT: The objective of this study was to evaluate the use of stochastic simulations in decision-making regarding the economic viability of feedlot finishing Charolais steers slaughtered at different weights (420, 460 or 500 kg live weight). Monte Carlo simulation was used, with or without Spearman correlation, to evaluate the risk associated with random input variables, and to compare the curves of pairs of slaughter weights by stochastic dominance. The financial indicator net present value (NPV) was the output variable. The expected means and standard deviations for the slaughter weights of 420, 460 and 500 kg were USD 28.77 ± 53.90; USD 36.27 ± 57.22 and USD 54.60 ± 66.74 for simulation with correlation, and USD 28.75 ± 96.15; USD 36.17 ± 103.11 and USD 54.53 ± 111.96 for simulation without correlation. The simulations without correlation were found to overestimate the standard deviation by 75% compared to simulations performed in addition to correlation analysis. The correlation between random input variables should be prioritized, as this resulted in better estimates of risk associated with investment. For all simulated situations, the lowest slaughter weights dominated the largest, according to the first- and second-order stochastic dominance criteria. For the simulation with correlation, the probability of NPV $\geq$ 0 was 29.4, 24.4 and 19.4% for slaughter weights of 420, 460 and 500 kg, respectively. Interpretation of these simulations allowed classification of feedlot technology as high risk, with a high probability of economic loss.

KEYWORDS: Decision-making. Monte Carlo simulation. Investment projects. Nonparametric statistics

INTRODUCTION

In Brazil, beef cattle production practices are constantly changing to meet demand for animals with a certain standard carcass quality. Among the available and accessible options from a technical point of view, feedlot is one technology with the potential to meet this demand. Between 2006 and 2015, the number of feedlot-finished animals increased by 105%, with an estimate of 4.5 million animals in 2015 (ANUALPEC, 2015). The advantages of feedlot include production of animals for slaughter in the off-season, in addition to reduced idleness in the slaughterhouse. In addition, feedlots benefit the production system both directly and indirectly by reducing the age of animals at slaughter, increasing working capital and allowing better use of pastures.

The slaughter weight is related to feeding time, food consumption, marketing time and expenses, therefore, determining the slaughter weight of animals is an important decision as it reflects the economic viability of feedlot.

Because feedlot represents a technology that requires a large amount of financial resources, making decisions about whether or not to invest can be facilitated using simulations that apply mathematical and statistical concepts to quantify the risk associated with investment in a particular project. This type of simulation is a relatively unexplored method in animal production compared with other areas of science, indicating the need to further expand this interesting line of research. Stochastic dominance and correlation amongst input variables are methodological alternatives that assist in decision-making and risk quantification, respectively. The mathematical details for the use of these models and examples of their application have been described in the literature (HANOCH; LEVY, 1969; EVANS; OLSON, 1998; HARDAKER et al.,

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2004; MUN, 2006; ALBRIGHT et al., 2010), however, studies evaluating the impact of the use, or lack thereof, in beef cattle production has been little explored (PACHECO et al., 2014).

The objective of this study was to evaluate the use of stochastic simulation for decision-making regarding the economic viability of feedlot-finished Charolais steers of different weights, using models of stochastic dominance with or without correlation between input variables.

MATERIAL AND METHODS

The study was conducted at the Department of Animal Science, Federal University of Santa Maria, Rio Grande do Sul, Brazil (29° 43' S and 53° 42' W).

Information regarding performance during the feeding stage of feedlot was obtained from eighteen Charolais steers with an average initial age of 30 months and initial weight of 297.0 ± 11.5 kg, all obtained from the same experimental herd.

The diet contained 12% crude protein and 67.84% total digestible nutrients based on dry matter (DM), consisting of crushed sugarcane (43.00%), ground sorghum grain (35.00%), defatted rice bran (14.30%), soybean meal (4.70%), minerals (1.44%) and urea (0.71%). The animals were fed twice daily in the morning and afternoon. The forage and concentrate were mixed at the time of administration. Steers were allowed to adapt to the diet and management for 14 days, after which the animals were randomly distributed into pens with three steers in each (10 m^2/animal), equipped with a trough and water drinker.

Each feedlot began in June, and animals were sold once they had reached the predetermined slaughter weights of 420, 460 or 500 kg. The final weights obtained were 421 ± 45.0, 461 ± 29.1 and 495 ± 17.8 kg, respectively. The total feeding period was 110, 145 and 184 days for these weights, respectively, and the average values for fat thickness obtained were 2.4 ± 1.0, 2.6 ± 1.8 and 5.4 ± 1.0 mm. Only animals in the highest slaughter weight group had a subcutaneous fat thickness above the threshold (3 mm) recommended by Brazil's slaughterhouse industry. The average daily weight gain (1.11 ± 0.10 kg/day) and DM intake (9.63 ± 0.3 kg/day) was similar ($P > 0.05$) among slaughter weights.

According to the methodology described by Pacheco et al. (2014), a historical series of average prices in the state of Rio Grande do Sul between 2004 and 2014 was used. These prices were obtained from both public and private companies (CONAB, National Supply Company; IEA, Institute of Agricultural Economics of São Paulo; EMATER/RS-ASCAR, Enterprise Technical Assistance and Rural Extension of the Rio Grande do Sul state; and ANUALPEC, Yearbook of Brazilian Livestock). All estimates were made per animal per year, deflated for the year 2014 by the general price index (internal availability calculated by the Getúlio Vargas Foundation). For currency exchange purposes, R$ 1.00 was considered to be equal to USD 0.32.

The cost items included: purchase of cattle, forage and concentrate, labor, health, opportunity (invested capital, land and machines, implements and facilities) depreciation (machinery, implements and facilities), and other operating expenses. Revenue items (only for finished cattle) were associated with performance traits obtained during the feeding period, including the initial and final weight, average daily weight gain and daily DM intake. The cost of facilities was estimated for a static capacity of 1000 animals with a lifespan of 10 years. Depreciation of the facilities, machinery, implements and equipment was calculated on a per year basis. The costs consisted of sanitary control products to control endo- and ectoparasites, analgesics and anti-inflammatories, antibiotics, and vaccinations for foot-and-mouth disease, clostridium and botulism, the dosage of which was calculated per animal according to the manufacturer's recommendations. The feed cost was calculated as the product of the total intake of forage DM and concentrate (kg DM/animal) for the respective cost/kg DM. For cost estimates of skilled labor, we considered the requirement for one laborer/500 feedlot steers. Other operating expenses, such as maintenance of facilities, machinery, implements and equipment, fuel, electricity, freight transportation, taxes and feeding labor, were estimated as the equivalent of 2.5% of operating expenses.

The output variable was the net present value (NPV; USD/animal), which was described by the following equation $\sum_{i=1}^{n} \frac{values_i}{(1+rate)^i}$, where *n* is the number of months, *i* is the n^{th} time period in which money is invested in the project, *rate* is the minimum rate of attractiveness, and *values* represent the net revenue. Cash flow was prepared for animals in each slaughter weight group with a planning horizon of one year, with or without correlation between input variables, considering separate investment projects.

Microsoft® Excel (Redmond, WA, USA), @Risk® (Ithaca, NY, USA) and SAS® System

(Cary, NC, USA) software were used for risk assessment and determination of stochastic dominance.

After deflating the values for 2014, the following steps were taken: (1) determination of the probability distribution of best fit for the following cost items, revenue and animal performance variables (input variables), feeder steer (USD/kg), finished steer (USD/kg), minimum wage (USD/month), forage (USD/kg DM), concentrate (USD/kg DM), facilities/equipment (USD/animal/day), machinery/implements (USD/animal/day), health (USD/animal), forage intake (kg DM/day), concentrate intake (kg DM/day), land (USD/ha) and average daily weight gain (kg/animal) (Table 1); (2) determination of Spearman's correlation coefficient between random input variables (Table 2); and (3) stochastic simulation of the output variables (NPV) with and without inclusion of correlations between the random input variables.

Table 1. Probability distributions for cost and revenue items, according to the slaughter weight.

Item	Slaughter weight, kg	Probability distribution
Feeder steer (USD/kg)	420; 460; 500	Weibull (0.603;0.468)
Finished steer (USD/kg)	420	Weibull (1.753;0.777)
	460	Logistic (1.161;0.088)
	500	Logistic (1.159;0.095)
Minimum wage (USD/month)	420; 460; 500	ExtvalueMin (2.074;23.744)
Land (USD/ha)	420; 460; 500	Invgauss (844.608;1133.888)
Forage (USD/kg DM)	420	Extvalue (0.135;0.022)
	460	Extvalue (0.148;0.022)
	500	Extvalue (0.158;0.022)
Concentrate (USD/kg DM)	420; 460; 500	Pareto (2.705;0.159)
Facilities/Equipments (USD/animal/day)	420; 460; 500	Logistic (164.042;10.469)
Machinery/Implements (USD/animal/day)	420; 460; 500	Logistic (56.668;10.433)
Health (USD/animal)	420; 460; 500	Uniform (0.435;2.237)
Average weight gain (kg/animal/day)	420; 460; 500	Normal (1.3;0.131)
Roughage intake (kg DM/animal/day)	420; 460; 500	Normal (4.14;0.41)
Concentrate intake (kg DM/animal/day)	420; 460; 500	Normal (5.49;0.55)
Discount rate (% a.m)	420; 460; 500	RiskTriang(0.004;0.006;0.011)

Table 2. Spearman correlation coefficients among the items of cost to slaughter weights.

Items*	Slaughter weight, kg	1	2	3	4	5	6	7	8
2	420	0.74†							
	460	0.78†							
	500	0.78†							
3	420	0.72‡	0.65‡						
	460	0.72‡	0.85†						
	500	0.72‡	0.85†						
4	420	0.7‡	0.47	0.85†					
	460	0.7‡	0.74†	0.85†					
	500	0.7‡	0.74†	0.85†					
5	420	-0.61‡	-0.34	-0.18	-0.06				
	460	-0.61‡	-0.19	-0.18	-0.06				

	500	-0.61‡	-0.19	-0.18	-0.06				
6	420	-0.16	-0.43	-0.53§	-0.19	-0.19			
	460	-0.16	-0.58§	-0.53§	-0.19	-0.19			
	500	-0.16	-0.58§	-0.53§	-0.19	-0.19			
7	420	-0.80†	-0.64‡	-0.98	-0.9†	0.25	0.44		
	460	-0.80†	-0.84†	-0.98	-0.9†	0.25	0.44		
	500	-0.80†	-0.84†	-0.98	-0.9†	0.25	0.44		
8	420	-0.79†	-0.59§	-0.97	-0.92	0.24	0.34	0.99	
	460	-0.79†	-0.8†	-0.97	-0.92	0.24	0.34	0.99	
	500	-0.79†	-0.8†	-0.97	-0.92	0.24	0.34	0.99	
9	420	-0.54§	-0.3	-0.86†	-0.87†	-0.07	0.47	0.89†	0.88†
	460	-0.54§	-0.62‡	-0.86†	-0.87†	-0.07	0.47	0.89†	0.88†
	500	-0.54§	-0.62‡	-0.86†	-0.87†	-0.07	0.47	0.89†	0.88†

1) Feeder cattle (USD/kg); 2) Finished cattle (USD/kg); 3) Minimum wage (USD/month); 4) Land (USD/ha); 5) Roughage (USD/kg DM); 6) Concentrate (USD/kg DM); 7) Facilitiess/Equipment (USD/animal/day); 8) Machinery/Implements (USD/animal/day); 9) Health (USD/animal).
† P < .01; ‡ P < .05; § P < .10.

The Monte Carlo method was used for the NPV simulation, with Latin hypercube sampling and a Mersenne Twister random number generator with 2000 iterations.

Pairs of cumulative probability distributions of simulated NPV between slaughter weights, with or without correlation, were compared according to first- and second-order criteria (HADAR; RUSSELL, 1969; HANOCH; LEVY, 1969; HARDAKER et al., 2004). Significant differences were identified using the asymptotic Kolmogorov-Smirnov test (CONOVER, 1999).

RESULTS

Higher slaughter weights resulted in an increase in all descriptive statistics presented in Table 3. Regardless of whether or not the correlation was included, the minimum values were all negative with a magnitude larger than the maximum values, which in turn were all positive.

Table 3. Net Present Value Statistics (USD/animal), simulated with or without correlation among input variables, according to slaughter weight.

Correlation	With			Without		
Slaughter weight, kg	420	460	500	420	460	500
Minimum	250.92	422.57	568.01	370.16	419.46	517.73
Maximum	126.86	159.93	158.30	235.27	522.99	393.98
Expected mean	28.77	36.27	54.60	28.75	36.17	54.53
Standard deviation (SD)	53.90	57.22	66.74	96.15	103.11	111.96
NPV ≥ 0	31.3%	25.2%	18.7%	41.2%	37.8%	31.7%

Values of the expected NPV average were negative for all slaughter weights, and increased linearly with increasing slaughter weight, i.e., the higher the slaughter weight, the more feasible feedlot-finished animals become. A similar trend was observed for the standard deviation (SD), demonstrating that the risk associated with the investment projects (slaughter weight) were greater as the slaughter weight increased. The average SD for all slaughter weights in simulations with and without the correlation was USD 58.70 and 104.34, respectively, representing a relevant difference in the perception of risk involved with feedlot technology.

The probabilities of NPV were positive (NPV ≥ 0), resulting in economic viability, however, this showed little significance and decreased with increasing slaughter weight. The values ranged between 18.7% (500 kg with correlation) and 41.2% (420 kg without correlation). Considering the average of all slaughter weights, the probabilities were 25% for the simulation with correlation and 37% for the simulation without correlation, representing a difference of 47%.

Comparison between the probability distribution curves (Figure 1) of the NPV for the different slaughter weights, determined by the stochastic dominance analysis (Table 4), showed that all were significantly different (P < 0.0001). For simulations with the correlation, the domain was first-order for all pairs of compared curves, where the lighter slaughter weights were dominant over the heavier weights.

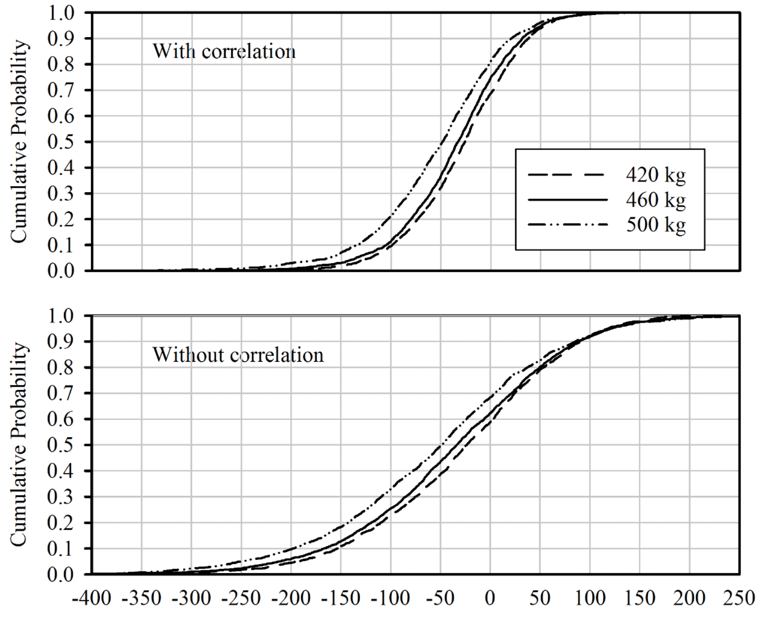

Figure 1. Distribution of cumulative probability in the simulation of Net Present Value (NPV) with or without correlation among the input variables, according to slaughter weight.

Table 4. Stochastic dominance and domain type, according to the Kolmogorov-Smirnov asymptotic test (KSa) in comparison of pairs of probability distributions of slaughter weight, with or without correlation among the input variables for the simulated Net Present Value.

Slaughter weights, kg	With correlation		Domain*	Type of dominance[T]
	KSa statistic	Pr>KSa		
420 vs. 460	2.86	<.0001	F	>
420 vs. 500	7.85	<.0001	F	>
460 vs. 500	5.94	<.0001	F	>
	Without correlation			
	KSa statistic	Pr>KSa		
420 vs. 460	2.39	<.0001	F	>
420 vs. 500	5.23	<.0001	F	>
460 vs. 500	3.82	<.0001	F	>

*F: first order stochastic dominance; [T] >: first slaughter weight dominates the second slaughter weight.

DISCUSSION

The stochastic analysis proved to be an important decision-making tool in intensive beef cattle production systems. The interpretation of descriptive statistics of the simulated financial indicator NPV (output variable) can be used to assist in the decision-making process for investment projects. For example, a less risk-averse investor would choose the feedlot of animals with higher slaughter weights, taking into account the maximum values (Table 3), while other more risk-averse investors would not make the same decision. Another explanation considers two segments (farmers and industries) of the beef cattle production chain, where cattle feedlot finishing with lower slaughter weights mainly benefits the farmer, given that this minimizes production costs, whereas a higher slaughter weight will benefit the industry by diluting the fixed operational costs of the slaughter process.

One of the most interesting benefits of probabilistic analysis of investment projects is the ability to quantify not only the average values for output variables, but also the risk associated with this estimate, statistically represented by the SD. The greater the SD, the greater the range of possible values around the mean for the output variable, and consequently, a higher possibility of scenarios occurring below the most expected values (mean). Therefore, it is important to evaluate methodologies aimed at improving the responses of models, resulting in more precise estimates. Mun (2006) and Albright et al. (2010) demonstrated that the choice of sampling, the type of probability distribution and/or the use of correlations between the random input variables determine the quality of the results obtained from the simulation. However, there is still limited knowledge regarding the application of these simulations to evaluate beef cattle production techniques. Pacheco et al. (2014) analyzed the use of Monte Carlo simulations on the economic viability of reducing the age at slaughter of feedlot-finished beef cattle, and developed a model for evaluating costs and revenues, considering past prices. They concluded that slaughter at younger ages was more likely to be economical, and simulation using correlations was the best method for estimating risk.

In the present study, the mean, SD and NPV ≥ 0 suggested that none of the proposed slaughter weights were important from an economical point of view. This result is particularly relevant for decision-making related to feedlot investments in Brazil, which provides a significant contribution to global beef production, where confined males are generally slaughtered at approximately 500 kg (MILLEN et al., 2009; COSTA JUNIOR et al., 2013). If we consider analysis of the direct benefits of application of feedlot techniques, only an unconcerned investor/farmer with small probability of return on invested capital apply financial resources in the feedlot activity.

Using correlation in addition to the NPV simulation resulted in better risk estimates and a substantial reduction in SD. Considering the average SD of all slaughter weights, the risk was overestimated by 75%.

In a previous study that evaluated engineering costs stimulated using the Monte Carlo method, Wall (1997) concluded that including correlations between random input variables was more important than the choice of probability distribution (lognormal or beta). In another study, Yang (2005) reported increased SD and underestimation of the unit cost of the project when correlations were not included in the simulation analysis. By quantifying the impact of the inclusion of correlations of data quality with simulations in beef cattle production systems, Pacheco et al. (2014) showed that the use of correlations resulted in a reduction in SD estimates between 43 and 57%, which was dependent on the age of animals at slaughter.

The results presented in the current study allow us to suggest that, prior to the application of feedlot techniques, simulations should be performed to evaluate decision-making for investment projects. Previous studies used a simulation technique to assist decision-making in a wide range of studies involving beef cattle, specifically for the evaluation of production systems (DOREN et al., 1985), mating systems (JOHNSON; JONES, 2008), beef cattle production forecasting (JAI SANKAR et al., 2010), silage energy concentration and price (BONESMO; RANDBY, 2011), feeding strategies for finishing steers (PERILLAT et al., 2004), cull cows (MINCHIN et al., 2010) and other examples described by Hardaker et al. (2004).

The use of stochastic dominance criteria to complement the risk analysis, described by Hadar and Russell (1969), Hanoch and Levy (1969) and Hardaker et al. (2004), presents interesting theoretical approaches for the analysis and interpretation of this method. For the dominance criteria considered in this study, the first-order domain was predominant, characterized by investments in which investors prefer a higher return. The lower slaughter weights dominated the larger, indicating less economic impairment at lighter slaughter weights. In the study by Pacheco et al. (2014), which evaluated the economic viability of feedlot steers at two slaughter ages under risk conditions, a slaughter age of 15 months dominated in the first-order over 22 months in the simulation with correlation, which was second-order in the simulation without correlation.

Thus, we verify that methodological refinement through the use of correlations can modify the results related to the perceived risk.

However, we experienced difficulty in estimating and/or obtaining coefficients for the cost and revenue items related to the finishing feedlot cattle, which was made possible in this study by analyzing changes in price over 11 consecutive years (2004 to 2014).

CONCLUSIONS

The stochastic simulation method is a valuable tool in the decision-making process, and the use of these simulations should be expanded in studies involving beef cattle feedlot.

Regarding the methodological aspects of simulation, the use of correlations between the random input variables is preferable. Considering the simulations and stochastic dominance criteria, feedlot technology was classified as being high risk, with a high probability of economic loss.

RESUMO: O objetivo deste estudo foi avaliar o uso de simulação estocástica na tomada de decisão sobre a viabilidade econômica da terminação em confinamento de novilhos Charolês abatidos com diferentes pesos (420, 460 ou 500 kg de peso vivo). O método de Monte Carlo foi utilizado para avaliar-se o risco com o uso ou não de correlação de Spearman entre as variáveis aleatórias de entrada, e comparar as curvas de pesos de abate pela dominância estocástica. O indicador financeiro Valor Presente Líquido - VPL foi a variável de saída. As médias esperadas e respectivos desvios padrão para os pesos de abate de 420, 460 e 500 kg foram de USD 28,77 ± 53,90; USD 36,27 ± 57,22 e USD 54,60 ± 66,74 para simulação com correlação e USD 28,75 ± 96,15; USD 36,17 ± 103,11 e USD 54,53 ± 111,96 para simulação sem correlação. As simulações sem o uso de correlação superestimaram o desvio padrão na ordem de 75%, em relação as simulações com uso de correlação. O uso da correlação entre variáveis aleatórias de entrada deve ser priorizado, pois resulta em melhores estimativas do risco associado ao investimento. Em todas as situações simuladas, os menores pesos de abate dominaram os maiores, de acordo com o critério de primeira e segunda ordem de dominância estocástica. Na simulação com correlação, a probabilidade de NPV≥0 foram 29,4; 24,4 e 19,4%, respectivamente, para pesos de abate de 420, 460 e 500 kg. A interpretação das simulações permitiu classificar a tecnologia de confinamento como de alto risco, com alta probabilidade de perda econômica.

PALAVRAS-CHAVE: Tomada de decisão. Simulação de Monte Carlo. Projetos de investimento. Estatísticas não paramétricas

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