Economic analysis, performance, and feed efficiency in feedlot lambs

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ABSTRACT - The objective of this study was to evaluate residual feed intake (RFI), residual intake and body weight gain (RIG) and their relationship with other traits of efficiency, performance, and economic analysis of sheep. Lambs (n = 102) were evaluated during 56 days and a herd consisting of 500 ewes was simulated with the mean of dry matter intake (DMI) and final body weight of the lambs, the same as that of the experimental lambs. The lambs were fed hay-based diet of Tifton 85 (*Cynodon spp.*), corn, and soybean in the voluminous:concentrate ratio of 35:65. Residual feed intake and RIG were correlated with DMI, feed conversion ratio, and feed efficiency. Residual intake and body weight gain were positively correlated with average daily gain, relative growth rate, and Kleiber's rate. The most efficient production systems (lower RFI and higher RIG) had lower costs and higher profit margins. The net present value (NPV) and internal rate of return (IRR) were higher in systems with more efficient lambs. In systems with less efficient lambs, NPV and IRR were negative and lower, respectively. Efficient animals for RFI and RIG showed satisfactory performance and better economic results.

Key Words: cost, profit, revenue, RFI, RIG, sheep

Introduction

The termination of feedlot lambs allows the exploitation of the animal earning potential, but may become an economically unviable practice due to the cost of nutrition, which can represent approximately 70% of the cost in confinement (Barros, 2004).

To reduce the feeding costs, besides using cheaper food, it is necessary to keep an efficient herd (Lima et al., 2013). Food conversion efficiency in animal products is important for the profitability of production systems (Santana et al., 2014).

Feed efficiency can be measured by various methods, such as feed conversion ratio, relative growth rate, Kleiber's rate, residual body weight gain (RG), and residual feed intake (RFI) (Archer et al., 1999). Residual feed intake and the RG were initially proposed by Koch et al. (1963), the

former based on intake independent growth and maturity standards and the latter based on weight gain independent intake and body weight (BW). Animals with lower RFI eat less food than that estimated to its body weight and weight gain (Leme and Gomes, 2007).

There is no way to identify animals with greater feed efficiency and higher gain through RFI because the model for the adjustment to weight gain makes it independent of the production level (Berry and Crowley, 2012). Despite low RFI, animals are efficient and those individuals with lower intake as well as lower gains may be less profitable. Thus, animals with the same RFI might have the same average daily gain in different weights and, therefore, generate different income.

This independence of performance characteristics has an impact on profit, since increasing profitability in confinement requires the identification of individuals with more efficient weight gain, as this variable is strongly correlated with profitability (Nascimento, 2011). Given the limitations on RFI, Berry and Crowley (2012) proposed a measure of feed efficiency, residual intake and BW gain (RIG), which takes into account both RFI and RG. Residual intake and BW gain identifies animals with fast growth, which, at the same time, consume less food than the average intake of the population, with no differences for BW.

The objective of this study was to evaluate two feeding efficiency measures, residual feed intake and residual

intake and BW gain, and their correlation with the other characteristics of efficiency, performance, cost analysis, and investment in a sheep production system.

Material and Methods

The study was conducted in two stages: assessment of feeding efficiency measures on a farm in Igarapé, MG (20º04'31 South latitude, 44º18'06 West longitude, and 786 m average altitude) in the second half of the years 2013 and 2014; and simulation of a property with 500 ewes using data evaluated for economic analysis and investment costs. The use of animals in the experiment was in accordance with the protocol approved by the Ethics Committee on Animal Use (CEUA), case no. 122/2012.

After 18 days of adaptation to handling and feeding, 102 ½ Dorper × ½ Santa Inês male lambs of approximately 70 days old and 24.58±3.76 kg of initial average body weight (± standard deviation) were confined for 56 days in individual pens to determine the individual feed intake. Pens had dimensions of approximately 1.0 × 2.0 m and contained individual drinkers and feeding troughs. The feed was provided *ad libitum* in the form of total diet with roughage:concentrate ratio of 35:65 and was offered twice a day, at 8:00 and at 16:00 h. Daily feeding was done by keeping leftover percentage at 10% of the supplied food. Roughage of Tifton hay was chopped to 5 mm. The diet was balanced so that the lambs had daily gain of 300 g according to NRC (2007) and contained 67.9% total digestible nutrients (TDN) and 20.5% crude protein (CP). The chemical analysis of the samples of the offered feed and leftover followed the methodology proposed by the National Institute of Science and Technology (NIST) (Detmann et al., 2012).

Along with weighting every 14 days, measurements were made of *Longissimus lumborum* area (LLA) and backfat thickness (BT) through ultrasound between the 12th and 13th ribs. Daily earnings (angular coefficients), LLA, and BT were also evaluated, taking time into consideration. To obtain average daily weight gain (ADG), linear regression of each animal and body weight were calculated, taking time into consideration. The first post-fitting weighing was called initial body weight (BWi) and the last, after 56 days of experiment, final body weight (BWf). The observed dry matter intake (DMI) was obtained by subtracting the average amount of feed provided by the daily amount of leftover, both adjusted to dry matter (DM).

Dry matter intake (DMIe) and average daily gain (ADGe) was estimated within each group, regression of DMIe based on metabolic body weight (BW$^{0.75}$), and ADG

of each animal during the period by the following equations, 1 and 2, respectively:

$$y_{DMIe_i} = \beta_0 + \beta_1 ADG_i + \beta_2 BW_i^{0.75} + e_{(RFI)i}, \qquad (1)$$

$$y_{ADGe_i} = \beta_0 + \beta_1 DMI_i + \beta_2 BW_i^{0.75} + e_{(RWG)i}, \qquad (2)$$

in which y_{DMIe_i} is the estimated dry matter intake for the *i*-th animal; y_{ADGe_i} is the estimated average daily gain for *i*-th animal; β_0 represented the intercept; β_1 is the linear regression coefficient of average daily gain (ADG) and dry matter intake (DMI), respectively (equations 1 and 2); β_2 is the regression coefficient of the metabolic body weight (BW$^{0.75}$); and e_i is the random residual of equations 1 and 2 associated to RFI and RWG, respectively.

For comparative purposes, two classes of animals were set up based on RFI and RIG, higher (> average + 0.5 standard deviation (SD)) and lower (<average − 0.5 SD). Feed conversion (FC), relative growth rate (Fitzhugh and Taylor, 1971), Kleiber's rate (Kleiber, 1947), RFI, RWG, and the RIG are contained in a brief description and calculation formula presented in Table 1.

In Stage 2, based on the data obtained in the experiment, a projection was made for a 500-ewe module, considering the rural property where the experimental lambs originated. The number of animals kept in the herd was preset and was therefore considered a stabilized herd and the animals regarded as surplus. The animal-performance indexes were those of the herd of the property of origin and/or those considered in the literature: 85% fertility, prolificity of 1.3 lambs per ewe, 2% mortality of adult animals, 6% pup mortality, discarding 20% of the sheep, eight-month calving intervals, and 2% sheep breeding. The female sheep were divided into the category of calving (over 90 days) and pregnant (over 150 days).

Costs with pasture included R$1,132.00/ha (ha = 10,000 m²) deployment and R$222.00/ha annual maintenance; corn silage showed a cost of R$248.00/t DM; values were obtained from ANUALPEC (2014). The type of pasture employed was *Brachiaria brizantha*, with annual production of 10.5 t DM/ha (Oliveira et al., 2003). The cost of the concentrate in confinement was R$0.67/kg of the total diet and Tifton hay, R$0.42/kg of diet. The total area was 79 ha and the pasture area was 59 ha. The total legal reserve and permanent preservation area was 25% and the rest of the area was improvements. The construction costs were calculated according to Brasil (2014) and installation of fences according to ANUALPEC (2014). The method for calculating the depreciation was obtained by the formula: (initial value of the property − 30% of the initial value, called residual value)/lifespan and the lifespan

recommended by Della Giustina and Lanzer (1995). The cost of medication and vaccination was estimated based on the property where the lambs originated, as well as the cost of electricity and fuel. The cost of technical assistance was R$400.00 per visit, totaling six annual visits. The labor was divided into temporary – i.e., 30 days a year, with cost of R$70.00 each) – and permanent – i.e., an employee who received a minimum wage + 40% social charges (R$1,103.20/month), social charges according to System FAEP (2005).

To establish the opportunity cost, the value of the land, herd, improvements, pasture, and working capital was considered. The land compensation rate was 3% per year of the actual average selling price (CONAB, 2010). The value of land, according to FAEMG (2012), was R$5,000.00/ha formed pasture. We decided to use R$4,000.00/ha because the cost of pasture establishment was calculated separately, as previously stated. Concerning the improvements, herd, machinery, equipment and pasture, and yearly interest were calculated for each asset individually by the following the formula: average value of each asset multiplied by the interest rate of 6% per year (Canziani, 2005; CONAB, 2010).The interest rate on working capital (variable cost + fuel − taxes) was 6% and only half the value was considered because the disbursement took place throughout the year. The ICMS (Government tax) was calculated at 4.4% rate on revenues from the total sales and the Rural Land Tax of 0.07% on the value of the land (Pitelli and Bacha, 2006). General maintenance and expenses accounted for 1% of the variable cost, except for technical assistance and taxes. All prices used in the calculations were carried out in 2013 and 2014 and, when not available in the literature, were obtained through budgets and market research. The sales prices were

based on those used in the Midwest region of Minas Gerais, R$6.80 per kilogram of live lamb ending with 40 kg and R$4.50 per kilo of disposal animal with 60 kg.

With all the items comprising the cost of producing sheep, a spreadsheet was elaborated with the following breakdown: variable operating cost (VOC), fixed operating cost (FOC), total operational cost (TOC), opportunity cost (OC), and total cost (TC). Fixed operating cos was considered that which did not vary according to the level of production and VOC, the opposite. Total operational cost was the sum of VOC + FOC and the total cost was TOC plus the opportunity cost (Barbosa and Souza, 2007; Barbosa et al., 2010; Santana et al, 2013). The revenues of activity were composed of the sales of lambs (R$450.00), lamb sales intended for slaughter, and sale of disposal animals (ewe). The calculation of costs and revenues allowed to carry out an economic analysis. Gross profit was obtained by subtracting the VOC revenue, while net margin (operating profit) was obtained by subtracting the revenue from TOC. The profit was the subtraction of revenue from TC. The profitability was the net margin divided by revenue and return net margin divided by the total investment (Barbosa and Souza, 2007; Barbosa et al., 2010; Santana et al., 2013). Cash flow was accomplished by deducting the expenditures from the revenue (TOC − depreciation), which resulted in the balance that is fixed every year by the interest rate of 6% per annum (Barbosa and Souza, 2007). In year 0, the total value of the investment was obtained and from year 1 to 15, the amount of expenses and income was obtained considering the renewal of assets or animals that were depreciated during this period. Regarding the land, its recovery or not was considered, being its appreciation at a rate of 10% per annum (MAPA, 2008). The cash flow

Table 1 - Definition of the indicator traits of feed efficiency

Trait	Formula[1]	Definition
Feed conversion ratio (FCR; kg DM/kg)	$\dfrac{DMI}{ADG}$	Amount of feed consumed divided by the weight gain. Lower values are favorable.
Relative growth rate (RGR; kg BW/day)	$100 \times \left[\dfrac{(\log BWf - \log BWi)}{(Days\ in\ test)} \right]$	Growth potential in relation to degree of maturity. Higher values are favorable.
Kleiber's ratio (KR; g gain/kg BW$^{0.75}$)	$100 \times \left[\dfrac{ADG}{BW^{0.75}} \right]$	ADG, in grams, proportional to each kilogram of metabolic weight. Higher values are favorable.
Residual feed intake (RFI; kg DM/day)	$DMI - DMIe$	Difference between observed and estimated DMI based on ADG and BW$^{0.75}$. Lower values are favorable.
Residual weight gain (RWG; kg gain/day)	$ADG - ADGe$	Difference between observed and estimated ADG based on DMI and BW$^{0.75}$. Higher values are favorable.
Residual intake and BW gain (RIG)	$RWG + [(-1) \times RFI]$	Simple index including RFI and RWG whose variance is adjusted at 1. Higher values are favorable.

Adapted from Grion et al. (2014).
DM - dry matter; ADG - average daily weight gain; DMI - dry matter intake; BW - body weight; BWf - final BW; BWi - initial BW; BW$^{0.75}$ - metabolic BW; DMIe - estimated DMI; ADGe - estimated ADG.

over the following fifteen years was considered to calculate the net present value (NPV) and the internal rate of return (IRR) of each treatment through spreadsheets using Excel (Microsoft Corporation, 2010) according to Guimarães and Canziani (2004).

The results obtained in the experiment (Stage 1) were analyzed using R (R Development Core Team, 2015). A randomized block design was used, in which the blocks were four groups for slaughter, two in 2013 and two in 2014 (27, 20, 25, and 30 animals each), according to the following statistical model:

$$y_{ijk} = \mu + \alpha_i + \beta_j + e_{ijk}, \qquad (3)$$

in which y (and its subscripts) represents the observed value for each variable; μ is the overall constant present in all observations; α_i is the fixed effect of i-th class of RFI or RIG; β_j is the fixed effect of j-th group of slaughter; and e_{ijk} is the random residual error, associated with each observation (y_{ijk}), supposed normally distributed and independent with zero mean and variance σ^2.

Based on this statistical model, all the dependent variables had their residual estimates tested for normality by the Shapiro-Wilk test (P>0.05). For the FC and feed efficiency (FE) variables, since they are resultant from the ratio between the average daily gain and the dry matter intake, they no longer present normal distribution (Detmann et al., 2005).

Therefore, the FC and FE data that did not present normal distribution were transformed by using the natural logarithm or by means of Box-Cox transformation analysis through the TRANSREG procedure of SAS (Statistical Analysis System, version 9.1.0). Transformed data were used

in the statistical analysis to generate the presented P-values. However, the corresponding means and standard errors were presented in the original scale to ease the interpretation of results.

Data from feed efficiency measures (RFI and RIG) were subjected to analysis of variance and Pearson's correlations were also performed. The differences of data were evaluated by the F test at 5% probability. The economic results (Stage 2) were obtained by calculations in spreadsheets developed in Excel (Microsoft Corporation, 2010), compared by descriptive statistics.

Results

The average DMI of the lambs was 1.350 kg, ranging from 0.770 to 1.735 kg (Table 2). The ADG was similar to that established by the NRC (2007); thus, the diet provided ADG close to 300 g.

The animal with lower RFI (−0.15 kg/day) ingested less feed than the animal with the highest RFI value (0.22 kg/day), which represents a difference of 0.38 kg/day between them. For both RFI and RIG, no differences (P>0.05) were observed in initial body weight, final body weight, mid-test body weight, and metabolic body weight, with averages of 24.65, 40.86, 32.80, and 13.69 kg, respectively (Table 2). These efficiency measures (RFI and RIG) showed no correlation with body weight measurements. These efficiency measures (RFI and RIG) showed no correlation with body weight measurements (Table 3).

Animals with higher RIG did not differ from those with lower RIG in regard to DMI (P>0.05), with 1.353 kg

Table 2 - Mean, standard deviation (SD), minimum, maximum, and phenotypic correlation of performance measures and feed efficiency with residual feed intake (RFI) and residual intake and body weight gain (RIG) in lambs

| Item	Mean	SD	Minimum	Maximum	RFI	RIG
Initial body weight (kg)	24.65	3.71	15.92	33.74	−0.001	−0.113
Final body weight (kg)	40.86	4.92	28.74	51.88	0.007	0.090
Mid-test body weight (kg)	32.80	4.04	23.18	41.42	−0.001	0.010
Metabolic body weight (kg)	13.69	1.27	10.56	16.33	0.0001	0.009
Dry matter intake (kg/day)	1.35	0.19	0.77	1.73	0.413*	−0.216*
Average daily gain (kg/day)	0.29	0.05	0.15	0.38	−0.001	0.328**
Feed conversion ratio (F:G)	4.70	0.64	3.53	6.85	0.443**	−0.685**
Feed efficiency (G:F)	0.21	0.02	0.14	0.28	−0.462**	0.699**
Relative growth rate	0.39	0.07	0.21	0.57	−0.006	0.332**
Kleiber's ratio	0.02	0.00	0.01	0.02	−0.010	0.355**
Residual feed intake (kg/day)	0.00	0.08	−0.15	0.22	-	−0.920**
Residual body weight gain (kg/day)	−0.00	0.03	−0.06	0.09	−0.695**	0.920**
Residual intake and body weight gain	0.00	1.84	−4.67	4.98	−0.920**	-
Longissimus thoracis area (LTA) (cm^2)	9.89	1.30	6.63	13.52	−0.101	0.122
Increase rate LTA (cm^2/day)	0.08	0.02	0.01	0.15	0.052	0.054
Backfat thickness (BT) (mm)	3.30	0.43	2.50	4.60	−0.084	0.040
Increase rate BT (mm/day)	0.03	0.01	0.01	0.07	−0.040	0.011

* (P<0.05).
** (P<0.01).

average. This result may be due to the poor correlation (−0.216) between the measures RIG and DMI, whilst the correlation between RFI and DMI was moderate (r = 0.413; Table 2). Animals with lower RFI consumed, on average, 0.17 kg/day feed, 12% less than the animals with higher RFI (P<0.01).

Average daily weight gain was not influenced by RFI (P>0.05) and there was no significant correlation between them (Tables 2 and 3). Thus, efficient animals may have higher or lower ADG, which was expected (Figure 1). Average daily weight gain was different between classes of RIG (P<0.01) and had moderate positive correlation (0.328), being observed the highest gain in higher RIG (0.265 vs. 0.307 kg/day).

Feed efficiency measures and FCR were highly correlated with RIG (0.699 and −0.685, respectively) and moderately correlated with RFI (−0.462 and 0.443, respectively) (Table 2). Feed efficiency and FC differed (P<0.01) between classes of RFI and RIG, in which the lowest value of FC and the highest of FE were observed in higher RIG lambs (4.48 and 0.23, respectively).

For relative growth rate (RGR) and Kleiber's rate (KR), there were no differences (P>0.05) between the classes of RFI of the lambs. Among the RIG classes, there were some differences in the values of RGR and KR (P<0.01), with higher values observed in animals with higher RIG (0.41 and 0.02, respectively).

Relative feed intake and RIG showed no correlation (P>0.05) with any of the carcass characteristics evaluated by ultrasound and, likewise, there was no difference (P>0.05) between classes of feed efficiency by RFI and RIG for the
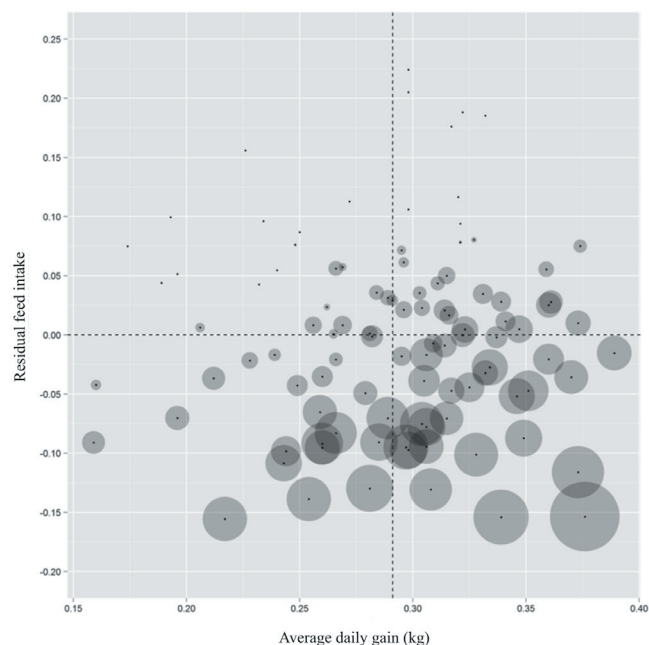
Diameter of halos corresponds to the residual intake and body weight gain.

Figure 1- Average daily gain according to the residual feed intake of the lambs.

Table 3 - Performance and feed efficiency traits for lambs ranked high and low for residual feed intake and residual intake and body weight gain

Item	Residual feed intake			Residual intake and body weight gain			SE
	Low (n = 32)	High (n = 29)	P-value	Low (n = 26)	High (n = 32)	P-value	
Initial body weight (kg)	24.78	24.86	0.759	25.36	24.54	0.335	0.370
Final body weight (kg)	40.62	40.30	0.504	40.15	41.70	0.355	0.490
Mid-test body weight (kg)	32.78	32.67	0.962	32.79	33.15	0.734	0.402
Metabolic body weight (kg)	13.67	13.65	0.966	13.68	13.79	0.733	0.127
Dry matter intake (kg/day)	1.24b	1.41a	<0.01	1.39a	1.31b	0.180	0.020
Average daily gain (kg/day)	0.28	0.27	0.086	0.26b	0.30a	<0.01	0.005
Feed conversion ratio (F:G)	4.43b	5.15a		5.32a	4.28b		0.064
Feed conversion ratio (F:G)[1]	0.77b	0.80a	<0.01	0.81a	0.76b	<0.01	0.003
Feed efficiency (G:F)	0.22a	0.19b		0.19b	0.23a		0.003
Feed efficiency (G:F)[1]	−0.77a	−0.80b	<0.01	−0.81b	−0.76a	<0.01	0.002
Relative growth rate	0.39	0.38	0.155	0.36b	0.41a	<0.01	0.007
Kleiber's ratio	0.02	0.02	0.135	0.01b	0.02a	<0.01	0.0003
Residual feed intake (kg/day)	−0.08b	0.09a	<0.01	0.09a	−0.08b	<0.01	0.008
Residual body weight gain (kg/day)	0.02a	−0.02b	<0.01	−0.03b	0.02a	<0.01	0.003
Residual intake and body weight gain	1.79b	−2.18a	<0.01	−2.44b	2.01a	<0.01	0.184
Longissimus thoracis area (LTA; cm²)	9.93	9.73	0.677	9.89	10.12	0.330	0.130
Increase rate LTA (cm²/day)	0.07	0.07	0.126	0.07	0.08	0.716	0.003
Back fat thickness (BT) (mm)	3.35	3.29	0.615	3.29	3.33	0.804	0.004
Increase rate BT (mm/day)	0.03	0.02	0.223	0.03	0.03	0.464	0.0001

SE - standard error.
[1] Variable was transformed by Box Cox.
a,b - Means followed by different letters in the row differ by F test at 5% probability.

variables analyzed (Tables 2 and 3). Changes in LLA and BT and their growth rates were not confirmed by the results obtained in this study (P>0.05).

Total operational costs were higher in less efficient animals (higher RFI and lower RIG) (Table 4). Feeding was responsible for most part of TOC (71%). A part of the FOC and the OC amounted to a high sum, superior to R$43,000.00 in all production systems, i.e., 23% of the total cost. The production systems had similar revenues. There was no correlation between RFI and RIG with final body weight (Table 4). Systems with efficient RFI and RIG lambs had higher gross margin values (R$51,165.87 and R$50,983.84) and net margin (R$34,501.05 and R$34,302.79), respectively.

When opportunity cost was included to obtain total cost, the systems composed of inefficient lambs (higher RFI and lower RIG) resulted in negative income (−R$589.39 and −R$338.79, respectively) compared with efficient animals with lower RFI (R$3,979.85) and higher RIG (R$3,734.81).

All production systems were cost effective (return) and profitable (lucrative), but those with efficient animals had higher return values, 5.06 and 5.03%, and profitability, 17.6 and 17.3%, respectively, for lower RFI and higher RIG (Table 4).

Regarding the investment analysis, the results of cash flow by the IRR and NPV of all production systems were positive when including the appreciation of the land (Table 4). The NPV of R$152,139.16 (lower RFI), R$150,213.64 (higher RIG), R$111,239.83 (lower RIG), and R$108,927.84 (higher RFI), being the price of land included in the calculation, showed IRR of 8.05, 8.02, 7.49, and 7.46% per annum, respectively.

The result of the cash flow just off the sheep production activity, disregarding the appreciation of the land, indicated IRR of 6.70, 6.64, 5.50, and 5.43% per annum for, respectively, lower RFI, higher RIG, lower RIG, and higher RFI (Table 4). With a value of opportunity rate below the 6% per annum, the NPV of −R$19,331.98 for higher RFI and −R$17,019.98 for lower RIG were obtained.

Table 4 - Cost analysis and investment analysis in lambs ranked high and low for residual feed intake and residual intake and BW gain

	Residual feed intake		Residual intake and BW gain	
	Low	High	Low	High
Variable operating cost (A)	144,817.87	148,802.07	148,374.94	146,440.78
Drug	2,027.42	2,027.42	2,027.42	2,027.42
Temporary work force	2,100.00	2,100.00	2,100.00	2,100.00
Technical assistance	2,400.00	2,400.00	2,400.00	2,400.00
Tax	8,623.28	8,604.58	8,596.07	8,686.68
Food	114,628.77	118,631.68	118,213.05	116,188.29
Energy	1,800.00	1,800.00	1,800.00	1,800.00
Permanent work force	13,238.40	13,238.40	13,238.40	13,238.40
Fixed operating cost (B)	16,664.82	16,704.66	16,700.39	16,681.05
Depreciation	13,263.05	13,263.05	13,263.05	13,263.05
Fuel	1,800.00	1,800.00	1,800.00	1,800.00
Government tax	153.59	153.59	153.59	153.59
Repair	1,448.18	1,488.02	1,483.75	1,464.41
Total operational costs (A+B)	161,482.69	165,506.74	165,075.33	163,121.83
Opportunity cost (C)	30,521.20	30,641.29	30,628.73	30,567.98
Total cost (A+B+C)	192,003.89	196,148.02	195,704.06	193,689.82
Revenue	195,983.74	195,558.63	195,365.27	197,424.63
Gross margin	51,165.87	46,756.56	46,990.33	50,983.84
Net margin (operational profit)	34,501.05	30,051.89	30,289.94	34,302.79
Total profit	3,979.85	−589.39	−338.79	3,734.81
Cost effective (return) (%)	5.06	4.41	4.44	5.03
Profitability (lucrative) (%)	17.60	15.37	15.50	17.38
Fixed operating cost (%)	8.68	8.52	8.53	8.61
Variable operating cost (%)	75.42	75.86	75.82	75.61
Opportunity cost (%)	15.90	15.62	15.65	15.78
Investment analysis				
With appreciation of the land (10% p.a.)				
NPV (R$)	152,139.16	108,927.84	111,239.83	150,213.64
IRR (% p.a.)	8.05	7.46	7.49	8.02
Without appreciation of the land				
NPV (R$)	23,879.35	−19,331.98	−17,019.98	21,953.82
IRR (% p.a.)	6.70	5.43	5.50	6.64

BW - body weight; NPV - net present value; IRR - internal rate of return.

Discussion

The RFI had an average close to zero, which was expected, since this measure is the residue of a prediction equation. Animals with lower RFI consumed, on average, 0.17 kg/day feed, 12% less than the animals with higher RFI. A similar result was reported by Paula et al. (2013) evaluating Ile de France lambs regarding RFI, in which more effective animals consumed 0.21 kg/day of feed than those animals considered with superior RFI. Redden et al. (2011), Muro-Reyes et al. (2011), and Paula et al. (2013) found correlation coefficients between RFI and DMI in sheep of 0.77, 0.58, and 0.81, respectively, values superior to the ones found in the present study.

As the definition of RFI considers ADG for the adjustment of regression, this leads to phenotypic independence between these characteristics (Sobrinho et al., 2011). As expected, several authors found no significant correlations between RFI and ADG, corroborating the results presented herein (Redden et al, 2011; Muro-Reyes et al., 2011 and Paula et al., 2013). Berry and Crowley (2012) reported differences in ADG of cattle of different classes for this measure, with the highest values found in animals with higher RIG (1.49 vs. 1.81 kg/day). Studies involving RIG in sheep are nonexistent; therefore, it was not possible to make a comparison with other published results. Feed efficiency measures and FC are simple ratios between DMI and ADG and provided that DMI did not differ in divergent animals to RIG, ADG was responsible for making efficiency measures (FE and FC) more favorable in these animals.

For relative growth rate and KR, similar to those found by Paula et al. (2013) in sheep, there were no differences between the classes of RFI of the lambs. Since the calculation of these rates considers body weight and ADG of the animals and do not correlate with RFI, the lack of significance for these measures is therefore justified. The correlations showed the importance of each trait of interest (BW, ADG, and DMI) in the composition of the indicator measures of feed efficiency. One of the major advantages of using RFI would be the reduced association with body weight and, consequently, with the maintenance of adult animals, especially mothers.

Paula et al. (2013), working with sheep, and Ramirez (2014), working with cattle, also reported no differences in carcass traits between animals of different RFI classes. Outcomes in the literature are contradictory on this fact as well as on the impact on the quality of meat of animals with lower RFI. Besides having a less tender meat, there is a possibility that animals identified as more efficient,

take longer in terms of deposition of fat in the carcass. Changes in LLA and BT and their growth rates were not confirmed by the results obtained in this study, probably due to reduced age and maturity of the experimental animals (approximately five months), provided that puberty in sheep is manifested between six and nine months of age (Price et al., 1995). Studies showing the impact on the selection of more efficient animals concerning meat quality are needed, especially with lambs.

Works that show the economic feasibility and investment analysis in sheep production systems are scarce, being found in regional conditions, limited to a certain year and/or certain segment of production. Lacking such information, the use of simulation allows predicting an outcome designed according to each scenario (Martha Júnior et al., 2007). Therefore, to carry out the economic analysis of this production system, the DMI data and final body weight of the experiment from stage 1 aimed at verifying the economic impact of a herd with more or less efficient lambs regarding RFI and RIG.

Systems with efficient RFI and RIG lambs had higher gross margin values and net margin. Therefore, the highest profit margin in these systems was the DMI of lambs, as this measure was representative in total operational cost, which is part of the calculation of profit margins. When opportunity cost was included to obtain total cost, the systems composed of inefficient lambs (higher RFI and lower RIG) resulted in negative income. This means that the activity with inefficient lambs regarding RFI and RIG did not compensate the invested capital as in the best market alternatives. In these situations, there is no capacity for further medium- and long-term investments; thus, the activity is maintained, but may not be the most attractive investment option for the next generation (Barbosa and Souza, 2007).

All production systems were cost effective (return) and profitable (lucrative), but those with efficient animals had higher return values and profitability. Green (2008) cited the average of the percentage of return on investment over the previous 20 years in New Zealand, which is 10.5% in sheep properties, but Morris (2009) reported values of 1 to 2% per year, the worst in 50 years.

The investment analysis of all production systems was positive when including the appreciation of the land. It means that, at a discount rate of 6% per year, the sum of revenue within a 15-year period was higher than the investment in the activity. The net present value being the price of land included in the calculation showed IRR above the opportunity rate of 6% per annum, which was the same used for savings accounts. Therefore, the activities

would be economically viable if the sale of the property was carried out at the end of the period, including land that showed an appreciation of 10% per annum.

The IRR must be the same or higher than the market interest rate (savings accounts and/or a comparison reference) and this positive result indicates that the capital invested in the activity is recovered and the balance available each year yields the same interest at IRR (Guimarães and Canziani, 2004). With the use of less efficient animals, the activity was not economically viable, even if sales of productive resources (pasture, herd, improvements, machinery, and equipment) were conducted at the end.

Conclusions

Considering residual feed intake and residual intake and body weight gain, efficient animals have satisfactory performance without alterations in the carcass traits measured by ultrasound.

The production system with the confinement of efficient lambs and according to residual feed intake and residual intake and body weight gain shows better results in both cost analysis and investment analysis.

Acknowledgments

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