Technical and allocative efficiency analysis for cattle fattening on Argentina Pampas

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Abstract

Management systems for cattle fattening in winter (‘wintering’) on Pampas region are studied. After analyzing 136 management records throughout 3 years, simulation models using linear programming were developed to optimize beef production according to the following decision criteria: minimum cost under energy and time constraints; and maximum yield under energy and time constraints. These simulation models, which represent the production frontiers that these enterprises may achieve, are later compared to the management results obtained; this allows us to analyze the technical and allocative efficiency of farms, simulate management proposals and establish production possibilities for different scenarios. The results obtained in the actual scenarios indicate that production may be fourfolded by modifying feeding strategy, increasing profits of around 140% if a criterion of maximum yield is adopted and the allocative efficiency is improved. © 2000 Published by Elsevier Science Ltd.

Keywords: Beef production; Optimization; Linear programming; Production frontiers
1. Introduction

The world’s beef cattle market is going through a commercial crisis. The modifications in consumer habits and the low population increase rate have notably decreased the demand of beef products.

Argentina is also affected by this fact. Traditional beef production in the country has been supported by a high internal demand increase due to immigrations and politics of development. In this scenario, management systems for livestock enterprises are deficiently developed, with minimum cost politics, obtaining a low price product which is destined for internal market.

This situation is aggravated in the country by the inflationary effect. With inflation control and open-market policy, agriculture and milk production react quickly, intensifying their production and increasing external inputs with the objective of increasing production and profit margins. Beef cattle production does not react with the same speed, and due to land competency for these activities, it is relegated to marginal zones and of minor production.

Regarding this scenario, the objective of this work may be resumed in four principal points:

1. to develop a simulation model for a fattening cattle system in the Pampas;
2. to define fattening strategy greatest profit in winter, determining for stock, type of supplement, quantity and moment of its use, combinations of grasslands and annual pastures ‘verdeos’, etc., that produce the best economic result;
3. to establish efficiency level of the enterprises on Pampas; and
4. to develop a computerized application for helping decision making facing hypothetical cases.

The area of study is located on the middle-east of Argentina. Situated in the south of the Province of Cordoba, it also contains a small region of the north of the Pampas and north-west of the Province of Buenos Aires, known as the sub-humid Pampas. The area is located within Pampas’ plains with a height above sea level of 300–600 m and a slight slope towards the east, normally inferior to 1%. Annual rainfall oscillates between 700 and 900 l/m², mainly in spring and autumn. The ground with good-excessive drainage, has good-moderated content of organic matter and an average high fertility (Pamio, 1989). Originally, it was a grass steppe practically without arboreal species and scarce legumes, but the autochthonous species have been substituted by pure meadows or grass–clover ley. Annual pastures also known as ‘verdeos’ are also sown. The meadows or pastures are based, mainly, in monophytic alfalfa (Medicago sativa) or associated to forage grass as barley (Bromus unioloides), Fescue (Festuca arundinacea), etc.

Argentina Pampas, according to the National Agricultural and Livestock Census of 1993, by the National Statistical and Census Institute (INDEC), has more than 41 million heads of beef cattle (79% of the total cattle in Argentina). Most come from English breeds and in lesser frequency from crosses with cattle of the zebu type (Nelore, Brahman) and autochthonous type (Criollo).
In Argentina, beef production is based on extensive and pastoral systems. Because of climatic diversity, there is a geographical specialization in cattle production with areas dedicated mainly to reproduction and cattle husbandry, and other areas with more favorable conditions for fattening or ‘wintering’. The region studied is the principal fattening zone of the country, specialized in the feeding of steers of 5–8 months of age and a weight of 120–180 kg, reaching these at 15 months of age and an average weight of 380–500 kg, depending on the breed and type of animal used (Frank, 1984). The diet is mainly pasture feeding, based on the utilization and exploitation of the permanent alfalfa pastures, with low levels of energy supplementation using maize and sorghum grains limited to the winter period (Danelón, 1994).

2. Methodology

2.1. Sample description

The study uses a sample of beef cattle farms that belong to the Consorcio Regional de Experimentación Agrícola (CREA) groups of the South Nucleus of the Central Region which includes 90 farms, from which information was obtained from 50 farms for the year 1991/1992, 45 farms for the period 1992/1993 and 41 farms for 1993/1994, as is shown in Table 1.

Technical and economical variables registered in management were taken from each establishment, obtaining a total of 136 records which were tabulated and processed. These breeders are selected because of their standardized management system over several years, comparing the results internally and externally throughout different years between different enterprises of the group, with foreign enterprises, with Argentinean experimental agencies, etc. In this way farms utilize resources relatively efficiently when compared to the rest of the farms.

2.2. Neoclassic theory of production

In order to establish the production function, the next expression may be used:

\[ Q = f(v_1, v_2, v_3, \ldots, v_n), \]

where \( Q \), product quantity; \( V \), productive factors.

<table>
<thead>
<tr>
<th>Series</th>
<th>Sample</th>
<th>Population (%)</th>
<th>Percent of CREA’S nucleus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991/1992</td>
<td>50</td>
<td>8.33</td>
<td>55.55</td>
</tr>
<tr>
<td>1992/1993</td>
<td>45</td>
<td>7.50</td>
<td>50</td>
</tr>
<tr>
<td>1993/1994</td>
<td>41</td>
<td>6.83</td>
<td>45.55</td>
</tr>
</tbody>
</table>

\( \text{CREA, Consorcio Regional de Experimentación Agrícola.} \)
In cattle fattening, the diet is the most important factor, since it may represent, on occasions, 90% of the total costs. Regarding this and taking into account that protein contents are not usually a constraint factor in the Pampas' meadows, it may be concluded that the growth of steers is a direct function of the quantity of energy that is consumed, according to the expression:

\[ Q = f(ENg). \]

In medium size steers (380–500 kg), the production function obtained, according to the revised sixth edition of the National Research Council (NRC) for beef cattle, 1994, is the following:

\[ ADPV = 13.91ENg^{0.9116}PV^{-0.6837}, \]

where \( ADPV \), daily live weight gain (kg/day); \( ENg \), net fattening energy (Mcal/day); \( PV \), live weight (kg); knowing that:

\[ B = Q Pq - (ENg Pe + CF), \]

where \( Q \), product units; \( Pq \), unit product price; \( ENg \), energy used in fattening or growth; \( Pe \), energy price; \( CF \), fixed costs.

Neoclassic theory of production allows calculation of an economic optimum. In the case of two substitutive factors \( ENg_1 \) and \( ENg_2 \), the maximum profit is obtained when these factors are combined at a minimum cost. Applying Lagrange’s multipliers method, it is established when:

\[ (\delta f/\delta ENg_1)/P_{ENg_1} = (\delta f/\delta ENg_2)/P_{ENg_2} = \ldots = (\delta f/\delta ENg_n)/P_{ENg_n} = 1/\delta, \]

where \( ENg_1 \), net energy level of fattening with alfalfa hay; \( ENg_2 \), net energy level of fattening with maize; \( P_{ENg_1} \), price of factor \( ENg_1 \); \( P_{ENg_2} \), price of factor \( ENg_2 \); which expresses the law of marginal productivity equality. The level of production of maximum profit is obtained for that combination of factors in which there is equality of the quotients, in respect to the price, of the marginal productivity of each factor.

2.3. Technical basis for the theoretical model

From previous analysis of the economic results and technical indexes of the sample, it is concluded that principal variable costs are those relative to nutrition and diet. This opinion agrees with Blaxter et al. (1956), Santinelli et al. (1981), and Barnard and Nix (1984).

Therefore, the model was developed based on three principal modules which allows simulation of the production conditions for the area of study:
1. feed;
2. voluntary intake; and
3. animal response.

In relation to feed the following information is available: available monthly production (kg MS), metabolic energy level (EM) and protein content of the meadows and ‘verdeos’ of frequent use; quality indexes of the different available supplements (basically maize and sorghum); and prices per kilogram of the dry matter of these products.

In order to predict the voluntary intake and animal response (expected animal fattening level in function of food intake) (Dulphy and Demarquilly, 1994) the equations established by the NRC previously mentioned are used.

2.3.1. Theoretic model development: optimization

Optimization allows allocation of resources in order to find the best solution following an economic criterion. In beef production process, there are two principal factors, time and energy, also competitive among themselves (Garret, 1980). These two factors can be allocated in beef production according to two criteria:

1. **minimum cost or maximum profit of the process**: consists in finding the combination of energy and time which allows to reach the final sale weight at a minimum cost; and
2. **maximum financial yield**: determines the time and energy combination that allows the highest gross margin.

Time factor is very important in cattle fattening (Frank, 1984). It is used as *price of time*, the cost of opportunity of the floating capital. This means that time depends on the economic valuation of beef production in function of the inter-annual interest rate. In regard to the energy, it is considered as price of the total cost of the animal’s ratio calculated at a minimum possible cost. With these ‘prices’ and according to the selected criteria, the composition of the optimum growth ration is determined, dividing the fattening process in intervals of 20 kg. When comparing the model with farm data, meadows production was fixed to 5400 kg/MS/year, quality of the pastures estimated through its content in EM and proteins, taking into account the average values of the zone. Wintering has a purchase price of $0.88/kg and a selling price of $0.80/kg (AACREA, 1994).

2.3.1.1. Minimum cost model or maximum profit of the process. To obtain minimum cost rations, multiple interaction technique with linear programming has been used, according to the development and sequence that is explained below (Fig. 1).

A. Feed data are introduced: EM/kg crude protein (PB), MS, and the price of the possible products, in this case the products frequently available in the Pampas’ fattening systems (Table 2). All parameters are expressed in relation to the kilogram of MS of the factor, as are the established restrictions. Prices to be
used for the cereals utilized as supplements are those of the market plus 15% estimated as the cost for preparation and distribution of the animals. In pastures and hay it is used for the total cost of production.

B. Model is developed for medium size animals (final weight ‘Pf’ between 400 and 500 kg and initial weight ‘Pi’ between 150 and 180 kg) of native British breeds, that are generally used in farms of the Pampas. ‘Pn’ is the weight in the ‘n’ moment. The growth interval ‘i’ is also introduced.

C. Metabolic energy level per kilogram (EM/kg) is determined at minimum cost between the components of the ration, in order to initiate the process. This value will be modified in each iteration according to the predetermined increment of EM. The method developed consists in the selection of the lowest price
among the proposed diet and subsequently the one with the highest concentration of energy at the same price. In a grazing system this energy will always come from the meadows due to its low price per kilogram of MS.

D. The level of EM/kg being established is calculated on this basis of the quantities of ENm and ENg that each kilogram of MS of the ration produces, according to the following equations of the NRC:

\[ \text{ENm} = 1.37\text{EM} - 0.138\text{EM}^2 + 0.0105\text{EM}^3 - 1.12; \]

\[ \text{ENg} = 1.42\text{EM} - 0.174\text{EM}^2 + 0.0122\text{EM}^3 - 1.65. \]

The maximum permitted intake (DMI) is also determined, in kilograms of MS per day, according to the equation:

\[ \text{DMI} = \text{PV}^{0.75}(0.1493\text{EN/kg} - 0.0460(\text{ENm/kg})^2 - 0.0196). \]

According to the following equation, the total possible EM intake is determined:

\[ \text{EMt} = \text{EM} \times \text{DMI}. \]

In those cases that there is a limiting factor in the availability of the pastures which will not permit the achievement of maximum intake, this limit will include instead the voluntary intake, therefore being:

If DMI < Forage offer: \[ \text{EMt} = \text{EM} \times \text{DMI}; \]

If DMI > Forage offer: \[ \text{EMt} = \text{EM} \times \text{Forage offer}. \]

Knowing that the requirements of ENm for maintenance of all bovines is:

\[ \text{ENm} = 0.077\text{PV}^{0.75}, \]

it is established that the energy available for growth and fattening (ER) is equal to intake minus dry matter destined for maintenance; therefore:

<table>
<thead>
<tr>
<th>Product</th>
<th>EM (Mcal/kg)</th>
<th>PB (g/kg MS)</th>
<th>Price ($/kg MS)</th>
<th>MS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucerne meadow</td>
<td>2.25</td>
<td>200</td>
<td>0.01</td>
<td>21</td>
</tr>
<tr>
<td>Maize grain</td>
<td>3.3</td>
<td>98</td>
<td>0.18</td>
<td>88</td>
</tr>
<tr>
<td>Sorghum grain</td>
<td>3</td>
<td>100</td>
<td>0.12</td>
<td>87</td>
</tr>
<tr>
<td>Soya seed</td>
<td>3.29</td>
<td>428</td>
<td>0.26</td>
<td>88</td>
</tr>
<tr>
<td>Hay</td>
<td>2</td>
<td>160</td>
<td>0.06</td>
<td>80</td>
</tr>
</tbody>
</table>

\[ ER = (DMI - (0.077PV^{0.75}/ENm/kg)) \times ENg/kg, \]

where EMT, total metabolic energy (Mcal/kg); EM, metabolic energy (Mcal/kg); ENg, fattening net energy (Mcal/kg); ENm, maintenance net energy (Mcal/kg); ER, available energy for growth and fattening (Mcal); DMI, maximum MS intake (kg/day).

With this parameter daily fattening level attained by the present ration is estimated as:

\[ ADPV = 13.91ER^{0.9116} \times PV^{-0.6837}. \]

From the estimation of fattening, the requirements of crude protein ‘PB’ are determined as:

\[ PB = (F + U + S + G)/D \times BV + CE, \]

where PB, crude protein (g/day); F, metabolic fecal protein loss (3.34% of DMI); U, endogenous urinary nitrogen = 2.75 PV^{0.5}; S, skin’s protein loss = 0.2 PV^{0.6}; G, protein of tissue deposit (g) = (268–29.4 caloric gain value, Mcal/kg) \times daily weight gain in kg; D, true protein digestibility (90%); BV, biological value (66%); CE, ration conversion to protected (‘by-pass’) protein (100%).

E. Minimum cost ration (CTR) is determined using linear programming, taking into account EMT, DMI and protein levels, so that:

\[ \text{Min } CTR, \text{ since } CTR = \sum_{j=1}^{n} X_j P_j, \]

subject to:

\[ \sum_{j=1}^{n} X_j \leq \text{calculated DMI} \]

\[ \sum_{j=1}^{n} X_j \cdot PB_j \geq \text{requirements of calculated PB} \]

\[ \sum_{j=1}^{n} X_j \cdot EM_j = EMT \]

\[ \sum_{j=1}^{n} X_j \leq DMI \times \text{maximum concentrate percentage established}, \]

where \( X_j \) is the quantity of ‘j’ concentrate intake in kilograms of MS.
F. Marginal monetary product (PMmg) is also determined as:

\[
PMmg = \frac{\delta Q \times Pq}{\delta CTR}\text{ respect to previous ration,}
\]

if \( PMmg = 1 \), optimum production level is achieved; if \( PMmg \neq 1 \); it may be due to:

\( PMmg > 1 \); production must be increased

\( PMmg < 1 \); production is situated in technical inefficiency zone.

Program does not displace \( PMmg < 1 \) since the process is initiated with the minor cost ration and descending relations of the marginal monetary product are established; therefore, results of \( PMmg \) values different to 1 mean that there must be an increase of production.

G. When \( PMmg > 1 \), EM/kg is increased 0.1 Mcal/kg and an iteration is developed beginning in ‘D’ estimating again the expected production with that ration.

H. When \( PMmg < 1 \), a subroutine is developed to decrease the calculus intervals, adding 0.02 Mcal/kg of EM in each iteration. Optimal ration report is internally stored.

I. It is verified if the animal’s weight ‘Pn’ is equal to the final proposed weight ‘Pf’.

J. If \( Pn \neq Pf \), it means that \( Pn < Pf \). In this situation the interval established in ‘B’ is added to the weight, starting again the process in ‘C’ (Fig. 2).

L. If \( Pn = Pf \), that means predetermined final weight was attained. Fatting maximization profit process is ended and a final report is generated. Average daily gain and optimal ration have been determined for each cattle weight level.

Subroutine has the same scheme as the previous main iteration, but increases are produced of 0.02 Mcal EM instead of 0.1 (Fig. 2).

Once the optimum ration is determined without considering the time factor, following a procedure similar to the previous one. The point where the time-energy factors combine at a minimum cost may be calculated. It can be expressed mathematically as:

\[
\frac{\delta t}{\delta e} = \frac{Pt}{Pe},
\]

where \( Pe \), energy price; \( Pt \), time price; \( \delta e \), energy variation; \( \delta t \), time variation. Since the proposed model follows the marginal product curve in a decreasing order, a more simple decissor may be accepted; it is mathematically expressed as:

\[
CTE_1/CRE_2 > 1; \text{ continue the process;}
\]

\[
CTE_1/CTE_2 \leq 1; \text{ stop the process,}
\]
where $\text{CTE}_1$, total fattening cost using the first ration; $\text{CTE}_2$, total fattening cost using the second ration.

Always following an increasing tendency of energy, it is verified that the total cost of the fattening process (time + energy) is decreasing; in other words, in price, the increase in the cost of the ration is less than the decrease produced in the fattening time.

To develop this model, the general scheme of the previous model is followed, changing the equations in the decision point in order to include the time effect in each period.

2.3.1.2. Maximum financial yield model. In this case the ration searched is the one that shows a daily marginal income equal to the daily marginal cost, keeping in mind the time-ration combination. Decision taking is expressed as:
δCTE/day = δIng/day,

where δCTE, total fattening cost variation; δIng, total income variation; being total fattening cost (CTE):

CTE = CTR × Dur + I × C × Dur,

where CTR, ration’s cost per day; Dur, length of fattening period in days; I, money interest per day; C, used capital, calculated as average kilograms of the period. Mathematically expressed, the formula used for deciding the process continuity is:

δCTR × Dur + CTR2 × δDur + I × C × δDur = δQ × Pq,

where δCTR, daily ration cost variation; CTR2, cost of the second calculated ration; δDur, period duration variation; δQ, meat production variation per day.

2.3.2. Sensitive analysis

The model permits modifications simulation of the system’s most significant variables. In this case extreme values have been considered in the period of study for the following variables:

1. type of interest: 15% annual;
2. price of the cereals: 14.5 $/qm for maize and 11.3 $/qm for sorghum;
3. price of the meat: 0.77 and 0.94 $/kg live weight as minimum and maximum, respectively;
4. quality of Lucerne hay: ±5% of the mean value of the EM/kg of MS in the area;
5. energy expenditure in maintenance: increment between 8 and 12% of the normal energy expenditure while grazing; and
6. consumption estimation: a correction factor of 0.93 and 0.97 considering hay’s freshness and availability, is weighted.

3. Result and discussion

3.1. Model outputs

The simulated models permit to obtain, firstly, optimum ration composition according to the used criteria (Tables 3 and 4). As it is observed, both criteria are different in supplement allocation; while minimal cost criterion proposes supplementation in winter and at the end of fattening, maximal yield criterion uses more supplement at the beginning of fattening to the maximal profit of feed conversion efficiency.

The second generated model report is a summary with the most frequent indexes used for fattening characterization (Tables 5 and 6). To compare both tables, it is observed that minimal cost fattening is longer, with less daily fattening and for that
By increasing supplementation costs (from 40 to 85$) fattening rate would improve but, overall, supplement would be replaced to obtain more rentability.

3.2. Model validation

This is carried out by classifying the farms in three production tiers (low, medium and high quartile), according to total beef production variable and simulating the average situation of these tiers (Table 7). Variables PP (meadows percentage), VI (winter ‘verdeos’ percentage), CCH (stock in heads/ha) and SP (supplementation in $/ha) or EQMZ (supplementation in kg of maize) are used as entry data and the three levels of production are simulated.

Next, minimum cost criterion is applied, adjusting the allocation of supplements in order to coincide with the total quantity of each segment. It was compared with beef production (PT) and daily live weight gain (ADPV) as final variables, using a contrast test and obtaining in all cases significance levels ($P$) higher than 90% (Table 8).

Table 3

<table>
<thead>
<tr>
<th>Initial weight (kg)</th>
<th>150</th>
<th>170</th>
<th>190</th>
<th>210</th>
<th>230</th>
<th>250</th>
<th>270</th>
<th>290</th>
<th>310</th>
<th>330</th>
<th>350</th>
<th>370</th>
<th>390</th>
<th>410</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting month</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
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<tr>
<td>Pastures a</td>
<td>4.01</td>
<td>4.41</td>
<td>4.88</td>
<td>3.47</td>
<td>2.54</td>
<td>2.54</td>
<td>5.30</td>
<td>6.77</td>
<td>7.12</td>
<td>7.46</td>
<td>7.80</td>
<td>8.13</td>
<td>8.22</td>
<td>6.92</td>
</tr>
<tr>
<td>Winter V a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td>Sorghum a</td>
<td>1.84</td>
<td>2.24</td>
<td>2.39</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.83</td>
</tr>
<tr>
<td>Hay a</td>
<td>0.84</td>
<td>1.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

a Expressed in kilogram of MS per day.

Table 4

<table>
<thead>
<tr>
<th>Initial weight (kg)</th>
<th>150</th>
<th>170</th>
<th>190</th>
<th>210</th>
<th>230</th>
<th>250</th>
<th>270</th>
<th>290</th>
<th>310</th>
<th>330</th>
<th>350</th>
<th>370</th>
<th>390</th>
<th>410</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting month</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>7</td>
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<td>9</td>
<td>1</td>
<td>11</td>
<td>11</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Pastures a</td>
<td>2.46</td>
<td>2.70</td>
<td>2.94</td>
<td>3.17</td>
<td>3.38</td>
<td>3.47</td>
<td>2.54</td>
<td>5.32</td>
<td>5.32</td>
<td>7.46</td>
<td>7.80</td>
<td>8.13</td>
<td>8.46</td>
<td>8.78</td>
</tr>
<tr>
<td>Winter V a</td>
<td>0.75</td>
<td>0.75</td>
<td>0.17</td>
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</tr>
<tr>
<td>Sorghum a</td>
<td>0.84</td>
<td>1.80</td>
<td>1.96</td>
<td>2.11</td>
<td>1.50</td>
<td>2.24</td>
<td>2.54</td>
<td>1.41</td>
<td>1.74</td>
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<tr>
<td>Hay a</td>
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<td>1.29</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

a Expressed in kilogram of MS per day.

less annual meat production, less incomes and final result than maximal yield fattening.

By increasing supplementation costs (from 40 to 85$) fattening rate would improve but, overall, supplement would be replaced to obtain more rentability.
### Table 5
Technical indexes of a minimum cost wintering

<table>
<thead>
<tr>
<th>Duration (months)</th>
<th>3.2</th>
<th>Incomes per cycle ($/ha)</th>
<th>403.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef production (kg/ha/year)</td>
<td>458.4</td>
<td>Incomes per year ($/ha)</td>
<td>366.69</td>
</tr>
<tr>
<td>Daily live weight gain (kg/heads/day)</td>
<td>0.7</td>
<td>Supplementation expenses ($/ha)</td>
<td>40.56</td>
</tr>
<tr>
<td>Average stock (kg/ha)</td>
<td>544</td>
<td>Other direct average expenses ($/ha)</td>
<td>48.00</td>
</tr>
<tr>
<td>Maize (kg/heads/cicle)</td>
<td>0.46</td>
<td>Annual gross margin ($/ha/year)</td>
<td>278.13</td>
</tr>
<tr>
<td>Sorghum (kg/heads/cicle)</td>
<td>187.09</td>
<td>Gross margin per cycle ($/ha)</td>
<td>309.86</td>
</tr>
<tr>
<td>Hay (kg/heads/cicle)</td>
<td>40.02</td>
<td>Cycle profit per day ($/ha)</td>
<td>0.77</td>
</tr>
</tbody>
</table>

* Calculated as the mean of the sample.

### Table 6
Technical indexes of wintering at maximum yield

<table>
<thead>
<tr>
<th>Duration (months)</th>
<th>10.1</th>
<th>Incomes per cycle ($/ha)</th>
<th>403.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef production</td>
<td>597.3</td>
<td>Incomes per year ($/ha)</td>
<td>477.81</td>
</tr>
<tr>
<td>Daily live weight gain (kg/heads/day)</td>
<td>0.91</td>
<td>Supplementation expenses ($/ha)</td>
<td>85</td>
</tr>
<tr>
<td>Average stock (kg/ha)</td>
<td>512</td>
<td>Other direct average expenses ($/ha)</td>
<td>48</td>
</tr>
<tr>
<td>Maize (kg/heads/cicle)</td>
<td>34.8</td>
<td>Annual gross margin ($/ha/year)</td>
<td>329.1</td>
</tr>
<tr>
<td>Sorghum (kg/heads/cicle)</td>
<td>338.8</td>
<td>Gross margin per cycle ($/ha)</td>
<td>277.8</td>
</tr>
<tr>
<td>Hay (kg/heads/cicle)</td>
<td>30.4</td>
<td>Cycle profit per day ($/ha)</td>
<td>0.9</td>
</tr>
</tbody>
</table>

* Calculated as the mean of the sample.

### Table 7
Average values of beef production (PT) quartiles

<table>
<thead>
<tr>
<th>PP</th>
<th>VI</th>
<th>CCH</th>
<th>SP</th>
<th>CKH</th>
<th>PT</th>
<th>ADPV</th>
<th>EQMZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>63.03</td>
<td>13.36</td>
<td>1.20</td>
<td>5.41</td>
<td>350.09</td>
<td>166.91</td>
<td>392.42</td>
</tr>
<tr>
<td>Medium</td>
<td>77.30</td>
<td>9.17</td>
<td>1.66</td>
<td>10.14</td>
<td>509.96</td>
<td>268.30</td>
<td>450.77</td>
</tr>
<tr>
<td>High</td>
<td>84.29</td>
<td>8.07</td>
<td>1.83</td>
<td>23.08</td>
<td>568.59</td>
<td>374.72</td>
<td>573.28</td>
</tr>
</tbody>
</table>

* PP, meadows percentage; VI, winter 'verdeos' percentage; CCH, stock in heads/ha; SP, supplementation in $/ha; ADPV, daily live weight gain; EQMZ, supplementation in kg of maize.

### Table 8
Sample and model comparison

<table>
<thead>
<tr>
<th>Quartiles</th>
<th>Sample</th>
<th>Model</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PT</td>
<td>ADPV</td>
<td>PT</td>
</tr>
<tr>
<td>Low</td>
<td>166.91</td>
<td>392.42</td>
<td>167.19</td>
</tr>
<tr>
<td>Medium</td>
<td>268.30</td>
<td>450.77</td>
<td>268.52</td>
</tr>
<tr>
<td>High</td>
<td>374.72</td>
<td>573.28</td>
<td>374.20</td>
</tr>
</tbody>
</table>

* PT, beef production; ADPV, daily live weight gain.
3.3. The model as production frontier

On average data of meadows’ quality and prices, different values of stock per hectare were assigned. Subsequently, this result was compared with the farms’ values. Comparisons in physical and economical aspect were realized.

3.3.1. Minimum cost frontier

In relation to the physical aspect, total beef production (PT) of the sampled farms was compared to the results of the model following a minimum cost criterion (Fig. 3); circles represent farms of the sample, while the results of the model are represented by a continuous line.

It is observed in this figure that the model adjusts very well to what is expected of a production frontier slightly above the sample, with some farms above the line and few that surpass it.

Three of the farms (Nos. 92, 100 and 86) are similar to the model; therefore, the proposed theoretical results are executable in the practice. Comparative physical data are shown in Table 9.

<table>
<thead>
<tr>
<th>No.</th>
<th>CREA farm</th>
<th>Stock (heas/ha)</th>
<th>ADPV (kg/heads/ha)</th>
<th>PT (kg/ha/year)</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stock (heas/ha)</td>
</tr>
<tr>
<td>92</td>
<td>1.16</td>
<td>690</td>
<td>292</td>
<td>1.2</td>
<td>680</td>
</tr>
<tr>
<td>100</td>
<td>1.58</td>
<td>656</td>
<td>378</td>
<td>1.6</td>
<td>670</td>
</tr>
<tr>
<td>86</td>
<td>1.94</td>
<td>647</td>
<td>458</td>
<td>1.9</td>
<td>690</td>
</tr>
</tbody>
</table>

*CREA, Consorcio Regional de Experimentación Agrícola; ADPV, daily live weight gain; PT, beef production.
In relation to economic aspect, the farms' gross margin was compared with that estimated by the model (Fig. 4). It stands out in this graph that in a general aspect, the outcome of the model (continuous line) adjusts well to a production frontier. It is also observed that the farms previously described obtain economic results adjusted to the model, although two farms notably modify their position.

The first one is No. 100, which is physically very close to the model, although economically below it. While checking the results of this farm (Table 10) it is observed that this farm presents similar levels of supplementation but with an outstanding decrease of the average sale price (P. Venta) obtained, which produces the fall of the economic results.

With this, it may be concluded that this farm is technically efficient, has an adequate beef production and allocates its resources well; although it uses breeds or categories of low performance in the market or it realizes a great part of its production during moments of low market price.

The other farm to analyze is No. 45, which well overcomes the model in physical part (Fig. 3), but stays below the model in the economical aspect (Fig. 4). This is well explained when the different variables are confronted (Table 11). It is easily observed that this farm is more productive than the one proposed by the model, with 60 kg more production per hectare and more than 80 g extra of daily gain.

![Fig. 4. Minimum cost economic frontier.](image)

| Table 10 |
| Farm No. 100 results<sup>a</sup> |
|---|---|---|---|---|---|---|---|
| Stock (heads/ha) | MB ($/ha/year) | SP ($/ha) | Sale price ($/kg) | Stock (heads/ha) | MB ($/ha/year) | SP ($/ha) | Sale price ($/kg) |
| 1.58 | 164.6 | 12.4 | 0.67 | 1.6 | 234.5 | 12 | 0.8 |

<sup>a</sup> SP, supplementation in $/ha.
However, its economic result is $28 less than the model and its supplementation expense results are higher in a similar way. Therefore, the farm is efficient at beef production, overcoming even the model, but exceeds in the use of supplements falling in anti-economical levels, which provokes the decrease of its gross margin.

The situation is similar in the other four enterprises from the seven that surpass the model in its physical aspect. Only two enterprises (Nos. 6 and 87) overcome the model economically and physically. Apparently, these are the only enterprises that use a maximum yield criterion instead of one of minimum cost in resource allocation. It is possible that these observations belong to the same enterprise, in which two production periods are analyzed (1991/1992 and 1992/1993).

### 3.3.2. Maximum yield economic frontier

When process yield is maximized, more supplement quantity is required in the diet of the fattening animal, strategically taking advantage of the moments of best feed conversion efficiency. This controlled use in supplements results in a detectable increase in the annual physical production and economic margins. The result is an economic intensification of the wintering using external sources of energy only when these are always profitable, causing an elevation of the production frontier, and therefore not being surpassed by any farm, in the physical and/or economical aspect.

Only the two points highlighted previously approximate to this curve. The comparison of the total beef production is shown in Fig. 5 and the one of the gross margin in Fig. 6.

### 3.3.3. Frontier expansion: simulation

In previous sections, behavior of the breeders within the production intervals of the sample has been analyzed. However, the model permits simulation of a stock superior to the one found. When increasing the stock, it is to be expected that some direct costs will be modified (Colom, 1993). While conservation and amortization of meadows remain constant (it is considered equal to $25/ha, which is the sample average), health and labor expenses are closely related to the number of heads per hectare. A simple regression shows that for each head, an expense of $6.44 is originated in health and of $10.22 in labor. With these values the direct costs intended to increase the stock are estimated.

Taking into account these direct costs, following a minimum cost criterion and with a restriction in the use of concentrates (cannot exceed 40% of the diet) in order to...
to maintain the extensive character of the system (Dulphy and Demarquilly, 1994), the stock was increased 5 heads/hectare. The result is shown in Fig. 7.

It is highlighted in this figure that when the stock is increased, an increase of beef production (segment A) is expected. This increase is maintained until 3 heads/ha (beginning of segment B). At that point, all the forage produced in the field is being consumed, provided with round bale. Production keeps increasing until it reaches 3.6 heads/ha (segment C), where production of green forage is not enough to cover the requirements, being, therefore, necessary to change from a pastoral system to a feed-lot system.

In the same figure the simultaneous evolution of the expected gross margin is shown (superior line). Highlighted is the continuous growth of the margin when the stock is increased, reaching a maximum plateau when it attains the point of maximum meadow consumption. This observation reinforces the technical criterion of...
maximum meadow exploitation (Lonne Ingvartsen, 1994). This is true, but it is necessary to simultaneously increase the stock and improve the supplementation. Profile of this optimal wintering for 1991–1994 is a wintering with 3–3.2 heads/ha, lasting about a year, producing 850 kg of meat per year, requiring a cost in supplements of $150–180/ha and an estimated direct cost of $79, which will produce a gross margin of $445.

It is against this ‘optimal’ production frontier which the farms must be compared in order to measure their efficiency. Technical efficiency is a physical measure that is obtained when comparing a farm’s beef production with the one proposed by the model in the same conditions (same stock, supplementation level, etc.), while allocative efficiency is established according to economic results comparing the enterprise’s gross margin with the best possible margin (Colom, 1994). In this way, allocative efficiency shows the ability with which resources have been assigned in order to achieve the best possible economic results. Observe in Fig. 7 how enterprises that have been analyzed result in being general technically efficient, but poorly efficient in allocation.

Lastly, maximum yield model needs to be analyzed. This frontier is always located above the minimum cost frontier, finding the point of maximum meadow consumption at stock levels superior to the ones of minimum cost. The frontier and its correspondent gross margin are shown in Fig. 8.

Maximum yield is obtained in this case with 4.4 heads/ha. Wintering lasts 300 days and produces 1500 kg of beef. A gross margin of $550/ha is produced with $500/ha supplementation and almost $100/ha of direct costs.

3.4. Sensitive analysis

The model of maximum financial yield is more sensitive than the one for minimum cost when the variables analyzed were modified. The one for minimum cost modifies its response to the variations in the quality of Lucerne hay, maintenance and consumption expenditure, while the model of maximum financial yield presents high
and medium sensitivity to the modifications of the farm’s endogenous and exogenous variables. These results are shown in Table 12.

This way the criteria of minimum cost is transformed in a model more safe and dependent of its own decisions than in the various scenarios of the market. Possibly, this is the reason why the Argentinean producers, habituated to a highly fluctuant market and with many external interventions, use a criteria of minimum cost, without considering maximum yield systems.

4. Conclusions

The analysis of the farms’ data permitted the conclusion that the breeders subject to study adjust well to a minimum cost decision model, not to a maximum yield model, maintaining low set stocking and scarce supplementation, notoriously below the optimum for that model. This demonstrates the aversion to the risk of livestock breeders, and also the lack of the process’ optimization. The technical efficiency of the farms is very good, as it may be appreciated in Fig. 3, while the allocative efficiency, shown in Fig. 4, results a little low. This indicates that small changes in the

| Table 12 |
| Sensibility analysis |
| Factor | Minimum cost | Maximum yield |
| Price of the money | Low | Medium |
| Price of the inputs | Low | High |
| Price of the product | Low | High |
| Quality of Lucerne hay | High | Medium |
| Maintenance expenditure | High | Low |
| Consumption | High | Medium |
allocation of resources and in the management of the capital will produce significant improvement in the production and in the economic result.

Optimum allocation of resources in beef farm, following a criterion of minimum cost and comparing with the actual finishing system for steers, will produce an increase of 94% in the generated gross margin and of 142% in beef production — achieving these results with 3–3.2 heads/ha and a supplementation cost of $150–180/ha. Using maximum yield criterion, maintaining the actual structure of 1.8 heads/ha, an improvement of 23% in gross margin will be produced and an increase of 33% in meat production. Optimal resource allocation following this criterion will produce, compared with the average scenario of the sample, an increment in gross margin of 140%, fourfolding production per hectare. The stock must be elevated to 4.4 heads/ha and assume a supplementation cost of $500/ha.

References


Further reading


