Bioeconomic evaluation of feedings strategies in the yearling beef cattle system in Mozambique

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HIGHLIGHTS

• Simulation is a valuable tool for the feeding management of beef cattle.
• Communal cattle grazing systems may be improved by using alternative feedstuffs.
• Diets based on low-cost feeding strategies provide better economic returns.

ABSTRACT

The application of feeding strategies (FS) to meet nutrient requirements of beef cattle grazing on native pastures during the dry season, are required to improve the productivity of production systems in tropical regions. The objective of this study was to evaluate the bioeconomic effects of different FSs applied to yearling bulls in Mozambique, using modeling and simulations as tools to support decision making. A simple deterministic simulation model was developed, assuming initial body weight (120 kg), average daily gain (ADG), feedstuffs, and production costs as inputs. FSs were simulated for a total of 120 days within four ADG systems: 0.000 kg (S000), 0.200 kg (S200), 0.400 kg (S400), and 0.600 kg/d (S600), and three diets were simulated for the positive and maintenance ADG systems, totaling 12 FS. The effects of 12 FS combinations were analyzed and a sensitivity analysis was performed. The effect of the change in the inputs of the model (feedstuffs purchase and calf purchase price) showed the sensitivity of the model to economic parameters (Gross Margin and Net Profit). The negative ADG (-0.200 kg) system (S-200) had the highest labor cost. Corn bran, considering its availability and low cost in the studied region, is a promising feedstuff for concentrates. Effective operational cost (EOC) was higher than 99% in all FSs. S-200, S000, and FS5 within the S200 system resulted in negative net profit (NP) values. Net profit proportionally increased as ADG increased. FS12 (Hyparrhenia rufa, corn bran, and Sesbania sesban) promoted the highest ratio (NP/total operation cost) (0.48), and consequently, the highest profitability (32.37%). In general, the simulation model shows that, in native and communal pasture beef production systems in regions of Africa with similar production conditions, the productivity of yearling beef cattle during the dry season may be improved by applying feeding strategies.

1. Introduction

Traditional livestock production systems contribute more than 70% of the livelihood of poor populations in rural areas of the world (Food and Agriculture Organization - FAO, 2014). On the other hand, the increasing demand for beef requires greater efficiency of all production systems, from intensive to extensive or subsistence systems, particularly in the African continent.

Mozambique has a cattle herd of 1277,044 heads produced mainly in extensive, small-scale systems, with an average of six heads per farm (INE, 2011). The main breeds are Landim, Angone, and Bovino de Tete, which are adapted to local production conditions (Bessa et al., 2009).

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However, although those systems are characterized by low numbers of animals, they play an important role in the meat supply of that country. The production system is based on the communal use of native pastures, in which animals from several farmers graze on a common pasture area, which is the feed base throughout the year (Timberlake and Reddy, 1986; Carvalheira et al., 1995). The dependence on native pastures limits cattle growth during the dry season (May to October) due to the qualitative and quantitative deficits, resulting in approximately 20% body weight (BW) losses (Dionisio, 1985). This weight loss may also be associated with the greater distances traveled by cattle during the dry season (17.3 km) in search for good-quality pasture areas compared with the rainy season (8.0 km) (Rocha et al., 1991). Therefore, interventions in such systems by feeding supplements during the dry season are essential to improve their bioeconomic efficiency. However, feed supplements, which are typically based on grains, are expensive for those low-income small farmers, who, therefore, seek local supplementation alternatives, such as multifunctional trees (Franzel et al., 2014).

Several authors have described the use of alternative feedstuffs as supplements, including *Leucaena leucocephala* and *Gliciridia sepium*, to compensate for the nutritional deficiencies experienced during the dry season (Abdulrazak et al., 1997; Quigley et al., 2009; Ojo et al., 2014; Gusha et al., 2015; Gusha et al., 2017), Pimentel et al. (2011) showed that beef cattle grazing on native pastures and supplemented with local and alternative feedstuffs (hay, native pastures, and *Leucaena pallida*) may potentially achieve daily weight gains of 0.400 kg/d under the production conditions of the district of Angónia, Mozambique.

Chakoma et al. (2016b) concluded that supplementation with *Mucuna pruriens* during the dry season allowed positive gross margin to be obtained due to the low cost of this protein source. Tinga et al. (2014) showed that the supplementation of locally-produced urea-molasses blocks (manufactured from the blend of water, molasses, urea, salt, industrial cement and corn bran) provided greater economic returns of 80% compared to non-supplemented animals. Alternative feedstuffs, such as the forage of perennial trees combined with pastures (*Leucaena leucocephala* + *C*4 tropical pastures) proved to be more profitable than annual crops (Bowen et al., 2016).

Although many studies have been published on the impact of supplementation on beef cattle performance, it is essential to evaluate its relative economic impacts, particularly taking into account the lack of information available on beef cattle production systems based on communal areas and local pastures. Therefore, the objective of this study was to evaluate the bioeconomic aspects of different feeding strategies applied during the dry season in production systems with different average daily gain (ADG) targets of yearling beef bulls using deterministic modeling and simulation.

2. Material and methods

2.1. Study area

The study was based on the beef cattle production systems of the district of Angónia, located in the extreme North-Northeast of Tete Province, at 14°39’ South and 34°14’ East. The climate of the region is humid tropical, with 18-22°C average annual temperature, 70% relative humidity, and with 1100-1200 mm average annual rainfall. The rainy season typically occurs between November and April, and the dry season between May and October (MOÇAMBIQUE, 2014). The predominant vegetation consists of *Hyparrhenia spp.*, *Hyparrhenia dissolata*, *Andropogon spp.*, and *Heteropogon contortus* grasses (Timberlake and Jordao, 1985).

Crops are the main regional economic activity, and it is typically practiced manually on small farms by most of the household members. The main food crops are corn and common beans (*Phaseolus vulgaris*). This area traditionally rears beef cattle, with the herd estimated at 21,000 head (MOÇAMBIQUE, 2014). Beef cattle are produced mainly to supply the local meat market, and the finished males achieve 350-570 kg body weight (Otto et al., 2000).

2.2. Description of the simulation model

The model was developed using Microsoft Excel® 2016 software to build deterministic relationships between input and output components of the system, aimed at illustrating the effects of intervention in the local production system of yearling cattle grazing on native pastures in communal areas. These interventions were represented by changes in average daily gain (ADG) during the post-weaning phase as a result of supplementation strategies during the dry season. Therefore, the composition of the total diet of each simulated feeding strategy as determined according to final body weight (Eq. 1).

\[
BW_t = BW_0 + (ADG \times SDs) \tag{1}
\]

Where, (i) BW\(_t\): final body weight (kg); (ii) BW\(_0\): initial body weight (kg); (iii) ADG: average daily gain (kg/d); (iv) SDs: simulation days, 120 days. The model inputs were initial BW, ADG, live weight gains, feedstuffs, and production cost. The outputs were economic indicators.

Five systems based on varying average daily gains (ADG) during the post-weaning period were evaluated: (1) BW loss of 0.200 kg/d (S-200); (2) BW maintenance, 0.000 kg/d ADG (S000); (3) 0.200 kg/d ADG (S200); (4) 0.400 kg/d ADG (S400); and (5) 0.600 kg/d ADG (S600) (Fig. 1). These systems were based on the typical production conditions of the studied area and on beef-cattle production literature (Pimentel et al., 2011; Kavishe et al., 2017). The S-200 system was based on the results of Dionisio (1985), who observed BW losses of approximately 20% during the dry season with no feeding intervention in Mozambique. The model consists of three components: (1) herd structure, represented by weaned calves; (2) feeding and (3) economics.

2.3. Herd structure component

The model considered male calves derived from a breeding system, of which the mating season is between January and March and the calving season between October and December (Fig. 2) (Uaila, 1999). Calves were 7- to 9-months old at weaning in July, still during the dry season. After weaning, an intervention was applied in the system, using dietary supplementation strategies for 120 days (July-October).

The bioeconomic effect of the applied feeding strategies was simulated considering a herd of 50 calves with 120-kg initial BW (Nhantumbo, 1985; Carvalheira et al., 1995). The initial weight was assumed from the average weight of the selected calves after weaning, the age differences considered between weaners did not influence the analysis of the systems (Fig. 2). After the supplementation period, yearling bulls were sold to local farmers for finishing.

2.4. Animal feeding component: Feedstuffs

The feedstuffs included (Table 1) in the diets formulated to achieve the pre-defined ADG of each feeding system were those available in the studied region. In all systems, *Hyparrhenia rufa* grass was the main feedstuff, as it is commonly used by the local farmers (Nhantumbo, 1985). The selection of these feedstuffs type was based on expert opinion and our observation.

The chemical composition of the feedstuffs is shown in Table 1. Diets were formulated using the Supercræce Software for beef cattle (TD Software, 2010), and the nutritional requirements of yearling bulls of the NRC - Beef Cattle (NRC, 1996). Energy content (total digestible nutrients, TDN) was estimated using Eqs. 2 and 3 for roughages and concentrates, respectively (Cappelle et al., 2001).

\[
TDN\% = \left[ \frac{-2.49 + (1.0167 \times OMD)}{5.60 + (0.8646 \times OMD)} \right] \tag{2}
\]

\[
TDN\% = \left[ \frac{-1.49 + (0.977 \times OMD)}{5.60 + (0.8646 \times OMD)} \right] \tag{3}
\]
Where, OMD (%) is organic matter digestibility.

Three feeding strategies (FS) were simulated for each of the four positive ADG systems, totaling 12 FS (Table 2). The S-200 system was considered the control treatment, as it was not submitted to any intervention. Each FS was based on feedstuffs availability in the region, nutritional characteristics, previous knowledge of the use and the costs of the feedstuffs included in each ADG system (S000, S200, S400, and S600).

In the model, the total body weights gains of yearling bulls were -24.00 kg (S-200); 0.00 kg (S000); 24 kg (S200); 48 kg (S400); and 72.00 kg (S600) (Table 2). Among positive average daily gain systems, the lowest and highest \( H. rufa \) intakes were obtained with FS7 (0.575 kg DM/d) and FS5 (1.8 kg DM/d), respectively. Corn bran was one of the most frequent feedstuffs included in the FSs. ADG efficiency was similar among FS applied in each ADG system.

2.5. Economic component

2.5.1. Feedstuff cost of each feeding strategy

The feedstuff cost of each FS was calculated based on two criteria: 1 - feedstuff (on DM basis) price in the local markets, and 2 - pasture implementation cost. The cost of implementing 1 ha of pasture included the costs related to tillage, sowing (including the number of additional seedlings to be planted, germination rate, number of seeds/kg), local labor, and fertilization with cattle compost, and reflected local conditions. Pasture maintenance cost per production cycle and its respective productivity (kg DM/ha) were also considered (Table 3). Production and feed costs were calculated according to the prices prevailing between June and September, 2018, in the region of Angónia.

Total production cycles of 10 years were considered for \( L. leucocephala \) (1), \( G. sepium \) (2), \( S. sesban \) (3), \( M. oleifera \) (4); and of 3 years for \( C. cajan \). A 5% annual productivity reduction was calculated in order to avoid overestimating pasture DM productivity during the production cycles. \( M. oleifera \) hay production was established as 120 kg per 1000 kg of fresh shoots (Mendieta-Araica et al., 2011).

To capture the uncertainty of the dry matter productivity of the forages on the simulation model, the average values of the forages productivity were varied to ± Standard Deviation (SD). This variation was reflected in the feedstuffs costs of these forages. With these costs, the gross margin (GM) was determined considering these SD of forage productivity.

2.5.2. Labor cost and economic indicators

The labor costs of the evaluated systems (S-200, S000, S200, S400, and S600) (Table 4), assumed, due to the different \( H. rufa \) intake levels among the systems, that the number of labor hours required varied as a function of daily pasture DM intake in each system. At a DM intake of 1.8 kg DM of \( H. rufa \) (FS5), a total of 8 man-hours (0.225 kg DM/h/head/d) was assumed (Pimentel et al., 2011).

Based on a minimum monthly wage of USD 66.81 (WageIndicator, 2019), daily labor cost of 8 hours of work was set as USD 2.23, resulting in an hourly labor cost of USD 0.278/d for a total of 50 heads/d.

Based on the studies of Lopes et al. (2011); Silva et al. (2014), and Sartorello et al. (2018). However, in order to represent the simulated system, the following items were included in the variable costs: (1) calf purchase cost; (2) total diet cost (TDC); (3) stockman labor cost; (4) health intervention cost, which included communal dipping; and (5)
other variable costs, resulting in the effective operational cost (EOC). Fixed costs included the depreciation of the equipment used for pasture cutting and transport and of the facilities. Depreciation was calculated according to Eq. 4, considering a 5-year life for pasture cutting equipment, a 2-year life for cut pasture transport, and a 10-year life for the facilities (pens). The residual value was considered as 0.0%.

\[
D = \frac{V_p/V_i \times SDs}{365 \text{ days}}
\]

(4)

Where: D - depreciation; \(V_p\): asset purchase value; SDs: simulation days; and \(V_i\): life. The calculation was based on a total number of 50 animals.

The other equations used to determine the economic indicators are as follows:

✓ Concentrate cost (CC), in percentage, is the ratio between concentrate cost (the sum of all concentrated feed costs intake during the simulation period) and total diet cost (TDC) in each feeding strategy.

\[
CC(\%) = \frac{CC}{TDC} \times 100\%
\]

(5)

✓ Total diet cost (TDC) represent the total dry matter intake in each feeding strategy, in USD per simulations days (SDs).

\[
TDC = kg \text{ DMI/SDs} \times \text{ price/kg feedstuff}
\]

(6)

✓ Feeding cost (FC) was considered as the sum of total diet cost (TDC) and labor cost (LC), in USD.

\[
FC = TDC + LC
\]

(7)

✓ Effective operational cost (EOC), represents the sum of all variable costs used in the model, in USD.

\[
EOC = (Price/ \text{ kg BW} \times BW) + FC + HIC + OC
\]

(8)

### Table 1

Chemical composition (on dry matter basis) of the feedstuffs used to simulate the feeding strategies (FS) for yearling beef bulls.

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>DM (%)</th>
<th>CP (%)</th>
<th>Ca (%)</th>
<th>P (%)</th>
<th>TDN (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cajanus cajan</td>
<td>31.80</td>
<td>19.00</td>
<td>0.72</td>
<td>0.18</td>
<td>63.19</td>
</tr>
<tr>
<td>Gliricidia sepium</td>
<td>25.30</td>
<td>22.30</td>
<td>1.19</td>
<td>0.23</td>
<td>74.37</td>
</tr>
<tr>
<td>Hyparrhenia rufa</td>
<td>31.10</td>
<td>7.10</td>
<td>0.38</td>
<td>0.17</td>
<td>54.45</td>
</tr>
<tr>
<td>Leucaena leucocephala</td>
<td>29.90</td>
<td>23.30</td>
<td>0.11</td>
<td>0.21</td>
<td>74.17</td>
</tr>
<tr>
<td>Mambos esculenta</td>
<td>22.50</td>
<td>24.90</td>
<td>0.119</td>
<td>0.37</td>
<td>62.48</td>
</tr>
<tr>
<td>Moringa oleifera</td>
<td>91.20</td>
<td>26.60</td>
<td>2.56</td>
<td>0.33</td>
<td>74.98</td>
</tr>
<tr>
<td>Muscuna pruriens</td>
<td>24.70</td>
<td>16.00</td>
<td>0.10</td>
<td>0.19</td>
<td>66.75</td>
</tr>
<tr>
<td>Sesbania sesban</td>
<td>26.00</td>
<td>24.40</td>
<td>1.59</td>
<td>0.33</td>
<td>81.39</td>
</tr>
<tr>
<td>Urea</td>
<td>100.00</td>
<td>287.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Zea mays</td>
<td>90.00</td>
<td>8.00</td>
<td>0.04</td>
<td>0.29</td>
<td>82.29</td>
</tr>
<tr>
<td>Limestone</td>
<td>100.00</td>
<td>0.00</td>
<td>38.5</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Corn bran</td>
<td>88.70</td>
<td>11.90</td>
<td>0.47</td>
<td>0.34</td>
<td>76.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cajanus cajan</td>
<td>(Heuze et al., 2016a)</td>
</tr>
<tr>
<td>Gliricidia sepium</td>
<td>(Heuze and Tran, 2015a)</td>
</tr>
<tr>
<td>Hyparrhenia rufa</td>
<td>(Heuze et al., 2015b)</td>
</tr>
<tr>
<td>Leucaena leucocephala</td>
<td>(Heuze and Tran, 2015b)</td>
</tr>
<tr>
<td>Mambos esculenta</td>
<td>(Heuze et al., 2016b)</td>
</tr>
<tr>
<td>Moringa oleifera</td>
<td>(Heuze et al., 2015c)</td>
</tr>
<tr>
<td>Muscuna pruriens</td>
<td>(Heuze et al., 2015c)</td>
</tr>
<tr>
<td>Urea</td>
<td>(INRA, CIRAD, AFZ 2017)</td>
</tr>
<tr>
<td>Zea mays</td>
<td>(Heuze et al., 2017)</td>
</tr>
<tr>
<td>Limestone</td>
<td>(Campon, 1980 quoted by Sousa, 1985)</td>
</tr>
<tr>
<td>Corn bran</td>
<td>(Heuze et al., 2016c)</td>
</tr>
</tbody>
</table>

- Aerial parts;
- Hay;
- Grain;
- Corn byproduct, containing the pericarp, tip, and some starch particles, derived from the milling of dry corn grains, which are one of the main components of the diet of the population of Mozambique;
- Native pasture; DM: dry matter; CP: crude protein; Ca: calcium; P: phosphorus; TDN: total digestible nutrients.

### Table 2

Total diet, total body weight gain (TWG), dry matter intake (DMI) and feed efficiency in different systems (S-200, S000, S200, S400 and S600) based on average daily gain (ADG) in yearling beef bulls.

<table>
<thead>
<tr>
<th>Feeds</th>
<th>S-200 ADG: 0.200 kg/d</th>
<th>S000 ADG: 0.000 kg/d</th>
<th>S200 ADG: 0.200 kg/d</th>
<th>S400 ADG: 0.400 kg/d</th>
<th>S600 ADG: 0.600 kg/d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NI</td>
<td>FS1</td>
<td>FS2</td>
<td>FS3</td>
<td>FS4</td>
</tr>
<tr>
<td></td>
<td>Total weight gain</td>
<td>-24.00</td>
<td>0.00</td>
<td>24.00</td>
<td>48.00</td>
</tr>
<tr>
<td>Feedstuffs</td>
<td>DMI (kg/d)</td>
<td>DMI (kg/d)</td>
<td>DMI (kg/d)</td>
<td>DMI (kg/d)</td>
<td>DMI (kg/d)</td>
</tr>
<tr>
<td>Cajanus cajan</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gliricidia sepium</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hyparrhenia rufa</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Leucaena leucocephala</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mambos esculenta</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Morinig oleifera, hay</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Muscuna pruriens</td>
<td>-</td>
<td>0.650</td>
<td>-</td>
<td>0.550</td>
<td>-</td>
</tr>
<tr>
<td>Sesbania sesban</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Urea</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.032</td>
</tr>
<tr>
<td>Zea mays, grain</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.071</td>
</tr>
<tr>
<td>Limestone</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.003</td>
</tr>
<tr>
<td>Corn bran</td>
<td>-</td>
<td>0.170</td>
<td>0.180</td>
<td>0.240</td>
<td>1.070</td>
</tr>
<tr>
<td>Total intake (kg DMI/head/SDs)</td>
<td>239.64</td>
<td>236.4</td>
<td>237.6</td>
<td>244.8</td>
<td>344.4</td>
</tr>
<tr>
<td>ADG Efficiency</td>
<td>-0.150</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.070</td>
</tr>
</tbody>
</table>

- Aerial parts;
- Calculated as the ratio between ADG and total DMI per head;
- Based on total dry matter intake (DMI) in S000; NI: no intervention; FS: feeding strategy; DMI: dry matter; SDs: simulation days;
- Native pasture; SDs: simulation days.
Where, FC: feeding cost; BW: body weight (kg); \(BW_i\): initial body weight (kg); HIC: health intervention cost (payment of communal dipping bats); OC: other variables costs.

- Total operational cost (TOC) was calculated as the sum of effective operational cost and depreciation, in USD.

\[
TOC = EOC + \text{depreciation}
\]  

(9)

- Effective operational cost (EOC) in percentage, was calculated as the ratio between effective operational cost (EOC) and total operational cost (TOC).

\[
EOC(\%) = \frac{EOC}{TOC} \times 100\%
\]

(10)

- Revenue was measured multiplying the final body weight (\(BW_f\)) by the price per kg body weight (BW), in USD.

\[
Revenue = BW_f \times \text{sales price/kg BW}
\]

(11)

- Gross Margin (GM) was calculated as revenue minus effective operational costs (EOC), in USD.

\[
\text{Gross margin} = Revenue - EOC
\]

(12)

- Net profit was calculated as revenue minus total operational costs (TOC), in USD.

\[
\text{Net profit} = Revenue - TOC
\]

(13)

- Profitability was calculated as a ratio between net profit and revenue, in %.

\[
\text{Profitability (\%) } = \left(\frac{Revenue - TOC}{Revenue}\right) \times 100\%
\]

(14)

Calf purchase and yearling bull sales price was the same (USD 1.21/
3. Results

Sensitivity analysis and economic performance of the feeding strategies

Feeding strategies were submitted to sensitivity analysis by decreasing and increasing calf purchase price per kg BW and feedstuff purchase price. The reduction of both prices resulted in both positive gross margin and net profit, while their increase resulted in negative net profit in the S000 system and in FS4 and FS5, and negative gross margin in all FS of the S000 and of FS5 of the S200 system (Table 5).

The simulated ADG loss (S-200) and ADG maintenance (S000) systems, respectively. Effective operational costs (EOC) represented the highest proportion of ADG systems evaluated, as shown by the highest and lowest TOC values obtained in the S-200 (USD 1.60) and S600 (USD 0.82) ADG systems, independently of FS, resulted in economic losses, as shown by the negative gross margin values, as well FS5 within the S200 system (Table 5).

The simulated ADG loss (S-200) and ADG maintenance (S000) systems, respectively. Effective operational costs (EOC) represented the highest proportion of total operational cost per kg of final BW decreased as final BW increased up to 400 g/kg. Total diet cost (Table 6) increased as ADG increased up to 400 g/kg BW) for all systems, except for the sales price of S-200 yearling bulls, which was lower (USD 0.81/kg BW) (Chakoma et al., 2016a). Price was determined based on the exchange rate of USD 1 = MT 62.00 (BM, 2018). The diet supply in all feeding strategies did not involve any cost. For this, family labor was assumed, as it constitutes one of the main assets of the farmers (Cumbe et al., 2017).

2.6. Sensitivity analysis

A sensitivity analysis was carried out by increasing and decreasing feedstuffs and calf purchase prices by 10% in the simulation model. This analysis was performed in order to understand the reliability of the simulation model, in relation to the output indicators, with emphasis on the values of gross margin and net profit.

Table 3

Average annual production (kg DM), cost of pasture implementation or maintenance during the entire production cycle (CPIM), and cost (kg/DM) of the feedstuffs used to formulate diets for yearling beef bulls.

<table>
<thead>
<tr>
<th>Feedstuffs</th>
<th>Yield (kg DM/ha)</th>
<th>SD</th>
<th>Per total cycles</th>
<th>CPIM USD/ha</th>
<th>Cost USD/kg DM</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cajanus cajan</td>
<td>6468.9</td>
<td>341.7</td>
<td>18452.4</td>
<td>500.00</td>
<td>0.027</td>
<td>(1, 2, 3, 4)</td>
</tr>
<tr>
<td>Giricidia sepium</td>
<td>5258.1</td>
<td>3352.9</td>
<td>42197.0</td>
<td>1020.97</td>
<td>0.024</td>
<td>(2, 5, 6, 7, 8, 9, 34)</td>
</tr>
<tr>
<td>Hyparrhenia rufa</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Leucaena leucocephala</td>
<td>9004.7</td>
<td>5680.7</td>
<td>72265.1</td>
<td>769.35</td>
<td>0.011</td>
<td>(2, 5, 7, 8, 9, 10, 31, 32)</td>
</tr>
<tr>
<td>Manihot esculenta</td>
<td>5179.7</td>
<td>1560.3</td>
<td>10359.3</td>
<td>346.77</td>
<td>0.033</td>
<td>(5, 11, 12, 13)</td>
</tr>
<tr>
<td>Moringa oleifera, hay</td>
<td>8899.3</td>
<td>5022.8</td>
<td>32711.1</td>
<td>1314.52</td>
<td>0.040</td>
<td>(14, 15, 16, 17, 19, 20, 33)</td>
</tr>
<tr>
<td>Mucuna pruriens</td>
<td>6249.6</td>
<td>3124.5</td>
<td>-</td>
<td>395.16</td>
<td>0.063</td>
<td>(21, 22, 23, 24, 25, 26, 27)</td>
</tr>
<tr>
<td>Sesbania sesban</td>
<td>7185.4</td>
<td>634.5</td>
<td>57664.7</td>
<td>625.00</td>
<td>0.010</td>
<td>(2, 10, 29, 30)</td>
</tr>
</tbody>
</table>

Table 4

Labor costs of the simulated average daily gain systems (S-200, S000, S200, S400 and S600) based on communal grazing of yearling beef bulls.

<table>
<thead>
<tr>
<th>Feed ing strategies</th>
<th>DMIp kg/d</th>
<th>Seasonal labor hours/d</th>
<th>Labor costs USD (heads/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>1.997</td>
<td>8.99</td>
<td>2.477</td>
</tr>
<tr>
<td>FS1</td>
<td>1.15</td>
<td>5.11</td>
<td>1.423</td>
</tr>
<tr>
<td>FS2</td>
<td>1.45</td>
<td>6.44</td>
<td>1.794</td>
</tr>
<tr>
<td>FS3</td>
<td>1.46</td>
<td>6.49</td>
<td>1.806</td>
</tr>
<tr>
<td>FS4</td>
<td>1.25</td>
<td>5.56</td>
<td>1.546</td>
</tr>
<tr>
<td>FS5</td>
<td>1.8</td>
<td>8.00</td>
<td>2.227</td>
</tr>
<tr>
<td>FS6</td>
<td>1.435</td>
<td>6.38</td>
<td>1.775</td>
</tr>
<tr>
<td>FS7</td>
<td>0.575</td>
<td>2.56</td>
<td>0.711</td>
</tr>
<tr>
<td>FS8</td>
<td>0.582</td>
<td>2.59</td>
<td>0.72</td>
</tr>
<tr>
<td>FS9</td>
<td>0.626</td>
<td>2.78</td>
<td>0.774</td>
</tr>
<tr>
<td>FS10</td>
<td>1.6</td>
<td>7.11</td>
<td>1.979</td>
</tr>
<tr>
<td>FS11</td>
<td>0.8</td>
<td>3.56</td>
<td>0.99</td>
</tr>
<tr>
<td>FS12</td>
<td>0.85</td>
<td>3.78</td>
<td>1.052</td>
</tr>
</tbody>
</table>

NI: no intervention; FS: feeding strategy; DMIp: dry matter intake of native pasture; h: hour; d: day; SDs: simulation days

3. References

Cost calculation for each feedstuff was CPIM/yield per entire cycle for the perennial forages. For annual forages, it was CPIM/yield per cycle; DM: dry matter; SD: Standard Deviation. Currency rate: USD 1 = MZN 62.00 on November 29, 2018 (BM, 2018). 1: (Babar, 1981); 2: (Dzowela et al., 1997); 3: (Rao et al., 2002); 4: (Costa et al., 2013); 5: (Wong and Sharunird, 1986); 6: (Cobbina and Atta-Krah, 1992); 7: (Barreto and Fernandes, 2001); 8: (Barnes, 1995); 9: (Kiwia et al., 2009); 10: (Casanova-Lugo et al., 2014); 11: (Islami and Howeler, 2016); 12: (FAO, 2013); 13: (Linsilta et al., 2002); 14: (Mendieta-Araica et al., 2013); 15: (Sánchez et al., 2006); 16: (Foidl et al., 2001); 17: (Ledes-Rodríguez et al., 2018); 19: (González-González and Crespo-Lópe, 2016); 20: (Zheng et al., 2016); 21: (Asongwed-Awa and Onana, 2002); 22: (Elliott et al., 2003); 23: (Fuji et al., 1991); 24: (Odhiambo et al., 2010); 25: (Carsky et al., 2013); 26: (Wang et al., 2009); 27: (Sanwal et al., 2016); 28: (Chakoma et al., 2016a); 29: (El-Morsy, 2009); 30: (Heering, 1995); 31: (Guevarra et al., 1978); 32: (Drumond and Ribaski, 2010); 33: (Sánchez et al., 2006) and 34: (Speedy, 1995).
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Table 5

Table 6

Feeding costs and economic benefits of feeding strategies per animal in different systems (S-200, S000, S200, S400 and S600) based on average daily gain (ADG) in yearling beef bulls.

Table 7

Sensitivity of the simulation model to change in feedstuffs purchase price and calf purchase price per kg BW in different systems (S-200, S000, S200, S400 and S600)
study are typical in beef-cattle production systems in tropical regions during the dry season, as previously reported by Tinga and Chimbalambala (2016) in the southern region of Mozambique, as well as by Quigley et al. (2009) in Indonesia and Franco et al. (2018).

Systems aiming at positive body weight gains may allow achieving better economic gains (Gonzalez et al., 2003; Quigley et al., 2009; Radrizzani and Nasca, 2014; Chakoma et al., 2016b). In addition, high body weight gain (BWG) targets may allow the intensification of beef cattle production systems and provide sales advantages due to the added value of marketing heavier yearlings at the end of the dry season, particularly under the conditions of Mozambique.

Feeding strategies may allow achieving BWG targets by supplying the nutritional requirements of growing cattle during periods when pastures contain low energy and protein levels (Poppi et al., 2018). The supplementation of energy- and protein-rich supplements increased the productivity of beef cattle grazing on H. rufa in communal areas during the dry season (Nouel and Combellas, 1999), when this pasture is not able to supply not even the maintenance requirements of post-weaning beef cattle.

Concentrates accounted for the highest proportion of the total diets due to the low nutritional value of the native pasture on which the simulation was based. However, in the study of Angel et al. (2018), native pastures represented 84.9% of DM intake, and a protein and energy supplement was separately fed in corrals. Those results emphasize that the worse is forage quality, the greater is the need of supplementation to achieve positive ADG or to maintain it.

Although the concentrate proportion of the total diet was similar among the three FS simulated for each ADG system, the composition of the total diet was different. In particular, the FS12 indicate that roughage type may promote higher ADG. The simulated FS strategies including corn bran promoted higher BWG, suggesting that it is the best feedstock option for supplementation, in agreement with Chingala et al. (2017) who reported that, in similar beef production systems in Malawi, 86% of the farmers mentioned the use of corn bran as supplement.

Average daily gain efficiency depended on the feedstock nutritional levels in this simulation, as previously observed by Quigley et al. (2009) when evaluating different feeding strategies for yearling cattle in Indonesia. As feeding cost accounts for most of the total production cost, farmers tend to choose the cheapest feeding intervention strategy for yearling cattle. However, other aspects should be taken into account, such the physical effort required to feed the animals, considering family labor.

The proportional increase in feeding costs per kg of total weight gain, except for FS12, demonstrates that, in order to achieve higher BWG, higher investments are needed. Although reporting different absolute values, several authors (Lopes et al., 2008; Shi et al., 2014) also observed that the feeding costs increases with BWG. However, it should be noted that FS12 promoted the highest ADG (0.600 kg) at the lowest FC/kg TWG, highlighting the opportunity to achieve high BWG with cheap feedstuffs, in agreement with Gusha et al. (2015), who stated that the strategic supplementation with alternative feedstuffs may reduce costs and increase profitability. However, it must be taken into account that total diet cost depends on the price of each feedstuff per kg of DM and its nutritional content, aiming at supplying the daily nutritional requirements to achieve that desired ADG.

Priyanti et al. (2010), evaluating different feeding strategies, obtained an ADG of 0.418 kg/d at a cost of USD 10.93/kg with L. leucocephala supplementation and 0.428 kg/d at USD 8.76/kg with supplementation of bran of rice + copra flour in yearling calves in Indonesia. Compared to the results of Priyanti et al. (2010), the costs of all FS simulated in the present study to achieve similar ADG (S400) were 65% higher. On the other hand, the relatively lower total diet cost (TDC) of FS12 (USD 7.08) to achieve higher ADG (0.600 kg/d) may be explained by the differences in feedstuff cost/kg or by the high productivity of Sesbania sesban. Furthermore, although the cost of USD 19.18 calculated to achieve 0.200 kg ADG by Priyanti et al. (2010) is comparable to that of FSS (USD 25.67), it is still much higher than that of the other FS applied to obtain the same ADG (FS4 and FS6), which TDC were lower than USD 8.5. This comparison shows that FSS is not economically feasible, and, therefore, it is not recommended under the conditions of this study.

The analysis of the simulated FS shows that higher ADG targets promote better economic benefits per kg WG, as indicated by the lower feeding cost, and both total and effective operational costs per kg of total weight gain. In pre-established production systems, these results are even more important, as only feeding management is required.

The reduction of total operational costs per kg BW as ADG increases indicates higher ADGs maximize the use of inputs, providing higher profits. Since family labor accounts for the largest proportion of the effective operational cost, the fixed costs of the simulated production systems were low.

The negative and low gross margin and net profit calculated for the simulated BW loss (S-200) and BW maintenance (S000) systems, respectively, which were based on extensive grazing in native pastures in communal areas, indicate that such systems are not profitable and require interventions to generate economic benefits in the medium term (Lopes et al., 2008).

In general, higher net profit to total operational cost ratios (NP/TOC) were obtained as ADG increased, differently from Shi et al. (2014), who calculated NP/TOC ratios of 2.71, 3.84, and 4.61 for ADGs of 1.72, 1.60, and 1.40 kg/d, respectively. In the present simulation, NP/TOC ratios were proportional to gross margin and profitability as equal feedstuff prices were assumed for the diets of all simulated FSs.

The highest profitability was obtained with FS12, followed by FS10, indicating the potential of the feedstuffs used in these FS. For instance, the concentrate fed in FS10 consisted of M. pruriens grains, which, according to Chakoma et al. (2016b), allows good economic returns due to its low cost and high nutritional value. This legume is widely distributed in Mozambique (Cassani et al., 2016), where it is an important source of nutrients in traditional cattle production systems.

The high profitability of FS12 was related to the inclusion of perennial forages and corn bran. Bowen et al. (2016), in Northern Australia, observed that beef production systems based on perennial L. leucocephala pastures were more profitable than those based on annual crops. This may be attributed to the low cost of perennial pastures, where production is maximized during a long productive cycle, and underscores that the supply of supplements is beneficial in the long term (Bennison et al., 1997). In addition, the inclusion of corn bran in FS12 promoted high profitability due to its low cost (May et al., 2005; Kavishe et al., 2017). This result corroborates the findings of Tahir et al.
production systems. Among the feedstuffs evaluated, corn bran, corn, wheat or rice bran in the diet of dairy cows, and concluded that more than 40% of the beef consumed in urban centers is imported (Vernooij et al., 2016).


Dzomba, L., Mulla, R., Bluhm, P., 2016. Effect of frequency of protein-energetic supplementation on the performance and ingesta composition of Nellore steers kept in a tropical pasture in the

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