

Feed technologies and efficiency in cow-calf systems

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ABSTRACT - This study was performed to evaluate the efficiency index of cow-calf systems, based on different feed technologies commonly employed in the Rio Grande do Sul state, southern Brazil. Hence, the efficiency of 35 cow-calf herds was evaluated by Data Envelopment Analysis (DEA). Data was collected by online survey and in-depth interviews, as well as data registers from the cow-calf systems, located in 31 municipalities. The analyzed indicators included rates of mortality, pregnancy, birth, and productivity. The feed technologies evaluated were the use of cultivated pastures during winter and summer, supplementation during winter and summer, creep feeding, deferral of natural pasture, use of grazing systems, and employee's capacitation. Approximately 80% of the evaluated farms showed low-to-medium Efficiency Index (EI; up to 0.79 in a scale of 0 to 1), 13% presented high EI, and only 7% had very high EI (above 0.95). The use of cultivated pastures with the inclusion of protein supplementation and employees' capacitation were highlighted as the main practices to increase efficiency of cow-calf systems in Rio Grande do Sul. The technologies identified as most impactful raise the EI of production systems from low to medium. Our results assist in decision-making in the use of feed technologies, pointing out a direction for the use of technologies that make breeding systems more efficient from a productive point of view.

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Received: October 27, 2021

Accepted: August 29, 2022

How to cite: Rosa, Y. M.; Zago, D.; Oliveira, T. E.; Camargo, V. A. and Barcellos, J. O. J. 2022. Feed technologies and efficiency in cow-calf systems. Revista Brasileira de Zootecnia 51:e20210193. <https://doi.org/10.37496/rbz5120210193>

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Keywords: beef cattle, ruminant nutrition, supplementation

1. Introduction

Measuring efficiency is an important tool for evaluating beef cattle production systems, identifying flaws, making decisions to improve results, and maintaining a competitive activity (Mello et al., 2005). Moreover, the adoption of technologies in production systems allows improvements in its zootechnical and economic indicators (Dill et al., 2015a), and the difference in results is related to the effectiveness of the technology adopted (Lampert, 2010). Hence, the success of livestock production is related to the correct control and planning of the selection and choice of technologies and the management of other interconnected factors, which demand understanding of these technologies and their effects on the production system.

The challenge of cow-calf systems, due to its complex production factors, narrow profit margins, and by different risks and intricacy of the technologies applied at this stage (Oliveira et al., 2018), makes it vital to understand and analyze the selection of the right technological strategy. Hence, cow-calf managers and investors face the upcoming hurdle of managing their farms, as well

as continuing learning the complex technical aspects and impacts of the use technologies for innovation and efficiency implementation.

The harmonic planning and monitoring of activities involving the introduction and maintenance of technologies allow the production systems to achieve maximum efficiency (Abreu et al., 2006). Among the available technologies, those related to feed strategies act directly on the biological responses of cow-calf herds and are responsible for a large proportion of production costs (López-González et al., 2020); therefore, their adoption must be evaluated with caution.

To measure the efficiency and improvement offered by a technology, zootechnical and economic indicators are used, and it is important to choose an effective method of evaluation for a better decision process. Data Envelopment Analysis (DEA) has been a methodological tool used to assess and estimate efficiency in beef cattle cow-calf systems (Gomes et al., 2015). Allied to this analysis, it is important to correlate the Efficiency Index (EI) with the indicators involved in the technology, so that results can be related to the generating effects of this index. Therefore, this study aimed to identify the EI in the cow-calf systems by analyzing the use of feed technologies of these herds.

2. Material and Methods

2.1. Data collection

Data was collected through online survey by questionnaires and presential interviews with 35 farm managers, located in 31 municipalities in Rio Grande do Sul state, Southern Brazil (Figure 1). The online questionnaire was formulated and distributed by Google Forms.

A pre-test of the questionnaire was carried out with six beef producers, to eliminate unnecessary questions and possible bias, as well as to add pertinent questions that could have been disregarded in the research. Personal in-depth interviews were conducted at traditional technical events and on the farms. When identifying the unfeasibility of personal interviews with some producers, they were asked to complete the online questionnaire, sent by email.

The questionnaire consisted of questions related to the productive characteristics, as well as technological, organizational, and socioeconomic aspects of the production systems (Table 1),

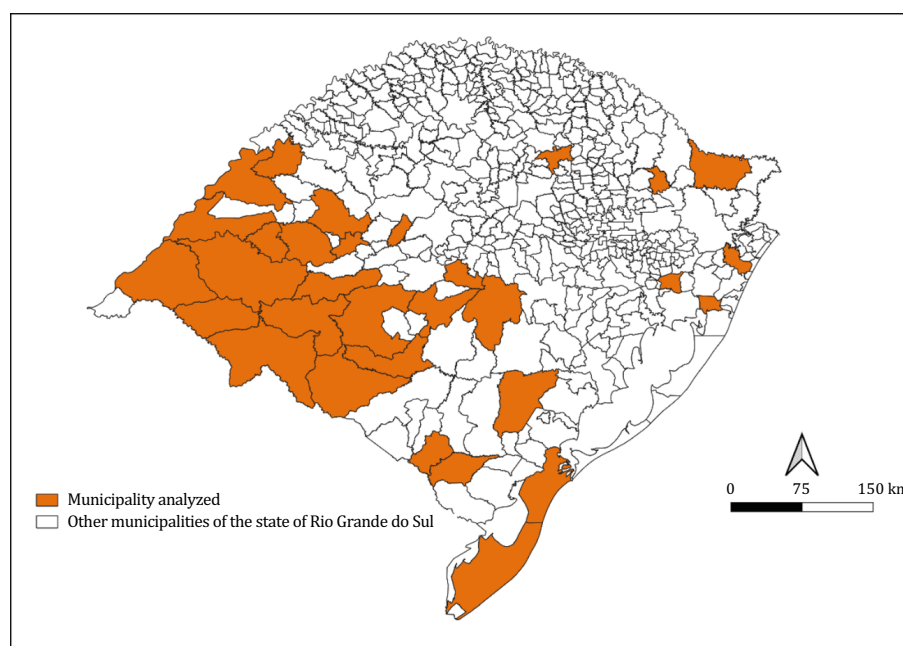


Figure 1 - Geographical distribution of the properties analyzed in the state of Rio Grande do Sul, southern Brazil.

predominantly the production indexes and technologies used in farm, totaling 26 questions. Productive information related to the physical characterization of the farm, herd structure, productive indexes, and management strategies adopted for the pasture and the herd were considered. Technological information includes the influences of the techniques and innovation implemented in the production systems. The organizational features, referred to the number of employees and their training, as well as the socioeconomic variables referring to the profile of the respondent, such as sex, age, and education.

The technologies evaluated were classified as input technologies and processes technologies. Input technologies include the use or not of some type of mineral supplementation, energy supplementation (crude fiber content less than 18% and protein less than 20%), protein supplementation (crude fiber content less than 18% and protein higher than 20%) or roughage supplementation (hay, silage or pre-dried silage); use or not of irrigation in pasture areas; use or not some kind of fertilizer on pasture areas; use or not of electric fence; and use or not of supplementation of calves before weaning (creep feeding).

The process technologies are represented by crop-livestock integration, which refers to the use of pastures in farming areas during the off-season of agricultural crops; weaning strategy

Table 1 - Classification in extracts of the questions applied to managers of cow-calf systems, in the responding properties in the state of Rio Grande do Sul, southern Brazil

Variable	Dimension			
	Productive	Technological	Organizational	Socioeconomic
Total farm area (ha)	X			
Useful farm area (ha)	X			
Use or not of crop/livestock integration	X	X		
Pregnancy rate (%)	X			
Weaning rate (%)	X			
Grassland stocking rate (kg BW/ha)	X			
Age at first mating (months)	X			
Weight at first mating (kg)	X			
Weaning type ¹	X	X		
Weaning weight (kg)	X			
Supplementation level (%)	X	X		
Average weight of cows (kg)	X			
Type of supplement		X		
Use or not of cultivated pastures	X	X		
Grazing techniques ²		X		
Use or not of stockpiling of natural pasture		X		
Use or not of irrigation		X		
Use or not of fertilization		X		
Use or not of electric fence		X		
Employee number			X	
Training use ³			X	
Scholarity				X
Age				X
Sex				X
Activity length				X

¹ Conventional (180 days), early (120 days), and very early weaning (60-90 days).

² Continuous, rotational, or temporary grazing.

³ Courses related to the cow-calf system.

(conventional at 180 days of age), early and very early weaning (at 120 and 60-90 days of age); supplementation level (percentage of supplements offered in relation to the animal's body weight); cultivated pastures (use of cultivated winter or summer pastures or only natural pastures); grazing technique (rotational, when the pasture area is separated into smaller paddocks and the group of animals is moved regularly between paddocks (Undersander et al., 2002); temporary, when animals have access to pasture only for a period of time, one day, or a few hours; or continuous grazing, when the animals have continuous, unrestricted access to the rangeland (Heady, 1961)); stocking rate planning (the amount of land allocated to each animal unit for the grazable period of the year); and stockpiling of natural pasture.

Stockpiling (fall-saved pasture or deferred grazing) implies the suspension of grazing until the wintering species has sown or recovered its vigor (McGeough et al., 2018).

The collected data was organized and tabulated Microsoft Excel®. After the tabulation, the information was verified to correct possible typing errors and eliminate unreadable data and biases. Descriptive and frequency analyzes were performed using IBM SPSS Statistics version 20 (Wagner, 2019). The productivity was validated in software @RISK version 7.6 (Palisade Corporation 2019), which allows incorporation of the probability of occurrence of variation in the result and evaluating risks to be taken or avoided.

2.2. Efficiency analysis

The amplitude determination of feed technologies effect on cow-calf herds efficiency were obtained by EI through the DEA, developed in the SIAD software (Sistema Integrado de Apoio à Decisão), version 3.0. The DEA allows the use of several calculation models. The most suitable model for analysis was elaborated by Banker, Charnes, and Cooper, (BCC) in 1984 (Banker et al., 1984), also known as Variable Return Scale (VRS), which considers variable returns to scale. This model allowed the comparison of herds with different sizes and considers that an input increase may promote a variation in the output, not necessarily proportional. The BCC softens the assumption of constant returns to scale and admits that the relationship between system inputs and outputs is affected by production scale (Abel, 2000).

The model was oriented for output, that is, the main objective was to increase the output—in this study, an increment either in the number or weight of calf produced by the system—without any change in the inputs, keeping them stable (Nogueira et al., 2012). This guideline was used because the primary objective was to identify the potential increased production with the technologies, not to assess increases in the investments or uses of feed technologies.

For EI calculating herds, the indicators used as inputs were percentage of mortality, birth, and pregnancy rates. The output productivity ($\text{kg of calf-cow}^{-1}\cdot\text{year}^{-1}$) relates the number of weaned calves and their weight at weaning according to the number of cows in reproduction in the previous year (Baker and Carter, 1976). These indicators were chosen because they fully represent the cow-calf systems, in addition to being data that herd managers normally have.

From the EI determination of cow-calf systems, the results of the efficiency indexes were associated with the technologies implemented in the herds, those observed in the initial questionnaire, all according to the feed system, such as: winter pastures, summer pastures, stockpiling of native pasture, supplementation, creep feeding, grazing techniques, and employee training. This step made it possible to determine the influence of technologies on the EI (Figure 2).

The results obtained through the DEA vary from 0 to 1, and was arbitrated that the classification extracts of farms, according to the efficiency index, would be low (<0.65), medium (0.65 to 0.79), high (0.80 to 0.95), and very high (>0.95).

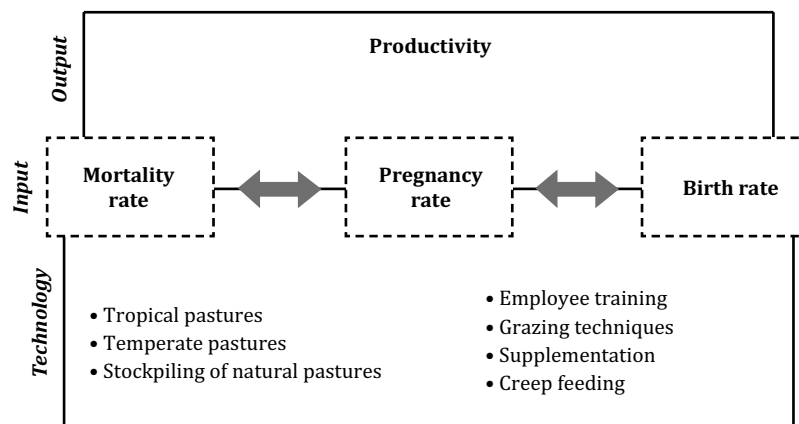


Figure 2 - Efficiency evaluation model of cow-calf system in Rio Grande do Sul state, southern Brazil.

3. Results

3.1. Cow-calf systems

There was a significant variation in the size of farms evaluated, 70% develop agricultural activities, with an average productivity in livestock of 124.2 kg per year. The average weaning rate was less than 80%, including farms with weaning rates of 26.4% (Table 2).

The weight of weaned calves, in the different types of weaning, was 176.8 kg in conventional weaning (at 180 days), 168 kg for early weaning (at 120 days of age), and 115.5 kg for very early weaning (until 90 days). The herds productivity according to the weaning strategy was 124.2, 119.8, and 114.8 kg for conventional, early weaning, and very early weaning, respectively.

Most cow-calf systems use pastures cultivated during the winter (Table 3), especially consisting of grasses such as oats (*Avena strigosa*) and ryegrass (*Lolium multiflorum*), and those that use consortium with legumes choose white clover (*Trifolium repens*). In these herds, the productivity was 126.5 kg, similar to the herds that do not use winter pastures, which obtained productivity of 122.3 kg. In the summer, farms that use only natural grazing had productivity of 118.8 kg. In herds that used tropical pasture, the productivity was 134.5 kg, 13.2% higher than those that do not use tropical pasture. Tropical pastures consist of forage sorghum (*Sorghum bicolor*) and millet (*Pennisetum americanum*). In some cases, the use of type C4 perennial pastures has been identified, such as *Brachiaria (Brachiaria brizantha* spp.).

The use of mineral supplementation in cow-calf systems is limited to 42% of the farms and those that use only mineral mix, have productivity of 119.6 kg. The use of mineral protein mix and energy

Table 2 - Descriptive analysis of 35 cow-calf systems developed in the state of Rio Grande do Sul, southern Brazil

Indicator	Mean	Minimum	Maximum
Farm area (ha)	1,567	173	7,500
Useful area for livestock (ha)	1,090	110	3,822
Weaning rate (%)	70	26.4	93.8
Weaning weight (kg)	175.6	123	205
Mortality rate of calves (%)	2.7	2	7
Productivity (kg weaned calves·cow ⁻¹)	124.2	40.4	246
Stoking rate of temperate pastures (kg·ha ⁻¹)	609.1	225	1,350
Stoking rate of tropical pastures (kg·ha ⁻¹)	902	250	1,800

Table 3 - Feed technologies used in cow-calf systems in the state of Rio Grande do Sul, southern Brazil

Technology	Number of farms	Farms using technology (%)
Temperate pastures		
Grasses	24	68.5
Grasses + leguminous	7	20.1
Do not use of cultivated pasture	4	11.4
Tropical pastures		
Grasses	17	53.1
Do not use cultivated pasture	15	46.9
Winter supplementation ¹		
Mineral mix	20	41.6
Protein supplement in mineral mixtures	10	20.8
Energy supplement in mineral mixtures	5	10.5
Roughage (hay or haylage)	6	12.5
Do not use supplement	7	14.5
Summer supplementation ¹		
Mineral mix	21	65.6
Protein supplement in mineral mix	7	21.8
Energy supplement	6	18.7
Roughage	4	12.5
Do not use supplement	9	28.1
Creep feeding		
Use	17	48.6
Do not use	18	51.4

¹ The sum exceeds the number of farms analyzed due to the use of different supplements.

supplements was observed in one third of the properties and increased productivity to 130.2 kg. Approximately 28% of the farms do not use any supplement and have productivity of 114.4 kg. For 57% of the managers, who do not use any type of supplementation in the cow-calf phase, the high cost of supplements is the limiting factor for the adoption of the technique, the difficulty in manpower is justified by 33% of producers, and 10% of them report not having adequate infrastructure and not observing satisfactory results with the adoption of this technique.

A balance was observed between grazing systems: 57% of the farms use rotational grazing, while 43% use continuous grazing (Table 4). Although the adoption of grazing strategies is widely implemented by the evaluated farms, about 30% do not adopt any method of controlling pasture availability, another 60% use empirical planning to control pasture height, such as visual assessment of the pasture. The productivity for continuous grazing was superior to rotational grazing, 143.4 and 114.4 kg, respectively.

About 77% of the farms use pasture stockpiling for a better use of natural grazing, this technique provided an increase of 29.5% in the productivity of herds in comparison with those that did not use it. The use of complementary nutrition strategies to improve reproductive performance of females in cow-calf systems was also evaluated, such as feed supplementation for calves and creep feeding. For this management, the distribution of farms that use it or do not use it was balanced (Table 4). However, this technique increased productivity by 17%, with 134.3 and 114.7 kg in the herds that use and do not use creep feeding, respectively, and was responsible for an 8% increase in weight at weaning. The weaning anticipation to reduce the nutritional requirements of cow is not a widespread technique among the analyzed farms, since almost 90% use conventional weaning. Very early weaning until 90 or Early weaning at 120 days of age are equally distributed in relation to their use (Table 5).

Table 4 - Technical grazing and pasture management implemented in cow-calf systems in the state of Rio Grande do Sul, southern Brazil

Technology	Number of farms	Farms using technology (%)
Grazing techniques		
Rotational	19	54.3
Temporary	1	2.9
Continuous	15	42.9
Stockpiling of natural pasture		
Perform	27	77.1
Do not perform	8	22.9

Table 5 - Weaning types used in calves in the state of Rio Grande do Sul, southern Brazil

Weaning type	Number of farms	Farms using this technology (%)
Conventional	31	88.6
Early (at 120 days of age)	2	5.7
Very early (from 60 to 90 days of age)	2	5.7

3.2. Efficiency analysis

The efficiency levels of cow-calf systems, taking into account the indicators used for DEA, allowed to identify that the productivity of evaluated herds varies from 111.6 to 153.9, and most of the properties have low and medium EI (Table 6).

The relationship between the efficiency level obtained and the technologies implemented in different farms was evaluated to identify the influence on the final efficiency index of the cow-calf system. Around 70% of input or process technologies that contributed to the EI of the systems remained average (Table 7).

The farms that use temperate pastures obtained a slightly higher EI, compared with those that did not use them. The use of legume pastures allowed a greater amplitude in the EI, although not raising its classification to a high index. The use of tropical pastures did not increase the EI. The properties that use tropical pasture had an EI of 0.63, considered low in this classification. The properties that use only natural grazing for feeding the cows obtained the highest index, reaching 0.69, considered average.

The stockpiling of natural grazing contributed to the result presented above. All properties that use only natural grazing in summer, stockpile natural grazing, favoring the development of the fields. When related to the use of the pasture deferral technique with the efficiency of the farms, it is observed that these had an efficiency index of 0.67, considered medium. The evaluation of grazing techniques allowed to observe that farms that adhere to rotational grazing presented the lowest EI, having an average of 0.60, considered low. The continuous grazing allowed the properties an average index of 0.74.

The evaluation of different mineral supplements to cow-calf systems identified that properties that do not use supplementation limit their EI to a maximum at 0.85, while others reach higher EI. The use of protein supplement allowed the highest EI.

Creep feeding was not decisive to improve the EI but increased the weaning weight by 8%. When evaluated in relation to the overall efficiency of the cow-calf system, the ones that do not use creep feeding showed a slightly higher efficiency rate.

The training of managers and their employees, with courses related to feeding in cow-calf system, played a fundamental role in activity development. In this study, 62.5% of respondents do not undergo

annual training, 22% trained their staff occasionally, and only 15% provide annual training for their employees. The EI of properties that annually train their human resources is average, 0.77 (Figure 3), whereas the ones that do not train or that have done it at some point, but without periodicity, is 0.64, a low index. The employee training, especially with courses related to feeding strategies, proved to be efficient to promote better EI of the techniques applied.

Table 6 - Efficiency index and productivity of cow-calf systems in the state of Rio Grande do Sul, southern Brazil

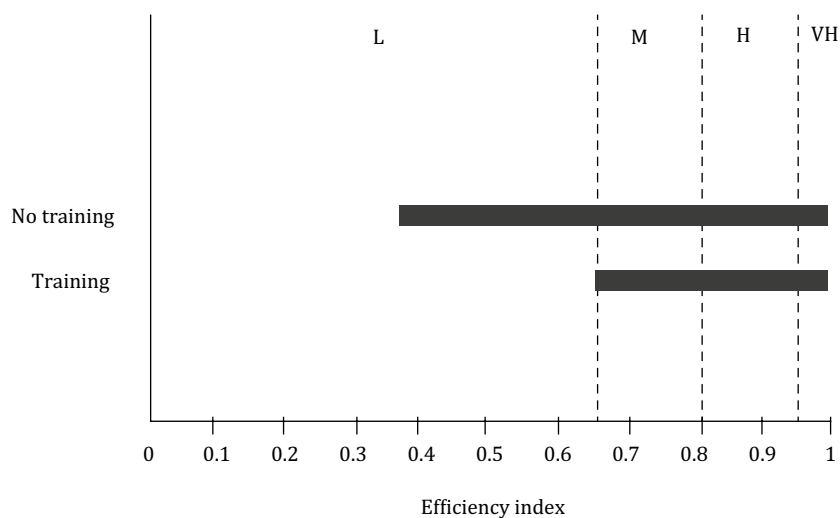
Efficiency index	Productivity ¹	Frequency of farms (%)
Low	111.6	43.3
Medium	121.8	36.6
High	126.1	13.3
Very high	153.9	6.6

¹ kg of weaned calf-mated cow⁻¹.year⁻¹.

Table 7 - Efficiency levels of the technologies used in feeding in cow-calf systems in the state of Rio Grande do Sul, southern Brazil

Technology	Efficiency index ¹	Amplitude of efficiency index	
Temperate pastures			
Use or not of grass	0.65M	0.36L	0.99VH
Use or not of grass + leguminous	0.67M	0.43L	0.90H
Do not use cultivated pasture	0.63L	0.52L	0.70M
Tropical pastures			
Use or not of grass	0.63L	0.63L	1.00VH
Do not use cultivated pasture	0.69M	0.52L	0.99VH
Stockpiling of natural pasture			
Perform	0.67M	0.36L	1.00VH
Do not perform	0.63L	0.42L	0.80H
Grazing techniques			
Use of continuous grazing	0.74M	0.52L	1.00VH
Use of rotational grazing	0.60L	0.36L	0.90H
Winter supplementation			
Mineral mix	0.61L	0.36L	0.84H
Protein supplement in mineral mix	0.67M	0.36L	1.00VH
Energy supplement	0.65M	0.36L	0.90H
Roughage supplement	0.64L	0.42L	0.85H
Do not use supplementation	0.64L	0.39L	0.85H
Summer supplementation			
Mineral mix	0.68M	0.54L	1.00VH
Protein supplement in mineral mix	0.76M	0.65L	1.00VH
Energy supplement	0.69M	0.36L	0.84H
Roughage supplement	0.67M	0.39L	0.99VH
Do not use supplementation	0.61L	0.36L	0.85H
Creep feeding			
Perform	0.65M	0.36L	1.00VH
Do not perform	0.67M	0.39L	0.99VH

¹ L - low efficiency; M - medium efficiency; H - high efficiency; VH - very high efficiency.



L - low; M - medium; H - high; VH - very high.

Figure 3 - Efficiency indices according to use or not of training of human resources for feed technologies implemented in cow-calf herds.

4. Discussion

The farm analysis of cow-calf systems in Rio Grande do Sul through DEA identified that, on average, these systems have low and medium productive efficiency. The knowledge and management capacity, demanded by this stage of the cattle production cycle (Barcellos and Oiagen, 2014), are factors that, once underestimated or not considered in use of available technologies, become limiting for the productivity progress of that system and the whole beef supply chain.

Although efficiency evaluations of the systems show medium and low values, it is possible to observe that the amplitude of efficiency levels among the herds is high, which proves the variability among farmers in the management strategies. In this way, properties that have very low efficiency demonstrate the potential to increase their EI, based on adjustments in the production system, based on farms that use similar technologies and achieved superior results.

The productivity per cow, an output in the model, proved to be an indicator of the productivity of these systems. Therefore, although analyzing the productivity of cow-calf system is a complex task (Walmsley et al., 2018), it was an interesting approach to simplify this analysis, since it is composed of other indicators such as pregnancy rate and weaning weight, which together allow a complete analysis of the cow-calf system. In several countries, the productivity of cow-calf herds is measured only individually, per cow. In Brazil, productivity is also measured by area, due to the cost of land and opportunities in the region.

The increase in system production is associated with birth rate, which must be at least 70%, together with the age reduction at first delivery (Lampert et al., 2012). Thus, considering that in systems with average weaning rate of 70% and that most farms implement the first mating at 24 months of age, it is understood that there is opportunity for increasing the productivity and consequent efficiency of these systems.

Moreover, factors such as high calves' performance and adequate pasture stocking are indicators that can be taken as a foundation for a profitable cow-calf systems (Taylor et al., 2018). Technological adoption as well as the use of methods for control and monitoring the results of each technology in the specific system are important points to maximize the productive results.

In relation to pastures, the lack of efficient methods of application, regarding the maintenance of supply and quality of pasture is one of the factors that prevents the best results made available by this

strategy. The inappropriate use of pastures and excess of stocking rate are factors that significantly affect cattle production in the analyzed region (Marques et al., 2011). Approximately 30% of the farms simply do not perform any control of pasture supply, and another 60% use empirical pasture height control methods, which favors the low efficiency rates found in this analysis. Therefore, although it has been proven in several studies that the use of cultivated pastures in the pre- or post-calving of cows increases their reproductive efficiency, in our study, a direct association between the use of these techniques was not established.

The relationship between the EI and grazing techniques demonstrated that rotational grazing did not promote better efficiency when compared with continuous grazing. The success in applying a grazing technique is associated with many factors; in this sense, practices that require greater intensity and training of human resources and very well-structured planning, present risks, a fact that corroborates the result mentioned above, regarding grazing strategies.

The consortium between grasses and legume pastures positively affected the EI. It is also noteworthy that the failure to use cultivated pastures during winter impairs farm efficiency, not allowing satisfactory rates to be reached, up to 0.70, while the use of grasses and the grass/legume consortium reach 0.99 and 0.90, respectively. The consortium offers a greater forage mass for grasses, as well as a high protein value and better digestibility of legumes (Fontaneli et al., 2012). In addition, it eliminates the feed deficit of the natural grazing in its period of scarcity, contributing to the efficiency of properties that use pastures in winter.

The EI amplitude for the use of pastures allows us to evaluate that, the lowest amplitude is observed when there is no use of cultivated pastures, which is precisely because natural grazing does not demand techniques of greater knowledge requirement and complexity. On the other hand, there is a limitation in the superior EI. Therefore, the complexity and cost of the technology (Oliveira et al., 2018) and the technological application means that decision-making process is exposed to factors that make it difficult to predict the results of each technology.

The stockpiling of natural grazing in the summer favored the increase of the farm EI, as it improves weight gain, animal stocking rate, and the resistance of natural grazing (Borges et al., 2014; Hoffmann et al., 2014) in strategic period, for the subsequent pregnancy rate and also for the weaning weight. On the other hand, it requires producers to initially redistribute cattle throughout the system according to their priorities and to invest in roughage and protein supplements (Barcellos et al., 2007).

Systems that differ natural grazing and carry out this management in an appropriate manner, such as stocking rate adjustment and stockpiling, reach an EI up to 20% higher. The lack of this technique becomes a limiting factor, stagnating this index at 0.80. Stockpiling is efficient to mitigate the seasonality effect of forage production and is technically efficient when considering the regrowth period and the grazing intensity of forage species (Silva et al., 2019).

Normally, cow-calf herds in Rio Grande do Sul are allocated to low-quality natural pastures (Dill et al., 2015b), which impairs performance of the cows, in relation to the corporal development and growth of their calf. Stockpiling, by improving natural grazing, contributes to the productivity of calves. Cows kept in better-quality natural pastures have higher pregnancy rates, in response to greater weight gain (Tanure et al., 2011), corroborating the efficiency of better systems.

The properties with protein supplementation reach the maximum EI (1.00), while not using the technique limits this index to 0.85. This result demonstrates that supplementation allows a greater energy supply for the maintenance of adequate body development and body condition score (Funston et al., 2012), also improving the reproduction rates and milk production of females (Hennessy et al., 2001). The justification of the majority (57%) of producers who do not use supplementation is the high cost of the supplement. However, the success with the technology adoption depends on the managerial capacity to evaluate and adapt the market variables (Lampert et al., 2012), with the indexes obtained from this implementation.

Creep feeding allows the best calf development by supplementary energy intake, favoring the weaning weight (Carvalho et al., 2019), with potential to increase herd productivity. In this study, the increase in weight gain (8%) observed on the farms that adhere to creep feeding was not sufficient to increase the EI of the cow-calf system. The success of this management depends on factors such as supplement type, calf genetics, feeding efficiency, and level of supplementation (Carvalho et al., 2019), which, when not adjusted, can generate negative effects on the performance of calves (Lopes et al., 2018).

Human resources capacitation, in some cases, represents an important participation in the systems costs (Abreu et al., 2008); precisely because of this characteristic, better use of this large investment in human resources is so meaningful. The assessment of staff capacity to implement the techniques used is vital for its impact on efficiency; in addition, there is a relationship between these assessments. The evaluation of farm efficiency due to the training of human resources, allowed us to observe that, on average, properties with training programs have higher EI (0.77) when compared with those that do not train or do it sporadically (0.64). In a way, with or without training, both can reach maximum efficiency levels; however, when there is no training, the efficiency rates reach extremely low values (0.34). This result may also be a consequence of limited access to knowledge (Marques et al., 2011), further reinforced by the limitation of rural extension aimed at technological diffusion in Brazil (Oliveira et al., 2018).

Nevertheless, training aims at preparing the employee and/or manager to perform tasks that are routine of production systems in the best possible way. The employee training makes the staff's performance more effective, operating their tasks more correctly and generating a critical look at their tasks. The knowledge development and the farmers' perceptions vary according to education, motivation, and experiences (Cezar et al., 2000), characteristics easily achieved with employee training.

The evaluation of the cost-benefit of technologies is complex for managers, even so there is a technological increase in farms encouraged by technological implementation by other farmers (Barcellos et al., 2011), not always evaluating the viability and the real need of each system. This is probably the reason for the variability observed in the use of technologies among the farms evaluated. Updating and maintaining competitiveness lead farmers to adopt technologies, but often the efficiency adjustment of existing practices on the farm is usually left out (Oliveira et al., 2018).

The effective use of technologies happens when they are managed in a systemic way, together with others, and the investment must be carried out in an orderly and balanced way (Abreu et al., 2006). However, to achieve this goal, managerial capacity is required, becoming one of the main factors to improve bioeconomic efficiency (Lampert et al., 2012). Intrinsic factors in some processes also interfere with the success of the firm, especially for complex ones, such as the analyzed in this study, a characteristic that does not allow the producer and employee to disorganize, since several factors are interconnected and are decisive for the sustainability of this production systems.

5. Conclusions

The adoption of feed technologies in cow-calf systems alone does not represent efficiency improvements, but most of the technologies routinely used reduce the variation in their efficiency levels. Thus, these practices make the system more productive when compared with systems with a low technological adoption. The use of cultivated pastures in consortium with legume pastures, the use of protein or energy supplements in the winter, and employee training stand out as the main strategies to increase the efficiency index in the cow-calf systems in Rio Grande do Sul.

The most complex technologies, which require greater technical knowledge, especially those related to feed, such as investments in cultivated pastures and supplementation, can affect the efficiency index, even with negative results. However, this was an isolated fact and is related to risk exposure, to which the production systems are commonly exposed.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: Y.M. Rosa, T.E. Oliveira and J.O.J. Barcellos. Data curation: D. Zago, T.E. Oliveira, V.A. Camargo and J.O.J. Barcellos. Formal analysis: Y.M. Rosa, D. Zago and V.A. Camargo. Funding acquisition: J.O.J. Barcellos. Investigation: Y.M. Rosa and J.O.J. Barcellos. Methodology: Y.M. Rosa and V.A. Camargo. Project administration: T.E. Oliveira and J.O.J. Barcellos. Resources: J.O.J. Barcellos. Software: Y.M. Rosa. Supervision: J.O.J. Barcellos. Validation: T.E. Oliveira. Visualization: D. Zago, T.E. Oliveira and V.A. Camargo. Writing – original draft: Y.M. Rosa. Writing – review & editing: D. Zago, T.E. Oliveira, V.A. Camargo and J.O.J. Barcellos.

Acknowledgments

The authors are grateful to the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the financial support to this study.

References

- Abel, L. 2000. Avaliação cruzada da produtividade dos departamentos acadêmicos da UFSC utilizando DEA (Data Envelopment Analysis). Dissertação (M.Sc.). Universidade Federal de Santa Catarina, Florianópolis.
- Abreu, U. G. P.; Lopes, P. S.; Torres, R. A. and Santos, H. N. 2006. Avaliação da introdução de tecnologias no sistema de produção de gado de corte no Pantanal. Desempenho e descarte de matrizes. *Revista Brasileira de Zootecnia* 35:2496-2503. <https://doi.org/10.1590/S1516-35982006000800040>
- Abreu, U. G. P.; Gomes, E. G.; Lopes, P. S.; Torres, R. A. and Santos, H. N. 2008. Avaliação sistêmica da introdução de tecnologias na pecuária de gado de corte do Pantanal por meio de modelos de análise envoltória de dados (DEA). *Revista Brasileira de Zootecnia* 37:2069-2076. <https://doi.org/10.1590/S1516-35982008001100025>
- Baker, R. L. and Carter, A. H. 1976. Influence of breed and crossbreeding on beef cow performance. *Proceedings of the Ruakura Farmers' Conference, New Zealand*. p.39-44.
- Banker, R. D.; Charnes, A. and Cooper, W. W. 1984. Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science* 30:1078-1092. <https://doi.org/10.1287/mnsc.30.9.1078>
- Barcellos, J. O. J.; Oaigen, R. P. and Christofari, L. F. 2007. Gestão de tecnologias aplicadas na produção de carne bovina: pecuária de cria. *Archivos Latinoamericanos de Producción Animal* 15(Supl. 1).
- Barcellos, J. O. J.; Queiroz Filho, L. A.; Ceolin, A. C.; Gianezini, M.; McManus, C.; Malafaia, G. C. and Oaigen, R. P. 2011. Technological innovation and entrepreneurship in animal production. *Revista Brasileira de Zootecnia* 40(supl. especial):189-200.
- Barcellos, J. O. J. and Oaigen, R. P. I. 2014. Cadeia produtiva da carne bovina e os sistemas de produção na bovinocultura de corte. p.21-41. In: *Gestão na bovinocultura de corte*. Agrolivros, Guaíba.
- Borges, J. A. R.; Oude Lansink, A. G. J. M.; Ribeiro, C. M. and Lutke, V. 2014. Understanding farmers' intention to adopt improved natural grassland using the theory of planned behavior. *Livestock Science* 169:163-174. <https://doi.org/10.1016/j.livsci.2014.09.014>
- Carvalho, V. V.; Paulino, M. F.; Detmann, E.; Valadares Filho, S. C.; Lopes, S. A.; Rennó, L. N.; Sampaio, C. B. and Silva, A. G. 2019. A meta-analysis of the effects of creep-feeding supplementation on performance and nutritional characteristics by beef calves grazing on tropical pastures. *Livestock Science* 227:175-182. <https://doi.org/10.1016/j.livsci.2019.07.009>
- Cezar, I. M.; Skerratt, S. and Dent, J. B. 2000. Sistema participativo de geração e transferência de tecnologia para pecuaristas: o caso aplicado à Embrapa Gado de Corte. *Cadernos de Ciência e Tecnologia* 17:135-169.
- Dill, M. D.; Emvalomatis, G.; Saatkamp, H.; Rossi, J. A.; Pereira, G. R. and Barcellos, J. O. J. 2015a. Factors affecting adoption of economic management practices in beef cattle production in Rio Grande do Sul state, Brazil. *Journal of Rural Studies* 42:21-28. <https://doi.org/10.1016/j.jrurstud.2015.09.004>
- Dill, M. D.; Pereira, G. R.; Costa Jr., J. B. G.; Canellas, L. C.; Peripolli, V.; Braccini Neto, J.; Sant'Anna, D. M.; McManus, C. and Barcellos, J. O. J. 2015b. Technologies that affect the weaning rate in beef cattle production systems. *Tropical Animal Health and Production* 47:1255-1260. <https://doi.org/10.1007/s11250-015-0856-x>

- Fontaneli, R. S.; Santos, H. P. and Fontaneli, R. S. (eds.) 2012. Forrageiras para Integração Lavoura-Pecuária-Floresta na Região Sul-brasileira. Embrapa, Brasília.
- Funston, R. N.; Summers, A. F. and Roberts, A. J. 2012. Implications of nutritional management for beef cow-calf systems. *Journal of Animal Science* 90:2301-2307. <https://doi.org/10.2527/jas.2011-4568>
- Gomes, E. G.; Abreu, U. G. P.; Mello, J. C. C. B. S.; Carvalho, T. B. and Zen, S. 2015. Economic and socio-environmental performance assessment of beef cattle production systems: a data envelopment analysis (DEA) approach with weight restrictions. *Revista Brasileira de Zootecnia* 44:219-225. <https://doi.org/10.1590/S1806-92902015000600004>
- Heady, H. F. 1961. Continuous vs. specialized grazing systems: A review and application to the California annual type. *Journal of Range Management* 14:182-193.
- Hennessy, D. W.; Wilkins, J. F. and Morris, S. G. 2001. Improving the pre-weaning nutrition of calves by supplementation of the cow and/or the calf while grazing low quality pastures. 1. Cow production. *Australian Journal of Experimental Agriculture* 41:707-714. <https://doi.org/10.1071/EA00151>
- Hoffmann, A.; Moraes, E. H. B. K.; Mousquer, C. J.; Simioni, T. A.; Junior Gomes, F.; Ferreira, V. B. and Silva, H. M. 2014. Produção de bovinos de corte no sistema de pasto-suplemento no período seco. *Nativa* 2:119-130.
- Lampert, V. N.; Barcellos, J. O. J.; Kliemann Neto, F. J.; Canellas, L. C.; Dill, M. D. and Canozzi, M. E. A. 2012. Development and application of a bioeconomic efficiency index for beef cattle production in Rio Grande do Sul, Brazil. *Revista Brasileira de Zootecnia* 41:775-782. <https://doi.org/10.1590/S1516-35982012000300042>
- Lampert, V. N. 2010. Produtividade e eficiência de sistemas de ciclo completo na produção de bovinos de corte. Tese (D.Sc.). Universidade Federal do Rio Grande do Sul, Porto Alegre.
- Lopes, R. B.; Canozzi, M. E. A.; Canellas, L. C.; Gonzalez, F. A. L.; Corrêa, R. F.; Pereira, P. R. R. X. and Barcellos, J. O. J. 2018. Bioeconomic simulation of compensatory growth in beef cattle production systems. *Livestock Science* 216:165-173. <https://doi.org/10.1016/j.livsci.2018.08.011>
- López-González, F. A.; Allende, R.; Lima, J. M. S.; Canozzi, M. E. A.; Sessim, A. G. and Barcellos, J. O. J. 2020. Intensification of cow-calf production: How does the system respond biologically to energy inputs in a long-term horizon? *Livestock Science* 237:104058. <https://doi.org/10.1016/j.livsci.2020.104058>
- Marques, P. R.; Barcellos, J. O. J.; McManus, C.; Oaigen, R. P.; Collares, F. C.; Canozzi, M. E. A. and Lampert, V. N. 2011. Competitiveness of beef farming in Rio Grande do Sul State, Brazil. *Agricultural Systems* 104:689-693. <https://doi.org/10.1016/j.agsy.2011.08.002>
- McGeough, E. J.; Cattani, D. J.; Koscielny, Z.; Hewitt, B. and Ominski, K. H. 2018. Annual and perennial forages for fall/winter grazing in western Canada. *Canadian Journal of Plant Science* 98:247-254. <https://doi.org/10.1139/cjps-2017-0228>
- Mello, J. C. C. B. S.; Meza, L. A.; Gomes, E. G. and Biondi Neto, L. 2005. Curso de análise de envoltória de dados. p.2520-2547.
- Nogueira, J. M. M.; Oliveira, K. M. M.; Vasconcelos, A. P. and Oliveira, L. G. L. 2012. Estudo exploratório da eficiência dos Tribunais de Justiça estaduais brasileiros usando a Análise Envoltória de Dados (DEA). *Revista de Administração Pública* 46:1317-1340. <https://doi.org/10.1590/S0034-76122012000500007>
- Oliveira, T. E.; Barcellos, J. O. J.; Whittier, J.; Teixeira, O. S.; Freitas, D. S.; Oaigen, R. P.; Dill, M. D. and McManus, C. 2018. Risks associated to different methods of increasing pregnancy rate of cows in cow-calf systems. *Revista Brasileira de Zootecnia* 47:e20180051. <https://doi.org/10.1590/rbz4720180051>
- Silva, P. H. F.; Carvalho, C. A. B.; Malafaia, P.; Garcia, F. Z.; Barbero, R. P. and Ferreira, R. L. 2019. Morphological and structural characteristics of *Urochloa decumbens* Stapf. deferred pasture grazed by heifers under two periods of protein-energy supplementation. *Acta Scientiarum. Animal Sciences* 41:e44472. <https://doi.org/10.4025/actascianimsci.v41i1.44425>
- Tanure, S.; Pötter, B. A. A.; Albornoz, B. A. and Lobato, J. F. P. 2011. Natural and improved natural pastures on the reproductive performance of first-calf beef cows. *Revista Brasileira de Zootecnia* 40:690-699. <https://doi.org/10.1590/S1516-35982011000300030>
- Taylor, R. F.; Crosson, P.; Kelly, A. K. and McGee, M. 2018. Benchmarking technical and economic performance of beef cow-calf to finishing production systems in Ireland. *The Professional Animal Scientist* 34:421-434. <https://doi.org/10.15232/pas.2017-01709>
- Undersander, D.; Albert, B.; Cosgrove, D.; Johnson, D. and Peterson, P. 2002. Pastures for profit: A guide to rotational grazing. Cooperative Extension Publishing, University of Wisconsin-Extension, Madison.
- Wagner, W. E. 2019. Using IBM® SPSS® statistics for research methods and social science statistics. Sage Publications.
- Walmsley, B. J.; Lee, S. J.; Parnell, P. F. and Pitchford, W. S. 2018. A review of factors influencing key biological components of maternal productivity in temperate beef cattle. *Animal Production Science* 58:1-19. <https://doi.org/10.1071/AN12428>