SEMINA
Ciências Agrárias

DOI: 10.5433/1679-0359.2025v46n5p1401

The economic impacts of the bovine respiratory disease complex on beef cattle feedlots from Brazil

Impacto econômico do complexo das doenças respiratórias de bovinos de corte confinados no Brasil

Anderson Lopes Baptista[1]; Ana Aparecida Correa Xavier[2]; Matheus Henrique dos Reis[3]; Ramiro Barros Madeira[3]; Hévila Dutra Barbosa de Cerqueira[1]; Rogério Gama[4]; Selwyn Arlington Headley[5]; João Paulo Elsen Saut[6]*

Highlights

The incidence of BRD-associated morbidity was 2.1 % in 10 Brazilian feedlots.
The incidence of BRD-associated mortality was 0.08 % in 10 Brazilian feedlots.
57.9 % and 22.1 % of diseases and deaths, respectively, were associated with BRD.
$6.9M and $4M annual USD losses estimated from BRD morbidity and mortality.

Abstract

Bovine respiratory disease (BRD) is a common cause of morbidity and mortality in beef cattle feedlots from countries such as USA, Canada, and Australia. However, data relative to the economic impacts, morbidity, and mortality are scarce in Brazil. This study investigated the incidence of BRD in 10 beef cattle feedlots from different geographical regions of Brazil, during January/2019 to December/2020, with a total of 699,526 cattle on feed. The incidence of general morbidity was 3.6%, while BRD-associated was 2.1%. The incidence of general mortality rate identified was 0.38% and the mortality rate BRD-associated was 0.08%. BRD accounted for 57.9% and 22.1% of all disease cases and deaths, respectively. The average body weight was 14.9 kg higher in cattle without BRD compared to cattle with BRD. The costs of BRD-related mortality and morbidity were estimated at $ 777.98 USD/animal and $ 51.4 USD/animal,

[1] PhD Graduate of the Postgraduate Program in Veterinary Science, Universidade Federal de Uberlândia, UFU, Uberlândia, MG, Brazil. E-mail: anderson@focosaudeanimal.com.br; hevila.veterinaria@hotmail.com
[2] PhD Graduate of the Postgraduate Program in Animal Health Science, Universidade Estadual de Londrina, UEL, Londrina, PR, Brazil. E-mail: ana.xavier@uel.br
[3] Researcher, Foco Consultoria em Saúde Animal, Araxá, MG, Brazil. E-mail: matheus@focosaudeanimal.com.br; ramiro@focosaudeanimal.com.br
[4] Researcher, M.e, DVM, Cotia, SP, Brazil. E-mail: gama.rogerio@yahoo.com.br
[5] Prof. Dr., Laboratory of Animal Pathology, Department of Preventive Veterinary Medicine, Multi-User Animal Health Laboratory LAMSA, Universidade Estadual de Londrina, UEL, PR, Brazil. E-mail: selwyn.headley@uel.br
[6] Prof. Dr. of the Postgraduate Program in Veterinary Science, UFU, Uberlândia, MG; Prof. Dr., Universidade de Uberaba, UNIUBE, Uberaba, MG; Researcher, Lume Pesquisa em Saúde Animal, Uberlândia, MG, Brazil. E-mail: jpsaut@lumesaudeanimal.com.br
* Author for correspondence

Received: Nov. 11, 2024 Approved: Sept. 10, 2025

respectively, and resulted in an estimated annual loss of $ 6.9 million USD due to morbidity and $ 4 million USD due to mortality. This is the only study in Brazil that investigated the incidence of BRD and the impact on production/economics and the data herein obtained can be used as the starting point to understand the BRD-related losses in the local cattle industry.
Key words: Economic consequences. Financial losses. Livestock production. Meat industry. Morbidity. Mortality.

Resumo

A doença respiratória bovina (DRB) é uma causa comum de morbidade e mortalidade em confinamentos de gado de corte de países como EUA, Canadá e Austrália. No entanto, dados relativos aos impactos econômicos, morbidade e mortalidade são escassos no Brasil. Este estudo investigou a incidência de DRB em 10 confinamentos de bovinos de corte, de diferentes regiões do Brasil, durante janeiro/2019 a dezembro/2020, com um total de 699.526 bovinos confinados. A incidência de morbidade geral de doenças foi de 3,6 %, enquanto a associada à DRB foi de 2,1 %. A mortalidade geral de doenças identificada foi de 0,38 % e a mortalidade associada à DRB foi de 0,08 %. A DRB foi responsável por 57,9 % e 22,1 % de todos os casos de doenças e mortes, respectivamente. O ganho de peso médio foi 14,9 kg maior em bovinos sem DRB em comparação a bovinos com BRD. Os custos da mortalidade e morbidade relacionadas à DRB foram estimados em US$ 777,98 /animal e US$ 51,4 /animal, respectivamente, e resultaram em uma perda anual estimada de US$ 6,9 milhões devido à morbidade e US$ 4 milhões devido à mortalidade. Este é o único estudo no Brasil que investigou a incidência de DRB e o impacto na produção/economia e os dados aqui obtidos podem ser usados como ponto de partida para entender as perdas relacionadas à DRB na indústria pecuária brasileira.
Palavras-chave: Consequências econômicas. Perdas financeiras. Produção pecuária. Indústria de carne. Morbidade. Mortalidade.

Introduction

The Brazilian states of Goiás, Minas Gerais, and São Paulo are localized within the central-western and southeastern geographical regions, collectively contribute towards 25.8% (56,355,851/ 218,150,298 cattle) of the effective cattle herds in the country, and were classified, respectively, as the 2nd, 4th, and 9th cattle producing states within all 26 Federative states of Brazil in 2021 (Instituto Brasileiro de Geografia e Estatística [IBGE], 2021). Furthermore, these three states are among the five states that slaughtered the most cattle in 2022 (IBGE, 2022). In 2021 approximately 913 billion USD were associated with the beef production industry in Brazil (Associação Brasileira das Indústrias Exportadoras de Carnes [ABIEC], 2022; Ministério da Agricultura e Pecuária [MAPA], 2021). Therefore, livestock production is important to the economy in Brazil.

The bovine respiratory disease (BRD) complex is a multifactorial and multi-etiological disease entity that is caused by a variety of infectious disease pathogens, associated with problems due to cattle management and drastic changes in climatic conditions (Fulton, 2009; Griffin et

al., 2010; Snowder et al., 2006; Taylor et al., 2010). Several agents associated with the development of BRD in cattle herds that resulted in clinical diseases in Brazil have been identified. The pathogens associated with BRD from Brazil includes *Histophilus somni* (Headley et al., 2014, 2017; Magalhães et al., 2017), *Mannheimia haemolytica* (Baptista et al., 2017; Magalhães et al., 2017), *Pasteurella multocida* (Baptista et al., 2017), bovine alphaherpesvirus 1 (BoHV1), bovine parainfluenza virus 3 (BPIV3) (Oliveira et al., 2020), bovine respiratory syncytial virus (BRSV) (Driemeier et al., 1997; Flores et al., 2000; Headley et al., 2014), bovine coronavirus (Beuttemmuller et al., 2017), and bovine viral diarrhea virus (BVDV) (Flores et al., 2000).

Respiratory problems have been associated with the highest percentage of losses among almost 3.6 million cattle and calves due to non-predator causes in the USA in 2015 (United States Department of Agriculture [USDA], 2017). BRD-infected cattle are generally associated with high mortality risk and high treatment costs, in addition to worse carcass performance as compared with healthy animals, and consequently affects animal welfare, performance, and economic parameters (White & Larson, 2020).

Although a large proportion of cattle in Brazil are reared on pasture systems, the use of feedlots for intensive cattle breeding has expanded annually (Dutch State Mines, 2021). A study of 144,340 cattle in a feedlot in the state of Goiás revealed that the overall morbidity was 3.18% in 2012 and 2.81% in 2013, with BRD being the primary cause of illness and accounting for 44.1% and 46.7% of all cases in 2012 and 2013, respectively (Malafaia et al., 2016). We have demonstrated that the morbidity rate of all cattle on feed was 7.05% (13,315/ 188,862), with BRD-related conditions accounting for 86.9% of all cattle morbidity during a two-year study from a single beef cattle feedlot in the state of Minas Gerais (Baptista et al., 2017).

It must be highlighted that information relative to the occurrence of BRD and the associated economic impacts in Brazil is restricted to one study (Baptista et al., 2017). This data contrasts the fact that Brazil is one of the largest commercial cattle producing country, with little data, when compared to similar information from the USA (USDA, 2017; Snowder et al., 2006) and Australia (Blakebrough-Hall et al., 2020). Therefore, data associated with the economic impacts of BRD on livestock production in Brazil is lacking when compared with other important beef producing countries. Consequently, this study evaluated the economic impacts on livestock production of BRD in beef cattle feedlots from the three major cattle producing states of Brazil.

Materials and Methods

Animals, data collection, and study area

This study analyzed data from 10 beef cattle feedlots, that contained cattle from the subspecies Bos taurus indicus and hybrids (*Bos taurus indicus* x *Bos taurus taurus*) of various breeds (Nellore, Nellore mixed breed, dairy cross, and industrial crossing), located in the Brazilian states of Goiás, Minas Gerais, and São Paulo. Each feedlot had a mean stocking capacity of 40,885 ± 32,974 heads of cattle in 2019 and 29,068 ± 19,162 in 2020. All animals maintained in these

feedlots were monitored using the Brazilian System of Individual Identification of Cattle and Buffalo (Ministério da Agricultura, Pecuária e Abastecimento, 2006). All cattle were maintained on feed in paddocks as previously described (Baptista et al., 2017).

All cattle from these feedlots originated from different states in Brazil, were non-castrated steers between 24 to 36 months of age, with an initial average body weight of 369.7 ± 74.97 kg. All cattle were maintained on feeding for approximately 106.4 ± 18.23 days until attained 525.1 ± 73.89 kg of body weight, with an average daily weight gain (ADG) of 1.46 ± 0.31 kg. All feedlots contained an automated feeding system; all cattle were fed four times daily with a ration consisting of corn silage, concentrate, and mineral salt. Water was available *ad libitum* from artesian wells at each feedlot.

The initial protocol included an individual examination of the overall health and well-being, immunization and deworming of all steers on arrival at each feedlot. All cattle were dewormed using a commercial solution containing 5 mg of fenbendazole per kg of body weight orally and immunized (inactivated vaccines) against the principal causes of BRD in Brazil: BoHV-1, BPIV3, BVDV, *P. haemolytica,* and *P. multocida.* Additionally, cattle at these feedlots were immunized against *Clostridia* spp., *E. coli,* and *Salmonella dublin.*

Data collection and characterization of BRD

This retrospective study collected data from January 2019 to December 2020 and includes a total of 699,526 cattle on feed. All animals exhibiting significant signs of any disease were promptly isolated, examined, and treated individually by the veterinary staff. The data obtained on clinical diagnosis, therapy, morbidity, and mortality were tabulated in a Microsoft Excel spreadsheet and used as data for the results of this study. Furthermore, the incidence of morbidity and mortality of cattle with and without BRD were determined relative to the total number of cattle during the fattening period.

The respiratory disease assessment was based on the DART system (Zoetis, Florham Park, USA) and was done by the trained veterinarians at each feedlot. Briefly, the clinical signs observed were depression, irregular appetite, and/or respiratory distress. Manifestations of depression included, but were not limited to, depressed attitudes, a low head, glazed over or sunken eyes, slow or restricted movements, arched back, difficulty standing or walking, finger joints or dragging toes when walking, and tripping. Signs of abnormal appetite included animals that were completely off feed, eating less than predicted or very slowly, had a lack of intestinal fullness or lean appearance, and evident loss of body weight. Respiratory signs included labored breathing, extended head and neck, and audible breathing noise.

Consequently, the BRD clinical case definition included animals with coughing, nasal discharge, rapid and shallow breathing, dyspnea, increased rectal temperature (> 40°C), rough hair coat, lethargy, lack of appetite, and treated for respiratory impairment.

Production indices

The ADG was determined by using 58.2% (407,425/ 699,526) of the total number of cattle on feed, since complete data were only available for these animals. Additionally, cattle that died (n = 2,661), diseased due to non-respiratory conditions (n = 10,573), and with any incomplete data (n = 278,867) were removed from the total number of cattle on feed and not used to determine the ADG. The entry and exit weight of each animal was determined by using the weight obtained on the first and last day on feed. In addition, the ADG was determined for cattle with and without BRD.

Economic impacts associated with BRD

The economic implications of BRD-related morbidity and mortality during this study were estimated by calculating the cost associated with (a) immunization, (b) therapy, (c) daily operational costs per head of cattle entering the feedlot; (d) total operating cost per animal associated with BRD-related morbidity and mortality; and (e) average value per head of cattle that died due to BRD (Table 1). All costs were expressed in USD and were based on the average cost of expenses at these feedlots.

Table 1
Variables used to estimate the costs associated with the mortality and morbidity of feedlot cattle due to bovine respiratory disease

VARIABLES	VALUE (USD)	DEFINITION
Immunization	1.32	*- Entry vaccinations protocol*
BRD therapy	75	*- Antibiotic and/or anti-inflammatory*
Daily operating cost	3.21	*- All expenses related with feeding and maintenance/ day*
Morbidity - Average operational costs/animal	35.92	*- The average number of days for cattle with BRD to attain the same average weight as healthy cattle by the daily operating expense (3.21USD).*
Mortality - Average operational costs/animal	134.72	*- It was calculated by multiplying the average days on feed of deaths (42 d.) by the daily operating cost (3.21USD).*
Average cost/animal	627.79	*- The purchase price of the animal based on the average entry weight.*

The general cost of morbidity was determined by the combination of several factors, including immunization, therapy, and the average operational costs/animal (morbidity). Alternatively, the cost of mortality was determined by computing the immunization, therapy, the average operational costs/animal (mortality), and the cost of the animal.

Statistical analyses

All graphs and data were tabulated using the GraphPad Prism 9 statistical software (GraphPad Software, San Diego, CA, USA). Cattle were considered as an experimental unit. Data were tabulated initially in Excel spreadsheets and descriptive statistics were presented as mean and standard deviation. Variable considered as quantitative (ADG) was subjected to the Anderson-Darling test to verify whether a parametric distribution was established, then it was used the Mann-Whitney test (non-parametric distribution). Statistical significance was considered as $P \leq 0.05$.

Results

Epidemiological data

Between January/2019 and December/2020, 699,526 heads of cattle were on feed at the 10 feedlots evaluated and represented 1.1% (699,526/ 62,332,886) of the total number of cattle slaughtered in Brazil. The geographic location of the ten feedlots monitored during this is shown at Figure 1. Cattle originated principally from five feedlots within the state of São Paulo (61.2%; 428,103/ 699,526), followed by animals from four feedlots from Minas Gerais (20.5%; 143,413/ 699,526), and cattle originating from one feedlot from the state of Goiás (18.3%; 128,010/ 699,526).

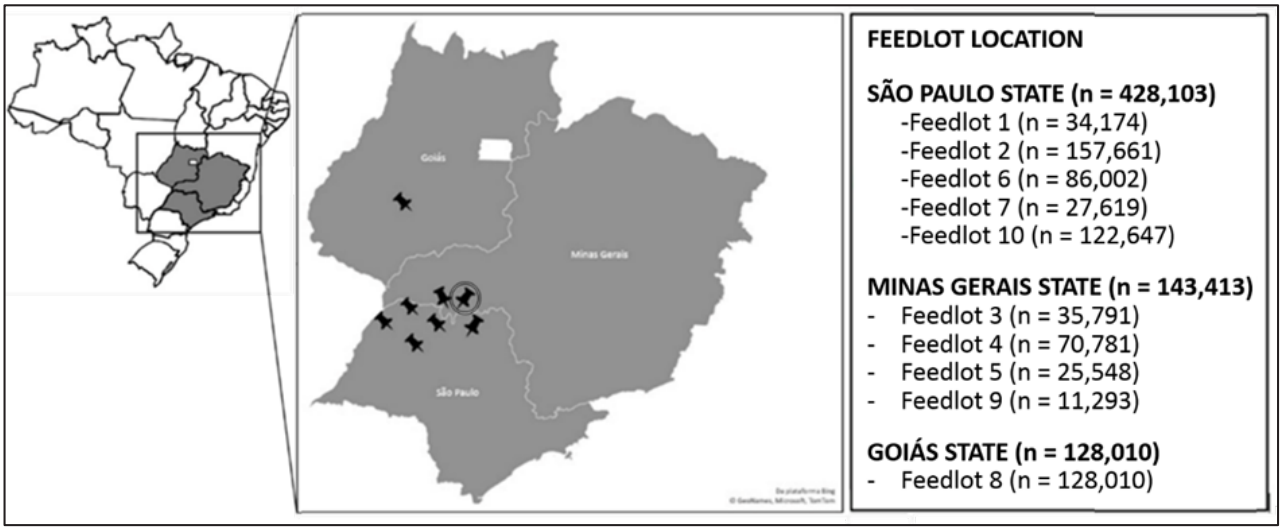

Figure 1. Geographical distribution and total number of cattle at each feedlot (n = 10) within the states of São Paulo (n = 5), Minas Gerais (n = 4), and Goiás (n = 1). Feedlots (n=3) that are within proximity in the state of Minas Gerais are identified within the circle.

The general and BRD-related incidence of mortality and morbidity of the 10 feedlots evaluated during this study are provided (Table 2). The mean morbidity rate was 3.6% (25,132/699,526) ranging between feedlots from 1.4% and 7.2%, with BRD-associated morbidity being identified as 2.08% (14,559/699,526), ranging between 0.89% and 6.41%. Additionally, the overall mortality was estimated at 0.38% (2,661/699,526), with a variation of 0.21% to 0.53%; with mortality attributed to BRD being 0.08% (588/ 699,526), varying between 0.05% to 0.15%. Furthermore, BRD accounted for 57.9% (14,559/25,132) and 22.1% (588/2,661) of the total number of diseases and deaths in this study, respectively.

Table 2
Incidence of mortality and morbidity of cattle identified in ten feedlots from three geographical regions of Brazil during January 2019 – December 2020

a	MORBIDITY - % (n)		MORTALITY - % (n)	
	All diseases[1]	BRD	All diseases[1]	BRD
1 (34,174)	1.4 % (479)	0.89 % (305)	0.35 % (118)	0.08 % (28)
2 (157,661)	1.9 % (3,045)	1.58 % (2,489)	0.44 % (694)	0.06 % (92)
3 (35,791)	7.1 % (2,558)	6.41 % (2,293)	0.31 % (111)	0.15 % (54)
4 (70,781)	3.3 % (2,350)	2.85 % (2,017)	0.35 % (248)	0.12 % (84)
5 (25,548)	4.2 % (1,061)	1.48 % (378)	0.28 % (71)	0.05 % (14)
6 (86,002)	2.8 % (2,426)	2.17 % (1,865)	0.27 % (235)	0.12 % (107)
7 (27,619)	3.2 % (874)	1.98 % (546)	0.21 % (58)	0.05 % (14)
8 (128,010)	4.1 % (5,258)	0.95 % (1,215)	0.53 % (677)	0.09 % (113)
9 (11,293)	7.2 % (811)	5.23 % (591)	0.23 % (26)	0.05 % (06)
10 (122,647)	5.1 % (6,270)	2.33 % (2,860)	0.34 % (423)	0.06 % (76)
Total = 699,526	3.6% (25,132)	2.08% (14,559)	0.38% (2,661)	0.08% (588)

[1] Including all diseases diagnosed and treated during the period (January/2019 - December/2020), such as BRD (metabolic, digestive, clostridial, lameness, fracture, trauma, and other diseases.

When the distribution of the frequency of morbidity related to BRD was evaluated in all 10 feedlots, it was observed that 29.1% (4,237/14,559) of all cases occurred during the first 15 days on feed, while 62.4% (9,082/14,559) during the first 30 days on feed. Additionally, the number of cattle with BRD-associated morbidly was proportionally reduced during the entire period on feed (Figure 2A). However, when the feedlots were evaluated separately (Figure 2B), each feedlot showed a different trend of BRD-associated morbidity that was grouped around the mean value.

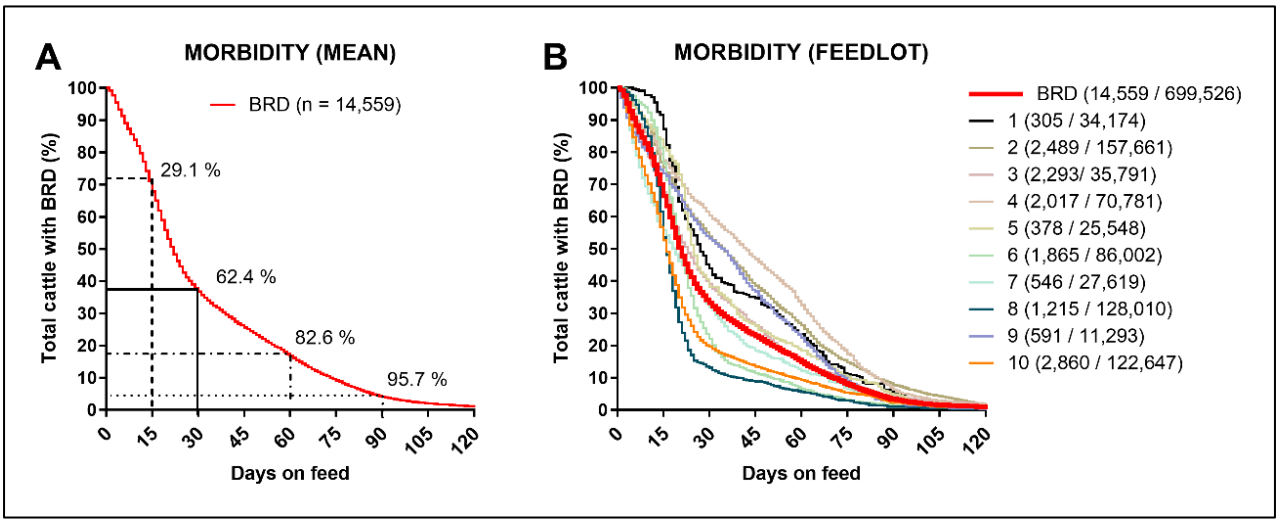

Figure 2. Distribution of the mean occurrence of BRD morbidity in cattle from (a) all 10 feedlots and (b) the individual feedlots relative to the number of days on feed.

When the BRD mortality indices were evaluated, more than half (64.2 %; 377/588) of all cattle on feed died within 60 days of entry into feedlots, with the frequency of cattle mortality due to BRD being reduced as the animals were maintained within feedlots (Figure 3A). A similar individual trend of BRD-related mortality, as described for morbidity, was identified with each individual feedlot having different mortality indices that were grouped around the mean BRD-related mortality (Figure 3B).

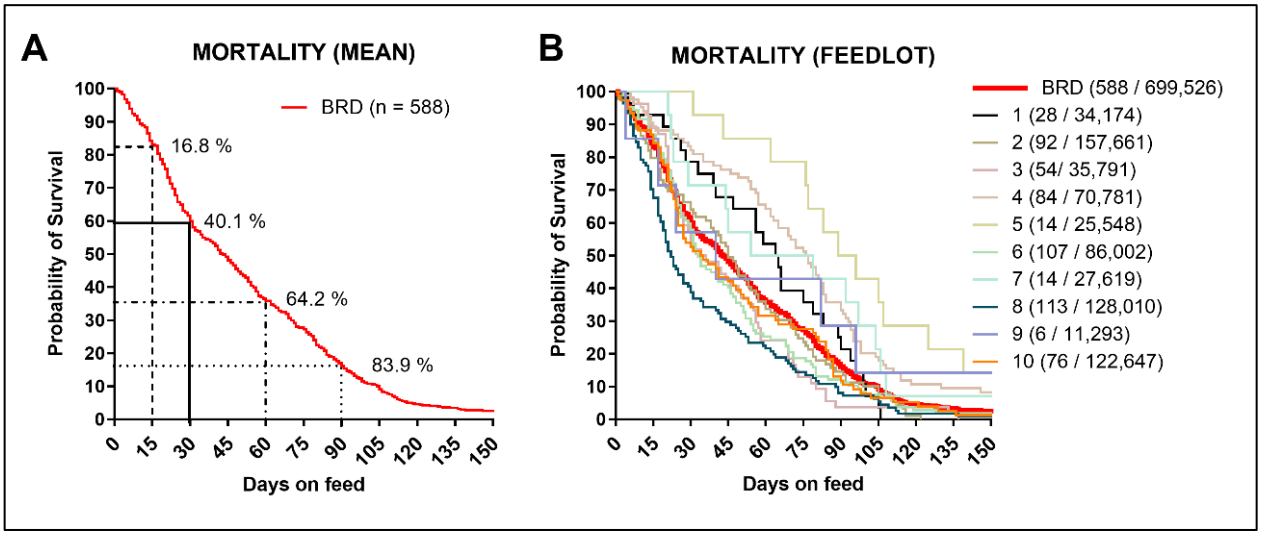

Figure 3. Distribution of the mean occurrence of BRD in cattle mortality from (A) all 10 feedlots and (B) the individual feedlots relative to the number of days on feed.

Production indices

The average duration of cattle on feed varied between 106.4 ± 18.23 days, with entry weights of 369.7 ± 74.97 kg and exit weights of 525.1 ± 73.89 kg. During this study, the ADG in cattle without BRD (404,887/ 407,425) was 1.47 ± 0.31 kg/d, with the ADG in cattle with BRD (2,538/ 407,425) being 1.33 ± 0.36 kg/d (Figure 4). A significant difference in ADG ($P < 0.0001$; Mann-Whitney test) was obtained, demonstrating that cattle on feed without BRD-related diseases gained 14.9 Kg in excess than cattle with BRD considering the average duration on feed.

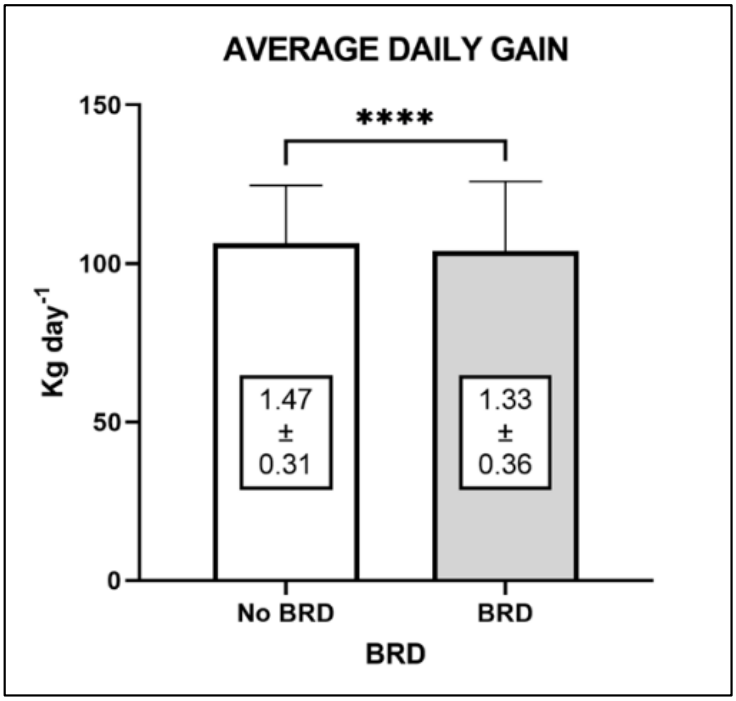

Figure 4. Comparative distribution of the average daily gain (ADG) of feedlot cattle without (n = 404,887) and with BRD (n = 2,538).

Economic impacts

The projected losses associated with BRD are represented in Table 3. The costs associated with vaccinations and therapy were estimated at 1.32 USD and 14.15 USD per animal, respectively. The average operational costs for BRD-related morbidity were 35.92 USD, while mortality was 134.72 USD. The maintenance cost of a sick animal at most feedlots was 51.4 USD / animal, being less than the 777.98 USD/ animal related to mortality. Furthermore, an estimated projection of the economic impacts due to BRD in Brazil revealed that the cost associated with morbidity was 6,930,356.58 USD, while losses due to mortality were 4,034,479.80 USD (Table 4).

Table 3
Estimated costs associated with the mortality and morbidity of feedlot cattle due to bovine respiratory disease

ESTIMATED COSTS	MORBIDITY - % (n)	MORTALITY - % (n)
Vaccinations	1.32	1.32
Therapy	14.15	14.15
Average operational costs/animal	134.72 *	35.92 ***
Average cost/animal	627.79 **	-
Cost/animal	**777.98**	**US$ 51.40**

* Average operational costs/animal (mortality) was calculated by multiplying the average days on feed of deaths (42 d.) by the daily operating cost (3.21USD).
** Average value of animal was calculated using the purchase price of the animal based on the average entry weight.
*** Average operational costs/animal (morbidity) was calculated by multiplying the average number of days for cattle with BRD to attain the same average weight as healthy cattle by the daily operating expense (3.21USD).

Table 4
Projected estimates of the economic impacts of bovine respiratory disease on cattle on feed in Brazil during 2020

Indices	ESTIMATES	ECONOMIC IMPACTS (USD)
Total cattle slaughtered	41,500,000 a	
Cattle on feed (15.62 % a)	6,482,300	
BRD Morbidity (2.08 % b)	134,831.84	
Morbidity cost/animal (51.40 b)		6,930,356.58
BRD Mortality (0.08 % b)	5,185.84	
Mortality cost/animal (777.98 b)		4,034,479.80

[a] Instituto Brasileiro de Geografia e Estatística (IBGE).
[b] This study (Table 3).

Discussion

This retrospective study reinforced the importance of BRD in beef cattle production in Brazil, as it represented 57.9 % and 22.1 % of the total diseases and deaths, respectively, identified during the evaluated period. An estimated projection of the economic impacts due to BRD in Brazil revealed that the annual cost associated with morbidity was US$ 6,930,356.58, while losses due to mortality were US$ 4,034,479.80. BRD-related morbidity was 2.08 %, with 29.1 % and 62.4 % of the cases occurring during the first 15 and 30 days on feed, respectively. Regarding BRD-related mortality, it was 0.08 %, and more than half (64.2 %) of all cattle on feed died within 60 days of entry into feedlots.

BRD also significantly impacted the ADG of cattle during the confinement period. Since the main interest of this study was to identify morbidity and mortality rates associated with the clinical manifestations of BRD, the associated infectious disease agents were not evaluated.

This is the first BRD study in Brazil to examine BRD-related morbidity and mortality rates, as well as production and economic indices in different feedlots from various states of Brazil, and consequently the data herein identified are more consistent than previous studies. Thus far, there are only two previous studies have investigated the indices of BRD morbidity and mortality in Brazil. In the first study, we evaluated the mortality, morbidity, and economic impacts associated with BRD from only one feedlot from the state of Minas Gerais (Baptista et al., 2017). While the second evaluated the economic impacts of digestive and respiratory disease on cattle maintained on feed from two feedlots within São Paulo (Malafaia et al., 2016). Accordingly, the general morbidity described in this study (3.6 %) was greater than that identified (1.35 %; n=144,340) in São Paulo (Malafaia et al., 2016), but less than the 7.05 % (13,315/188,862) described in Minas Gerais (Baptista et al., 2017). However, it must be highlighted that these indices identified during these two previous studies are within the variations (1.4 – 7.2 %) observed at the 10 feedlots. Consequently, the general morbidity rates identified in the two previous reports are consistent with the results herein presented. Although the previous studies evaluated comparatively less animals and feedlots, the collective data suggests that feedlot morbidity in Brazil is probably between 1 – 7%.

However, when the BRD-related morbidity and mortality rates were compared with the only study from Brazil that effectively investigated pulmonary disease of feedlot cattle, our previous study described indices of 6.13 % (11,577/188,862) and 0.21 % (397/188,862), respectively (Baptista et al., 2017), which are less than the current mean indices of morbidity (2.08 %; 14,559/699,526), but similar to the mean mortality rate (0.08 %; 588/699,526) herein identified. However, these BRD-associate mortality and morbidity rates previously identified in our previous study (Baptista et al., 2017) are within the variations of the current study, suggesting that the results from these two investigations are consistent.

It must be highlighted that BRD-associated morbidity was the most frequently occurring diseases at these feedlots and contributed towards 57.9 % of all diseases. BRD also contributed towards the largest single disease entity (86.9 %) in our previous study (Baptista et al., 2017), and in another study done in São Paulo, where BRD-related disease contributed towards 45.5 % of all diseases evaluated (Malafaia et al., 2016). Accordingly, these initial data suggest that BRD is the principal problem at beef cattle feedlots in Brazil, but more elevated that the results identified in studies from the USA (USDA, 2017; Snowder et al., 2006), and Australia (Blakebrough-Hall et al., 2020). Although the exact reason for the vast differences in these indices between Brazil and other beef producing countries is not known, we believe that the rearing of cattle during prolonged dry seasons in Brazil may predispose cattle to a larger percentage of stress-induced conditions that favor the development of BRD.

During this study, more than half of BRD-associated mortality (62.4 %; 377/588) occurred within the first 30 days on feed; similar findings were previously described by our group (Baptista et al., 2017), and in studies done in other countries (Edwards, 1996; Gagea et al., 2006; Ribble et al., 1995a,b). The elevated prevalence of BRD during the initial period on feed is probably due to the adaptation, related to transport and stress-induced immunosuppression effects and incomplete seroconversion since immunization is frequently done on entry in feedlots. This is in accord with the general concept of the complexity of BRD, which is a multifactorial disease entity, having variables such as different infectious disease agents, breed of the affected cattle, stress, abrupt changes to management practices and environmental conditions (Fulton, 2009; Snowder et al., 2006; Taylor et al., 2010).

The estimated impacts due to BRD-associated morbidity at these ten feedlots was 6.9M USD, while loss due to BRD-mortality was 4M USD; these economic costs are similar to those described in our previous study where the associated BRD-mortality was estimated at 6.3M USD and mortality 5.5 M USD (Baptista et al., 2017). Consequently, these data demonstrate that although these two studies were done with different number of animals and feedlots, the economic impacts are quite similar and can be used to estimate the economic impacts of BRD in Brazil.

During this study, cattle with BRD had comparatively lower ($P < 0.0001$) exit weight (ADG 0.14 kg/d; mean 14.9kg) compared to healthy cattle. Similar findings were described in a commercial feedlot from Southern Australia, where slaughtered cattle with severe lung lesions weighed 14.3 kg (0.3 kg/d) less than animals without pulmonary disease (Blakebrough-Hall et al., 2020), and in feedlots from Western Canada, where the ADG varied between 0.04 to 0.16 kg/d (Blakebrough-Hall et al., 2020). Collectively, these results demonstrate that animals with respiratory problems have a lower weight gain and corresponding reduced productivity. It must be highlighted that the initial results from this study are the only available data associating ADG with respiratory disease in cattle from Brazil, since all previously used data were derived from studies done in other countries.

BRD continues to be a major threat for beef cattle maintained in feedlots from Brazil, affecting their health and well-being and leading to increased mortality rates. The data collected clearly shows that the occurrence of BRD in feedlots varies according to the geographical region of the country and may reflect distinct management practices and/or particularities of each feedlot. Furthermore, it was shown that the rate of BRD in some feedlots is comparable to that existent in other countries, while there is still room for improvement in others. It must be highlighted that the high costs associated with therapy and the reduced productivity make the understanding of the impacts of BRD a critical issue that cannot be ignored in the local livestock industry.

Conclusion

This is the only study that demonstrated the incidence of BRD in feedlots from diverse geographical regions of Brazil. It is estimated that the annual loss due to BRD in terms of morbidity amounts

to 6.9 million dollars, and mortality losses are 4.0 million dollars, representing 57.9% and 22.1% of the total number of diseases and deaths due to BRD, respectively. These findings provide initial data that can be used to evaluate the effects of BRD in beef cattle feedlots and may be a national guide to understand the economic losses in the local livestock industry.

Acknowledgments

The authors are grateful to the farmers and veterinarians involved in the clinical examinations and data collection. SA Headley is recipient of the National Council for Scientific and Technological Development (CNPq; Brazil) fellowship and grant. Xavier, A.A.C., and Cerqueira, H.D.B. is a recipient of CAPES studentships. This research was funded by CNPq, grant number 400863/2019-7.

References

Associação Brasileira das Indústrias Exportadoras de Carnes (2022). *NBeef report - perfil da pecuária no Brasil - 2022* (2022nd ed.). ABIEC.

Baptista, A. L., Rezende, A. L., Fonseca, P. de A., Massi, R. P., Nogueira, G. M., Magalhães, L. Q., Headley, S. A., Menezes, G. L., Alfieri, A. A., & Saut, J. P. E. (2017). Bovine respiratory disease complex associated mortality and morbidity rates in feedlot cattle from southeastern Brazil. *Journal of Infection in Developing Countries, 11*(10), 791-799. doi: 10.3855/jidc.9296

Beuttemmuller, E. A., Alfieri, A. F., Headley, S. A., & Alfieri, A. A. (2017). Brazilian strain of bovine respiratory coronavirus is derived from dual enteric and respiratory tropism. *Genetics and Molecular Research: GMR, 16*(2), 1-7. doi: 10.4238/GMR16029580

Blakebrough-Hall, C., McMeniman, J. P., & González, L. A. (2020). An evaluation of the economic effects of bovine respiratory disease on animal performance, carcass traits, and economic outcomes in feedlot cattle defined using four BRD diagnosis methods. *Journal of Animal Science, 98*(2), skaa005. doi: 10.1093/JAS/SKAA005

Driemeier, D., Gomes, M. J. P., Moojen, V., Arns, C. W., Vogg, G., Kessler, L., & Costa, U. M. da. (1997). Manifestação clínico-patológica de infecção natural pelo Vírus Respiratório Sincicial Bovino (BRSV) em bovinos de criação extensiva no Rio Grande do Sul, Brasil. *Pesquisa Veterinária Brasileira, 17*(2), 77-81. doi: 10.1590/S0100-736X1997000200006

Dutch State Mines (2021). *DSM divulga censo de confinamento de 2021/ Brasilagro.* https://www.brasilagro.com.br/conteudo/-dsm-divulga-censo-de-confinamento-de-2021.html

Edwards, A. (1996). Respiratory diseases of feedlot cattle in central USA. *The Bovine Practioner, 30,* 5-7. doi: 10.21423/bovine-vol1996no30p5-7

Flores, E. F., Weiblen, R., Medeiros, M., Botton, S. A., Irigoyen, L. F., Driemeier, D., Schuch, L. F., & Moraes, E. M. (2000). A retrospective search for bovine respiratory syncytial virus (BRSV) antigens in histological specimens by immunofluorescence and immunohistochemistry. *Pesquisa Veterinária Brasileira, 20*(4), 139-143. doi: 10.1590/S0100-736X2000000400002

Fulton, R. W. (2009). Bovine respiratory disease research (1983-2009). *Animal Health Research Reviews, 10*(2), 131-139. doi: 10.1017/S146625230999017X

Gagea, M. I., Bateman, K. G., Van Dreumel, T., Mcewen, B. J., Carman, S., Archambault, M., Shanahan, R. A., & Caswell, J. L. (2006). Diseases and pathogens associated with mortality in Ontario beef feedlots. *Journal of Veterinary Diagnostic Investigation, 18*(1), 18-28. doi: 10.1177/104063870601800104

Griffin, D., Chengappa, M. M., Kuszak, J., & McVey, D. S. (2010). Bacterial pathogens of the bovine respiratory disease complex. *Veterinary Clinics of North America - Food Animal Practice, 26*(2), 381-394. doi: 10.1016/j.cvfa.2010.04.004

Headley, S. A., Alfieri, A. F., Oliveira, V. H. S., Beuttemmüller, E. A., & Alfieri, A. A. (2014). Histophilus somni is a potential threat to beef cattle feedlots in Brazil. *Veterinary Record, 175*(10), 249. doi: 10.1136/VR.102562

Headley, S. A., Balbo, L. C., Alfieri, A. F., Saut, J. P. E., Baptista, A. L., & Alfieri, A. A. (2017). Bovine respiratory disease associated with Histophilus somni and bovine respiratory syncytial virus in a beef cattle feedlot from Southeastern Brazil. *Semina: Ciências Agrárias, 38*(1), 283-293. doi: 10.5433/1679-0359.2017V38N1P283

Instituto Brasileiro de Geografia e Estatística (2021). *Pesquisa da pecuária municipal - efetivo dos rebanhos, por tipo de rebanho - 2021.* IBGE.

Instituto Brasileiro de Geografia e Estatística (2022). *Pesquisa trimestral do abate de animais - 2022.* IBGE.

Magalhães, L. Q., Baptista, A. L., Fonseca, P. A., Menezes, G. L., Nogueira, G. M., Headley, S. A., Fritzen, J. T. T., Alfieri, A. A., & Saut, J. P. E. (2017). Use of metaphylactic protocols based on the risk to develop bovine respiratory diseases in feedlot cattle. *Ciência Rural, 47*(8), e20161110. doi: 10.1590/0103-8478CR20161110

Malafaia, P., Granato, T. A. L., Costa, R. M., Souza, V. C. de, Costa, D. F. A., & Tokarnia, C. H. (2016). Major health problems and their economic impact on beef cattle under two different feedlot systems in Brazil. *Pesquisa Veterinária Brasileira, 36*(9), 837-843. doi: 10.1590/S0100-736X2016000900008

Ministério da Agricultura e Pecuária (2021). *Animal exportation - 2021*. MAPA.

Ministério da Agricultura, Pecuária e Abastecimento (2006). MAPA. Instrução Normativa no 17, de 13 de julho de 2006. *Diário Oficial da União, 23-27.*

Oliveira, T. E. S., Pelaquim, I. F., Flores, E. F., Massi, R. P., Valdiviezo, M. J. J., Pretto-Giordano, L. G., Alfieri, A. A., Saut, J. P. E., & Headley, S. A. (2020). Mycoplasma bovis and viral agents associated with the development of bovine respiratory disease in adult dairy cows. *Transboundary and Emerging Diseases, 67*(S2), 82-93. doi: 10.1111/TBED.13223

Ribble, C. S., Meek, A. H., Janzen, E. D., Guichon, P. T., & Jim, G. K. (1995a). Effect of time of year, weather, and the pattern of auction market sales on fatal fibrinous pneumonia (shipping fever) in calves in a large feedlot in Alberta (1985-1988). *Canadian Journal of Veterinary Research, 59*(3), 167-172.

Ribble, C. S., Meek, A. H., Jim, G. K., & Guichon, P. T. (1995b). The pattern of fatal fibrinous pneumonia (shipping fever) affecting calves in a large feedlot in Alberta (1985-1988). *Canadian Veterinary Journal, 36*(12), 753-757.

Snowder, G. D., Van Vleck, L. D., Cundiff, L. V., & Bennett, G. L. (2006). Bovine respiratory disease in feedlot cattle: environmental, genetic, and economic factors. *Journal of Animal Science, 84*(8), 1999-2008. doi: 10.2527/JAS.2006-046

Taylor, J. D., Fulton, R. W., Lehenbauer, T. W., Step, D. L., & Confer, A. W. (2010). The epidemiology of bovine respiratory disease: what is the evidence for predisposing factors? *Canadian Veterinary Journal, 51*(10), 1095-1102.

United States Department of Agriculture (2017). *Death loss in US cattle and calves due to predator and nonpredator causes, 2015.* USDA–APHIS–VS–CEAH.

White, B. J., & Larson, B. L. (2020). Impact of bovine respiratory disease in U.S. beef cattle. *Animal Health Research Reviews, 21*(2), 132-134. doi: 10.1017/S1466252320000079