NRC Research Press

ARTICLE

Perception of consultants, feedlot owners, and packers regarding the optimal economic slaughter endpoint in feedlots: a national survey in Brazil (Part I)[1]

Thiago Sérgio de Andrade, Tiago Zanett Albertini, Luís Gustavo Barioni, Sérgio Raposo de Medeiros, Danilo Domingues Millen, Antônio Carlos Ramos dos Santos, Rodrigo Silva Goulart, and Dante Pazzanese Duarte Lanna

Abstract: Little information exists regarding the optimal economic slaughter endpoint (OSE) for feedlot-finished cattle in Brazil. This study investigated the perceptions of Brazilian feeders regarding the optimal time for slaughter. A total of 52 interviews were conducted involving nutritionist-consultants ($n = 23$), feedlot owners ($n = 21$), and packer-owned feedlots ($n = 8$). The results showed that 65% of the interviewees used weight and fat cover, both estimated visually, to determine the moment for slaughter. Identifying the ideal time for slaughter was considered a challenge for respondents, and 85% of them recognized that their current slaughter endpoint identification method needed improvements. Regarding decision support systems, 58% of respondents reported they would purchase a computer program to help identify OSE, and 73% would be interested in incorporating a prototype of such a system into their feedlots. Carcass dressing (38%) and price (25%) were the main factors driving the feeder's choice of meatpacker, followed by carcass premiums (10%). Meat quality was found to be an irrelevant criterion for Brazilian meatpackers in awarding both premiums (5%) and deductions (3%). Slaughter endpoint is determined subjectively by the Brazilian feeders, based on a visual evaluation of both weight and fatness.

Key words: beef, carcass, cattle, feedlot, management.

Résumé : Peu d'information existe en ce qui a trait à la limite économique optimale d'abattage (OSE — « optimal economic slaughter endpoint ») des bovins finis en parcs d'engraissement au Brésil. Cette étude avait pour but d'examiner les perceptions des engraisseurs brésiliens par rapport au temps optimal d'abattage. Au total, 52 entrevues ont été effectuées qui concernaient des nutritionnistes-consultants ($n = 23$), des propriétaires de parcs d'engraissement ($n = 21$), et des parcs d'engraissements possédés par les conditionneurs ($n = 8$). Les résultats montraient que 65 % des personnes passées en entrevue utilisaient le poids et la couverture de gras, les deux étant à estimation visuelle, afin de déterminer le moment d'abattage. Fixer le moment idéal d'abattage était considéré un défi par les répondants, et 85 % d'entre eux reconnaissaient que leur méthode actuelle d'identification de limite d'abattage nécessitait des améliorations. En matière des systèmes de soutien aux décisions, 58 % des répondants ont rapporté qu'ils achèteraient un programme d'ordinateur afin d'identifier l'OSE, et 73 % seraient intéressés d'incorporer un prototype d'un tel système dans leurs parcs d'engraissement. L'habillage des carcasses (38 %) et le prix (25 %) étaient les facteurs principaux qui propulsaient le choix de conditionneur de

Received 19 December 2019. Accepted 15 June 2020.

T.S. de Andrade, A.C.R. dos Santos, and D.P.D. Lanna. Departament of Animal Science, University of São Paulo (ESALQ/USP), Piracicaba, São Paulo 13418-900, Brazil.

T.Z. Albertini. @Tech — Innovation Technologies for Agriculture, Piracicaba, São Paulo 13418-900, Brazil.

L.G. Barioni. Embrapa Informática Agropecuária, Campinas, São Paulo 13083-886, Brazil.

S.R. de Medeiros. Embrapa Pecuária Sudeste, São Carlos, São Paulo 13560-970, Brazil.

D.D. Millen. College of Technology and Agricultural Sciences, São Paulo State University (UNESP), Dracena, São Paulo 17900-00, Brazil.

R.S. Goulart. Department of Animal Science, College of Animal Science and Food Engineering, University of São Paulo (FZEA/USP), Pirassununga, São Paulo 13635-900, Brazil.

Corresponding authors: T.S. de Andrade (email: tsazoo@hotmail.com) and D.P.D. Lanna (email: dplanna@usp.br).

[1]This paper is part one of two companion papers published in this issue of Can. J. Anim. Sci. (Andrade et al. 2020. Can. J. Anim. Sci. This issue. doi:10.1139/cjas-2019-0220).

viande par les engraisseurs, suivi des primes de carcasse (10 %). Il s'est avéré que la qualité de viande n'était pas un critère pertinent pour les conditionneurs de viande brésiliens pour l'attribution des primes (5 %) et des déductions (3 %). La limite d'abattage est déterminée subjectivement par les engraisseurs brésiliens, basée sur une évaluation visuelle du poids et de la quantité de gras. [Traduit par la Rédaction]

Mots-clés : bœuf, carcasse, bovins, parc d'engraissement, gestion.

Introduction

Brazil has the second-largest cattle herd in the world, estimated to consist of 238 million animals in 2019 (USDA 2019), which are predominantly finished in grazing systems. Of the 42 million animals slaughtered in 2015, roughly 11% were feedlot-finished (ANUALPEC 2018). The seasonal forage supply, annual meat demand, and quality standards required by foreign markets present opportunities for an increase in the quantity of feedlot-finished cattle. In this context, the number of cattle fed on feedlots in Brazil has increased from 2.3 million in 2005 to 4.0 million animals in 2015 (ANUALPEC 2018). Although some studies have characterized the type of animals and the national beef production system (Ferraz and Felício 2010), in addition to the feedlot system in Brazil (Pinto and Millen 2018), no study has characterized the slaughter endpoint for feedlot-finished cattle. It is important to note that the current Brazilian carcass grading system (Brasil 1989) is not in widespread use. Brazil does not have a standardized carcass classification system, and every meatpacker is responsible for their own metrics (Felício 2010).

Despite much debate regarding proper slaughter criteria for the comparison of beef cattle, no studies have specifically focused on understanding the perception of Brazilian feeders in establishing appropriate slaughter criteria for comparing beef cattle.

The optimal economic slaughter endpoint (OSE) is defined as the point at which the present value of profits from the farm enterprise is maximized (Amer et al. 1994*a*). The OSE of feedlots is not simple to identify as it is related to factors associated with animal type and condition, as well as to market conditions and criteria for premiums and discounts on carcass values by meatpackers. Factors associated with national policies (e.g., international meat trade) and markets (e.g., meat feedstuffs and prices — in particular, grain prices) also increase the difficulty of determining the OSE for each specific situation (Amer et al. 1994*a*, 1994*b*). However, mistakes in determining the OSE on feedlots may consequently decrease feedlot profit by feeding animals on the feedlot for longer or smaller periods than necessary.

Thus, the objectives of this survey were (*i*) to characterize the method for selecting feedlot-finished animals for slaughter according to three classes of respondents including nutritionist-consultants (NC), feedlot owners (FO), and packer-owned feedlots (PF) for beef cattle in Brazil and (*ii*) to identify the main criteria of Brazilian slaughterhouses for carcass rewards and penalties.

Materials and Methods

Description of respondents and questionnaire

The questionnaires were structured using the SurveyMonkey® web tool, which has also been successfully applied in previous studies (Costa et al. 2013; Samuelson et al. 2016; Pinto and Millen 2018). The predefined classes of respondents were NC ($n = 37$), FO ($n = 68$), and PF ($n = 64$) for beef cattle in Brazil.

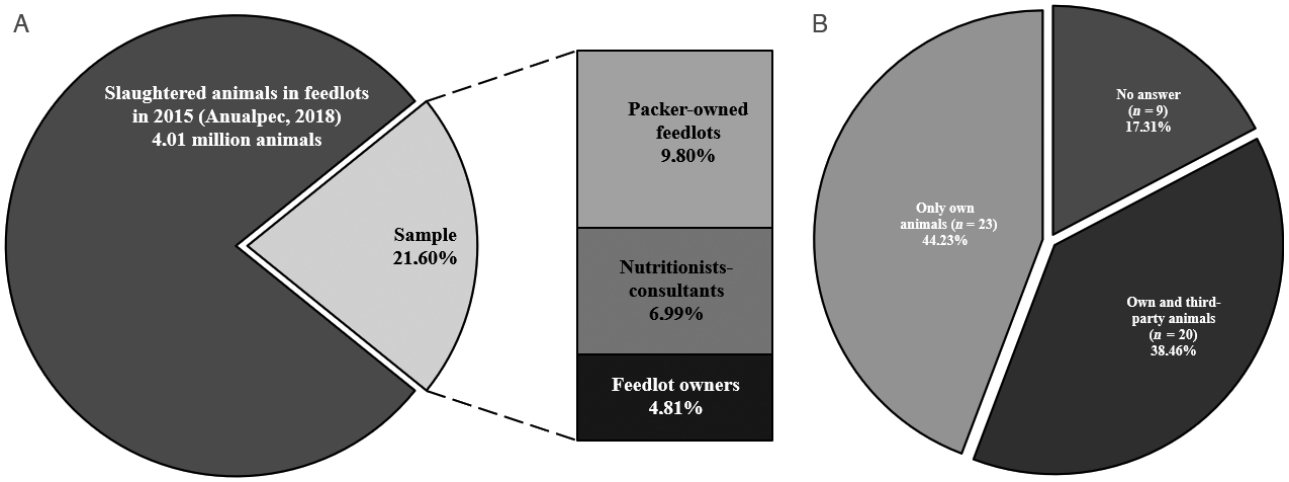
The NC class was defined as the professionals who evaluate and provide services related to diet and management of animals in third-party feedlots. The FO was defined as those who owned the facilities but not necessarily the animals, which were either partially or fully owned by third parties. The meatpackers were defined as companies that own feedlots for their own animal supply, and their PF were interviewed.

Databases of the Laboratory of Animal Nutrition and Growth at the University of São Paulo, the National Feedlot Association (ASSOCON), and the Department of Inspection of Products of Animal Origin of the Brazilian Ministry of Agriculture, Livestock, and Food Supply were used to identify the target survey groups. Slaughterhouses located in traditional cattle-producing regions (primarily in the *Cerrado* biome) were selected, largely in the states of Mato Grosso (MT), Goiás (GO), Mato Grosso do Sul (MS), Minas Gerais (MG), São Paulo (SP), and Paraná (PR), which collectively held over 50% of the Brazilian cattle herd in 2015 (ANUALPEC 2018). The PF were contacted by telephone and asked whether they slaughtered animals from their own feedlots or from third-party feedlots. Only the PF who slaughtered their own animals were selected for the study.

The authors first rated all questions before submitting them to the respondents, based on the degree of relevance of each question (using a scale of 1–10, where 1 = low relevance and 10 = high relevance). This rating allowed for the elaboration of objective questions based on their degree of importance. The final questionnaire for each class had 37 questions divided into the following areas: (*i*) general respondent information ($n = 2$) and (*ii*) slaughter criteria and information on carcasses produced ($n = 35$).

The survey was conducted in 2015 and resulted in a dataset from 23, 21, and 8 complete questionnaires for NC, FO, and PF groups, respectively.

Fig. 1. Finished and slaughtered animals in feedlots in Brazil in 2015 (ANUALPEC 2018). (A) Sampled animals (pie chart) broken down by interview classes (column): nutritionists-consultants, feedlot owners, and packer-owned feedlots. (B) Number of respondents feeding own or third-party animals in feedlot.



Statistical analysis

The responses from the questionnaire were analyzed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). For the parametric variables, standard descriptive statistics were generated and outliers identified. The effects of the respondent class were analyzed using the following linear model:

$$y_{ij} = \mu + C_i + e_{ij}$$

where y_{ij} is the jth response from the ith respondent class; μ is the average respondent population; C_i is the respondent class, where i = NC, FO, or FP; and e_{ij} is the model error, where $e_{ij} \sim NID\ (0, \sigma^2)$.

A Tukey's test was used to compare respondent classes. The studentized residuals were tested for normality using the CAPABILITY command and, whenever necessary, data were transformed using the Box-Cox method (Peltier et al. 1998) using the TRANSREG command.

The non-parametric variables were evaluated and compared using the Kruskal–Wallis multiple sample test using the NPAR1WAY command. In the Kruskal–Wallis test, a score was generated for each observation. The non-parametric variables were those having both descriptive and binary responses.

Results and Discussion

General respondent information

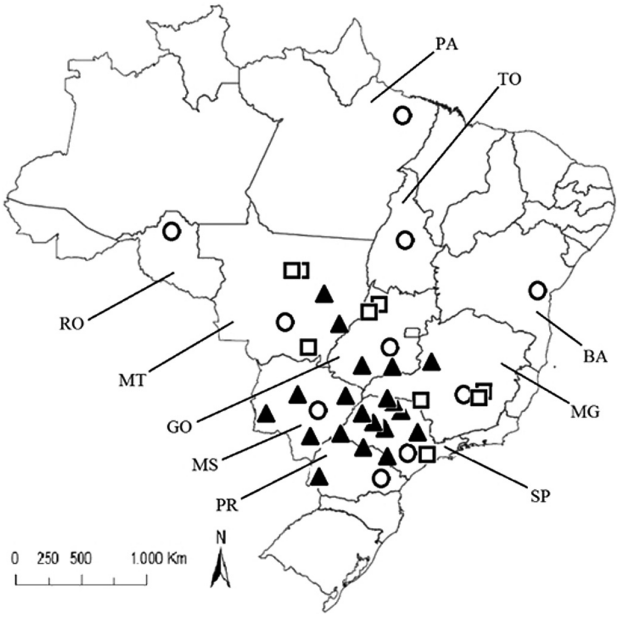
The interviewees ($n = 52$) were responsible for approximately 1.1 million head of cattle, which accounted for approximately 27% of the animals slaughtered from feedlots in Brazil in 2015 (ANUALPEC 2018; Fig. 1A). Most of the respondents held a bachelor's degree in animal science ($n = 17$; 32.7%) — particularly in the case of NC ($n = 13$; 56.7%) — or were veterinarians or agronomists ($n = 10$; 19%). Agronomists were also prevalent among FO ($n = 6$; 28.5%), although the FO respondents had the greatest diversity of educational backgrounds (e.g., law, business management, and high school degrees).

Nearly half of the respondents ($n = 23$; 44.8%) had other activities on their farms such as cow–calf production or stocker cattle operations, in addition to their feedlot operations, with the FO class having a higher frequency of other activities ($n = 13$; 62%). The core business of a few FO and PF respondents (13.8%) was restricted to only feedlot operations. Respondents from the FO class had greater experience in operating feedlots (21 ± 2.0 yr) than those from NC and PF classes (10 ± 1.9 and 6 ± 4.1, respectively).

The PF class held the lowest number of respondents ($n = 8$), but reported having the highest number of animals (501 400 head; 9.80%). The number of respondents in the NC ($n = 23$) and FO ($n = 21$) classes were similar and accounted for 357 690 (6.99%) and 245 900 (4.81%) animals, respectively (Fig. 1A).

The respondents were located in regions of highest feedlot concentration in Brazil in 2015 (ANUALPEC 2018), primarily in the Brazilian Central-West states of MT, GO, and MS. The survey covered 10 states, four of which comprised only NC respondents (Roraima, Pará, Tocantins, and Bahia). The classes FO and PF were represented in the states of MT, GO, MS, MG, SP, and PR (Fig. 2). The number of respondents in FO was highest in the state of SP ($n = 9$), followed by MS ($n = 4$). Feedlots controlled by PF were located in the states of MT ($n = 3$), GO ($n = 3$), SP ($n = 2$), and MG ($n = 2$). Many respondents from the NC (73.9%) and PF respondent classes claimed to run more than one feedlot, and NC (43.5%) respondents reported having clients in more than one state. In our interviews, the number of feedlot operations by state was 37 (MS), 30 (SP), 27 (MT), and 24 (GO), and NC interviews followed a similar breakdown by state.

Fig. 2. Map of Brazil with distribution of respondents in which nutritionist-consultant (○) are shown by states and feedlot owners (▲) and packer-owned feedlots (□), by location. Figure was created using GIMP software version 2.10.18 and assembled from the following data sources: google imagens (SOURCE).



The percentage of NC servicing feedlots with more than 10 000 animals was 28.5%.

The results by Pinto and Millen (2018) are in accordance with the growth in Brazilian feedlot capacity in recent years, which was near 100% from 2005 to 2015 (ANUALPEC 2018). However, the average size of the Brazilian feedlot remains mostly small or medium sized (<5000). Oliveira and Millen (2014) and Pinto and Millen (2018) reported that 65.6% ($n = 21$) and 51.5% ($n = 17$) of the interviewed nutritionists serviced feedlots with less than 5000 animals.

Most of the interviewees fed their own animals (44.3%; $n = 23$) and some fed third-party animals (38.2%; $n = 20$), as shown in Fig. 1B. Among the NC, FO, and PF classes, 4%, 52.3%, and 25.0% fed only their own animals, respectively. The smaller proportion of PF feeding only their own animals may be explained by the interest of slaughterhouses in feeding third-party animals to strategically supply their own slaughter demand. Among those interviewed, only 13.3% ($n = 7$) had their feedlots occupied by more than 80% of third-party animals (FO = 18.9%; PF = 37.5%). According to the interviewees, slaughter dates for third-party-owned cattle ($n = 20$; 38.5%) were determined by the owner ($n = 24$; 46.1%).

Slaughter criteria

According to 34 participants (65.4%), the optimum slaughter point criterion for feedlot cattle was defined by weight and fat cover, both estimated strictly by visual evaluation (Table 1). The evaluation of these criteria was performed at pen level by trained personnel ($n = 26$; 50%).

The relationship between live weight and backfat thickness of cattle at slaughter plays an important role in the economic return of the activity (Tatum et al. 2006) as it directly affects carcass and meat quality characteristics. Therefore, determining the OSE for feedlot cattle is relevant. However, discrepancies in preference may exist between farmers and packers. Specifically, packing plants generally prefer heavier animals with greater backfat thickness, whereas beef producers prefer to maximize muscle gain to obtain greatest feed efficiency.

Previous studies have found that the interest of the FO in OSE is related to improved feed efficiency during the feeding period (by changes in rate of weight gain) and better prices adopted by packers (for body composition; Amer et al. 1994*a*; Medeiros et al. 2014), among other market characteristics. Changes in body composition and live weight during the feeding period decrease feed efficiency because fat deposition in the carcass increases (BCNRM 2016). Thus, for beef producers, determining the OSE is associated with greater profit and not necessarily with lower costs. Improvements in methods for identifying animals with better OSE are a necessity according to 84.6% of respondents, with similar responses among the three classes of NC, FO, and PF (Table 1).

And while determining the OSE for beef cattle in the U.S. is difficult, determining the OSE on Brazilian feedlots is even more challenging. The beef cattle industry in Brazil is based on grass-fed animals, and the feeding period on Brazilian feedlots is traditionally shorter compared with that in the U.S. feedlot system (86 vs. 180 d, respectively; Oliveira and Millen 2014; Samuelson et al. 2016).

Due to the current concerns and difficulties in identifying OSE, some studies have been conducted in Brazil (Mello et al. 2009; Pazdiora et al. 2013), or in other countries (Amer et al. 1994*a*, 1994*b*). Brazilian studies have concluded that economic viability depends on a favorable exchange between the transformation of feed into carcass and increasing weight, and on improving the efficiency of this transformation, as an increase in carcass fat deposition is responsible for a reduction in feed efficiency.

In this study, few respondents mentioned the use of any technology or device (i.e., a sensor) for defining OSE. Thus, the respondents essentially provided no alternative to a visual estimation of weight and body condition. Some respondents ($n = 17$; 32.7%) reported that they normally bring animals to the chute from their home pen to evaluate cattle, using weight as a primary parameter (Table 1). This management provides a strong argument for adapting new technologies to replace the subjectivity of the visual analysis currently practiced,

Table 1. Information about method used to identify animals for slaughter according to the classes of respondents: nutritionists-consultants (NC; $n = 23$), feedlot owners (FO; $n = 21$), and packer-owned feedlots (PF; $n = 8$) in Brazil.

Question	Total	NC	FO	PF
What are the criteria used to slaughter the animal? More than one option can be informed.				
Weight and fat cover (visually estimated)	34	15	15	4
By means of diet formulation system	15	7	5	3
Fat cover visually estimated	6	3	3	0
Market	6	1	4	1
Others	4	4	6	0
No answers	8	3	2	3
The weight and fat cover of feedlot animals to be slaughtered are evaluated where: More than one option can be informed.				
Feedlot pen (visually by trained personnel)	26	10	14	2
Processing pens (weighed and evaluated visually)	17	9	5	3
Others	10	2	6	0
No answer	8	3	2	3
Can the current method used to identify animals for slaughter be improved?				
Yes	44	20	19	5
No	0	0	0	0
No answer	8	3	2	3

particularly since the correct OSE would increase profitability.

In general, the technologies available for monitoring animals throughout the feeding period (Herd 1992) are incipient in commercial feedlots in Brazil. One example of such technology are automated systems installed in feedlot pens for real-time and individual monitoring, which include walkover weigh scales or scales located at the water (Wolfger et al. 2015; Flores et al. 2017). Meanwhile, software can be used to monitor weights, which are generally measured more than once per day, and therefore provide further information for determining OSE.

The use of ultrasound is an indirect measurement for predicting carcass composition, but generates information for only a certain, fixed age or body weight (Kempster and Owen 1981; Lanna et al. 1995; Fisher 1997). In addition, such technologies are expensive and difficult to incorporate into the routine of a commercial feedlot. Therefore, the challenge at hand is to generate more information for determining OSE, but without impairing or compromising the profitability of the system.

The current method used to identify animals for slaughter should be improved as it mainly relies on visual criteria by the pen riders, managers, or nutritionists and is highly subjective.

Responsibility for time of slaughter and follow-up of slaughter

The education of those responsible for determining the ideal moment for slaughter in the survey was primarily that of an undergraduate level ($n = 25$; 48.1%), but those with a high school degree ($n = 7$; 30.4%) or a basic education ($n = 4$; 17.4%) were also frequently observed as the professional filling this role in feedlots serviced by NC (Table 2). However, regardless of education level, 53.8% ($n = 28$) of respondents were trained to identify the animals to be slaughtered in feedlots.

Of the respondents, 46.1% ($n = 24$) reported that the person who monitors the slaughter at the slaughterhouse is not the same as the person who selects animals for slaughter on the feedlot. In addition, 19.2% of the respondents ($n = 10$) reported that their feedlots have no one assigned to follow up and monitor the slaughter at the slaughterhouse. Similarly, 28.5% ($n = 6$) of the FO also reported having no one designated to follow up on slaughter. Cattle confinement operations may have people defined who work on and outside of the property. As the manager and nutritionist are indispensable to a confinement operation, they often end up deciding which animals to send to slaughter. When the animals are sent to slaughter, the manager and nutritionist do not monitors the slaughter in the slaughterhouse.

In 71.1% of cases ($n = 37$), the person responsible for making the decision for slaughter later receives information from the slaughterhouse regarding hot carcass weight. This feedback was considered important for improving the decision to slaughter for 32 (61.5%) respondents (Table 2), and for all three classes interviewed ($P = 0.08$; Table 3). The respondents were not asked specifically what information beyond hot carcass weight was transmitted from the slaughterhouse back to the feedlot, but feedback from slaughterhouses likely included information regarding feedlot performance and carcass traits of slaughtered lots.

Table 2. Profile of those responsible for the timing of the slaughter and the follow-up of the slaughter of feedlot animals according to the interviewee classes: nutritionists-consultants (NC; $n = 23$), feedlot owners (FO; $n = 21$), and packer-owned feedlots (PF; $n = 8$) in Brazil.

Question	Total	NC	FO	PF
Who is responsible for the decision to slaughter the animals in feedlots?				
Feedlot manager	37	17	15	5
Feedlot nutritionist	25	15	7	3
Others employees	12	1	7	4
No answer	10	5	2	3
The person responsible for the decision to slaughter is also responsible for evaluating the animals?				
Yes	36	19	14	3
No	8	1	5	2
No answer	8	3	2	3
What is the educational level of the person responsible for the decision to slaughter?				
Undergraduate education	25	9	12	4
High school	11	7	3	1
Basic education	6	4	2	0
Others	2	0	2	0
No answer	8	3	2	3
Does the person who identifies the animals to be slaughtered in feedlot pens receive any training?				
Yes	28	13	11	4
No	15	6	8	1
No answer	9	4	2	3
How many people are responsible for identifying animals to be slaughtered?				
Two people	17	9	7	1
One person	13	7	4	2
Three people	9	1	7	1
Nobody	5	3	1	1
No answer	8	3	2	3
Does the person responsible for identifying animals to be slaughtered follow the evaluation of carcasses at slaughter?				
Yes	15	8	7	0
No	24	12	12	0
No answer	13	3	2	8
Since the person is not responsible for identifying the animals that can be slaughtered, who is responsible for evaluating the carcass of animals in the meatpacking?				
Nobody	10	3	6	1
Feedlot technician	6	4	2	0
Others	12	5	7	0
No answer	24	11	6	7
Does the person responsible for identifying the animals for slaughter receive feedback information from the meatpacking about carcass (weight, fat cover, etc.)?				
Yes	37	18	15	4
No	6	2	3	1
No answer	9	3	3	3
Do you notice an improvement in detecting the best time to slaughter the animals of feedlots through this "feedback"?				
Yes	32	18	11	3
No	6	2	5	0
No answer	14	4	5	5

When slaughter follow-up occurs ($n = 18$; 34.6%), it is performed by a feedlot technician ($n = 6$; 11.6%), a third-party (specific) technician ($n = 5$; 9.6%), or by a slaughterhouse technician ($n = 4$; 7.7%). Thus, only 28.9% ($n = 15$) of the total respondents follow up on slaughter via one of these technicians. In general, these responses

Table 3. Kruskal–Wallis test for criteria and decision for slaughter according to the classes of respondents: nutritionists-consultants (NC; $n = 23$), feedlot owners (FO; $n = 21$), and packer-owned feedlots (PF; $n = 8$).

	Class (mean score)			
Question	NC	FO	PF	*P*
Can the current method used to identify animals for slaughter be improved?	0.50	0.50	0.50	1.00
The person responsible of the decision for the slaughter is also responsible for evaluating the animals in the pens?	0.42	0.55	0.63	0.09
Does the person who identifies the animals adequate to be slaughtered in feedlot pens receive some training?	0.46	0.54	0.37	0.61
Do the person responsible for identifying animals to be slaughtered follow the evaluation of carcasses at slaughter?	0.47	0.50	—	0.84
Does the person responsible for identifying the animals for slaughter receive feedback from the meatpacking about carcass (weight, finish, etc.)?	0.46	0.50	0.52	0.77
If "yes", do you notice an improvement in detecting the best time to slaughter the animals of feedlots?	0.44	0.59	0.41	0.08
Would the meatpacker where you slaughter your cattle be interested in paying premium-prices for certain animals?	0.63a	0.42ab	0.30b	0.04
Is the consumer interested in a possible premium-price for the animals?	0.48	0.48	0.48	1.00
Would feeders and the meatpackers be interested in paying a fee for trader software?	0.49	0.53	0.37	0.65
Are there financial government incentives to identify animals OSE?	0.48	0.48	0.51	0.84
Are there financial incentives from meatpackers to identify animals OSE?	0.49	0.48	—	0.95
There would be an interest, on the part of feeder, participating in the software evaluation for OSE identification?	0.48	0.51	0.56	0.21

Note: Means within a line not sharing lowercase letter differ significantly at the $P < 0.05$ level.

show that animal monitoring after the animal has left the feedlot or farm was infrequent and when performed, was generally done by professionals outside the property.

According to 71% ($n = 37$) of respondents, the feedlot manager was the person responsible for deciding the moment for slaughter, followed by the feedlot nutritionist ($n = 25$; 48%; Table 2). Similarly, 32.6% ($n = 17$) of respondents reported that the feedlot manager and nutritionist were jointly responsible for determining the moment for slaughter (Table 2). According to the three classes of respondents ($P = 0.09$), 69% ($n = 36$) reported that the same person who evaluates the animals in feedlots to be shipped for slaughter also makes the decision of when an animal is to be slaughtered (Table 3).

According to 38.5% ($n = 20$) of the respondents, a decision support system to assist in identifying the OSE could significantly contribute to increasing profitability of the activity and providing a higher quality product to the market. The perception of 28.8% of the respondents ($n = 15$; Table 4) was that a system that included information on meatpacker demand for finished cattle would make trading easier and more attractive, as well as increase profit.

Roughly 57% ($n = 30$) of the respondents believe that meatpackers will pay premiums for cattle within an OSE identification system (Table 5). Respondents from the PF class believe in this premium, whereas those from the NC class do not ($P = 0.04$; Table 3). This variation may be due to the lack of confidence in meatpackers, which

Table 4. Information on software use to identify the optimal economic slaughter endpoint (OSE) in Brazilian feedlots according to the classes of respondents: nutritionists-consultants (NC; $n = 23$), feedlot owners (FO; $n = 21$), and packer-owned feedlots (PF; $n = 8$).

Question	Total	NC	FO	PF
What are the advantages and disadvantages of software that allows identification of OSE? Animals in the OSE presented the quality criteria (carcass and meat) defined by the producer.				
Name at least one advantage				
Increased profitability and carcass quality	20	12	7	1
Assistance in the optimum identification	4	2	1	1
Facilitated trading of the animals	4	2	1	1
Valuing the best animals (Genetics)	4	2	2	0
Others	11	6	4	3
No answer	13	4	6	3
Name at least one disadvantage				
High cost of software	5	1	4	0
Software use (or usability)	4	4	0	0
Only the meatpacking benefits	4	1	3	0
No bonuses (premium-prices)	3	2	0	0
Others	18	7	8	3
No answer	18	8	6	4
If this software indicated the need for heavier and fatter animals at slaughter, what would be the advantages and disadvantages?				
Name at least one advantage				
Ease of trading and higher pay	15	9	5	1
Standardization of carcasses	9	2	4	3
Planning slaughter dates in advance	4	2	2	0
Others	7	4	2	1
No answer	17	6	8	3
Name at least one disadvantage				
The feeders animals incompatible with demand	5	1	2	2
None	4	2	2	0
Uncertainty that meatpackers will pay the premiums	4	1	3	0
Excessive discounts of nonstandard animals	3	2	1	0
Others	13	8	3	2
No answer	23	9	10	4

will be further discussed when analyzing respondents' choice of meatpacker.

Respondents ($n = 43$; 82.6%) ranked carcass price premiums as something of high interest, and these responses were similar among the different classes interviewed ($P = 1.00$; Table 3). Premiums are associated with higher profitability, according to 23.1% ($n = 12$) of the respondents. Roughly 54% of respondents ($n = 28$) would be willing to pay for a decision support system, and most (73%; $n = 38$), regardless of respondent class, reported interest in testing such software in their feedlots (Table 5).

Most respondents reported no current financial incentive by the Brazilian federal government ($n = 41$; 78.8%) or meatpackers ($n = 33$; 63.4%), to identify animals for OSE given different situations (Table 5). This finding appears to be related to the Brazilian meat industry's lack of a standardized carcass grading system common to all meatpackers in the country, a point that will be discussed later.

Business strategies involving feedlot

The main factors that interfere with finishing period duration and the number of cattle on feedlots during the year are presented in Table 6. The main criteria for bringing few or no animals to finish on feedlots in a given year were related to high feed costs (52%; $n = 27$) and low prices paid by meatpackers for finished cattle ($n = 22$; 42.3%; Table 6). When not considering cattle value, feed ingredients are the costliest component in a feedlot operation and may account for more than 70% of the total feedlot production cost (Sartorello et al. 2018).

Profitability calculations should consider the production of carcass weight, as it serves as the basis for paying producers (Lanna et al. 1999). In this context, evaluating the nutritional value of ingredients used and the diet formulation for matching an animal's requirements and increasing carcass weight gain is relevant for the economic viability of the feedlot operation.

Table 5. Economic information as it pertains to software for the decision-making of optimal economic slaughter endpoint (OSE) according to the classes of respondents: nutritionists-consultants (NC; $n = 23$), feedlot owners (FO; $n = 21$), and packer-owned feedlots (PF; $n = 8$) in Brazil.

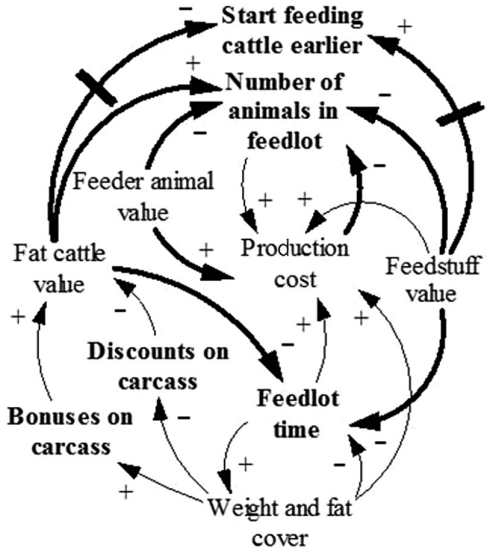
Question	Total	NC	FO	PF
Would the meatpacker where you slaughter your cattle be interested in paying premium-prices for certain animals?				
Yes	30	10	14	6
No	12	9	4	0
No answer	10	4	3	2
If the answer is "no" explain				
Just if economically viable	2	2	0	0
Depends on the current market situation	2	1	1	0
Others	7	3	3	1
No answer	41	17	17	7
Is the consumer interested in a possible premium-price for the animals?				
Yes	43	19	18	6
No	0	0	0	0
No answer	9	4	3	2
Would feeders and the meatpackers be interested in paying a fee for this type of trader software?				
Yes	28	13	10	5
No	13	6	6	1
No answer	11	4	5	2
If "yes". Explain how you think this rate should be priced				
A percentage of the economic gain added	5	2	3	0
A percentage of the animal price	3	1	1	1
Others	13	6	5	2
No answer	31	14	12	5
What are the main advantages and disadvantages for the feedlot regarding the software presented previously?				
Name at least one advantage				
Higher profitability	12	5	7	0
Slaughter at the optimum point (i.e., OSE)	5	3	2	0
Others	10	6	4	0
No answer	25	9	8	8
Name at least one disadvantage				
Vulnerability if meatpacking does not pay bonuses	4	3	1	0
High software cost	3	1	2	0
Others	14	8	6	0
No answer	31	11	12	8
Would you be interested in participating in the software evaluation if it were developed to identify the OSE of beef cattle in Brazil?				
Yes	38	19	15	4
No	3	0	2	1
No answer	11	4	4	3
Are there financial government incentives to identify animals at their OSE?				
Yes	2	1	1	0
No	41	18	17	6
No answer	9	4	3	2
Are there financial incentives from meatpackers to identify animals at their OSE?				
Yes	4	2	2	0
No	33	17	16	0
No answer	15	4	3	8

In addition, prices for leaner cattle to be finished on the feedlot may turn an operation unprofitable within one cycle in certain situations, which is the second factor that producers consider to either shorten the feedlot period or to make the decision to not place cattle in the feedlot. According to Santos et al. (2015), who compiled

Table 6. Information on number of cattle in feedlots and duration of the feedlot period according to the classes of respondents: nutritionists-consultants (NC; $n = 23$), feedlot owners (FO; $n = 21$), and packer-owned feedlots (PF; $n = 8$) in Brazil.

Criteria	Total	NC	FO	PF
What factors make you reduce the number of animals in feedlots or stop feeding?				
High feed prices	27	16	11	0
Low prices of finished cattle	22	12	10	0
Price of the feeder animals	7	4	3	0
Other factors	7	2	5	0
No answer	16	4	8	8
What are the factors that make you extend the feeding period?				
Expectation of better prices for finished cattle	18	7	11	0
Expectation to achieve heavier finishing weights	15	9	6	0
Take advantage of low prices of feed ingredients	14	6	8	0
No extension of this period	9	3	6	0
Other factors	16	7	9	0
No answer	14	4	2	8
What factors (forecasts) lead you to start feeding cattle earlier?				
High price of some feeds or by-products	16	6	10	0
Beginning of the feeding is never changed	12	6	6	0
Forecast indicating lower prices for finished cattle (futures market)	12	5	7	0
Insufficient budget to purchase animal feed	5	3	2	0
Lowering prices for finished cattle	3	3	0	0
Others	5	3	2	0
No answer	15	6	2	8

Fig. 3. Market variables that affect the optimal economic slaughter endpoint (OSE) as defined by weight and visual fat cover, where (–) represents the direction of the responses of respondents, (—) represents possible interactions, (‖) represents a prediction or "delay" in the system and the signs (+/–) represent the direction of the correlation between the variables.



data from the Center for Advanced Studies in Applied Economics, the price of cattle carcasses increased by 5.04% per year between 2010 and 2015. Furthermore, when comparing prices of all agricultural products, carcass values demonstrate greater variation than industrialized or manufactured consumer goods.

Feedlot activity in Brazil occurs mainly during the dry season, when the quality and supply of forage in grazing systems decreases. Other factors that contribute to increasing the number of cattle on feedlots during the dry season are related to low domestic beef supplies and an allocation of lighter cattle such as calves and heifers to pasture areas within properties (Costa et al. 2013).

Among the motivations for keeping cattle on feedlots for longer periods, most participants reported this decision involves waiting for better prices for finished cattle ($n = 18$; 34.6%), followed by waiting for ideal live weights or better premiums offered by meatpackers ($n = 15$; 28.8%), and low feed prices ($n = 14$; 26.9%), all factors related to business strategy. However, 17.3% ($n = 9$) reported that they did not extend the feedlot period (Table 6). This response is likely due to facts already mentioned regarding days on feed and, in particular, to costs. The responses regarding motivation for keeping cattle longer on feedlots is in accordance with reports from 2011 involving the largest feedlots in the country (Cavalcanti et al. 2011), where 78% of respondents wished to increase the number of animals on feedlots. The motivations of respondents in the 2011 study were also related to business strategies involving the aforementioned factors.

With respect to factors that cause a feedlot season to begin early, respondents expressed being most

Table 7. Perceptions on the use of carcass classification systems according to the classes of respondents: nutritionists-consultants (NC; $n = 23$), feedlot owners (FO; $n = 21$), and packer-owned feedlots (PF; $n = 8$) in Brazil.

Question	Total	NC	FO	PF
What carcass classification system do you consider more appropriate?				
American	18	6	10	2
Brazilian	10	7	1	2
None	5	3	2	0
No know answer	4	0	4	0
Others	3	3	0	0
No answer	12	4	4	4
What are the reasons for you to slaughter your animals in a specific packer?				
Carcass yield	17	10	7	–
Price	13	9	4	–
Trustworthiness	9	6	3	–
Payment guaranteed	6	4	2	–
Premium prices (bonus)	5	2	3	–
Others	14	7	7	–
No answer	18	5	5	–

concerned with an increase in feed or co-product prices ($n = 16$; 30.8%). Meanwhile, 23.1% ($n = 12$) reported that they never moved the feedlot feeding period forward in a given year. In addition, 23.1% ($n = 12$) of the interviewees mentioned that the forecast of a fall in cattle prices is the main variable driving a decision to place cattle on feed earlier in the year. Variables such as an insufficient budget for feed purchases and a reduction in finished cattle prices were also mentioned as factors for bringing cattle to feedlots earlier, according to 15.4% of respondents ($n = 5$ and 3, respectively).

To understand cattle business strategies involving feedlot characteristics and the way cattle are deemed ready for slaughter or not, the following structure was elaborated. Figure 3 aims to describe the interactions between business decisions reported by the interviewees.

Choosing the grading system and meatpacker

The carcass grading system of the United States Department of Agriculture was considered the most appropriate by 34.6% ($n = 18$) of the respondents (NC = 26%; FO = 48%; PF = 25%). Seven NC (30.4%) respondents considered the Brazilian grading system more appropriate, whereas 19% ($n = 4$) of FO were unable to identify a preference for any grading system (Table 7). The current Brazilian system (Brasil 1989), which has not been implemented, is criticized because it groups carcasses with diverse characteristics into the same categories, whereas meat quality or boneless yield should be uniform within a category (Felício 2010). Measures in the ribeye area depend upon sectioning the carcass between the 12th and 13th ribs. This is uncommon in Brazil due to loss of value of the rib primal cut. Similar to Mexico (Mendez et al. 2009) and other countries, Brazil does not have its own carcass classification system standardized at a national level, such as in the United States (Gray et al. 2012). Although all meatpackers are responsible for their own metrics (Felício 2010), most respondents from the PF ($n = 5$; 62.5%) group admitted that they do not use an adequate classification system.

Among the main reasons (NC and FO) for choosing a particular meatpacker to slaughter their animals (Table 7), dressing percentage ($n = 17$; 32.7%) and price ($n = 13$; 25.0%) were the most frequently cited. Respondents also considered trustworthiness ($n = 9$; 17.3%) and payment guarantee ($n = 6$; 11.5%) as important. Only five interviewees (9.6%) cited carcass premiums as a reason for choosing a particular meatpacker. Thus, premiums are not the main factor driving cattle sales by producers in Brazil (Table 7). Although many factors contribute to choosing a meatpacker, respondents recognize that carcass values can vary from one meatpacker to another. The dressing percentages or hot carcass weights reported and paid for by Brazilian packers are variable.

Carcass premiums

Regarding carcass premiums awarded and discounts taken by meatpackers, the respondents recognized that premiums exist for traceability (SISBOV; $n = 21$; 40.9%), Hilton quotas ($n = 20$; 38.4%), and exports specifications ($n = 15$; 28.8%). Regarding carcass characteristics, fat thickness ($n = 17$; 32.7%), weight ($n = 13$; 25.0%), and carcass fat ($n = 10$; 19.2%) were the factors most cited in determining carcass discounts or premiums. The respondents additionally reported steer (1–3 yr; $n = 19$; 36.5%), heifers ($n = 14$; 27.0%), young bulls ($n = 14$; 27.0%), age or maturity ($n = 16$; 30.7%), and whether the animal is Angus ($n = 15$; 28.8%) or Hereford ($n = 10$; 19.2%) as factors determining carcass premiums.

Traceability (Brazil 2006) is a considerable factor for premiums, and it is the result of joint action by the government and producers to offer safer products to the consumer (Ferraz and Felício 2010). Moreover, traceability is a requirement from certain Brazilian beef export markets such as the European Union. This market is served by specific farms that represent a small portion of the total Brazilian herd (Brasil 2011). According to the Brazilian Ministry of Agriculture, Livestock and Food Supply, only 1668 properties were registered as able to export and had been audited by January 2019 (Brasil 2019).

Exports were cited by 18% of respondents as a motivating factor for premiums because Brazil is one of the world's largest meat exporters (USDA 2019), and premiums directly affect the price paid to the producer. Countries such as the United States, Canada, Australia, and Japan have national standardized carcass classification systems for meat and carcass quality. These countries are competitors to Brazil and major importers on

Fig. 4. Number of respondents (outside the pie chart) and percentage of responses (inside the pie chart) that indicated each criteria for premiums paid for carcasses.

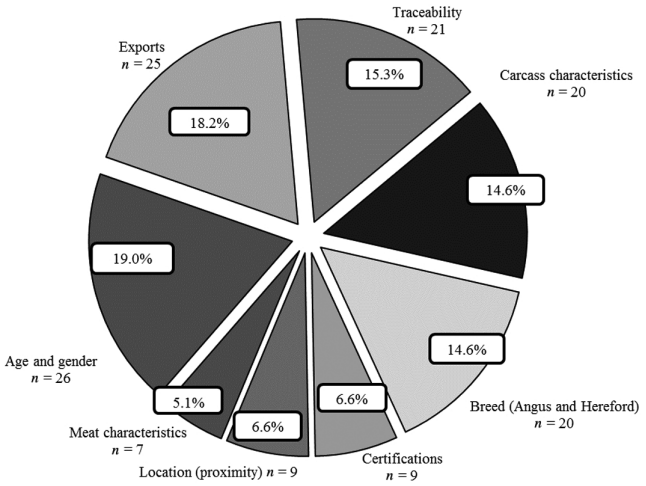
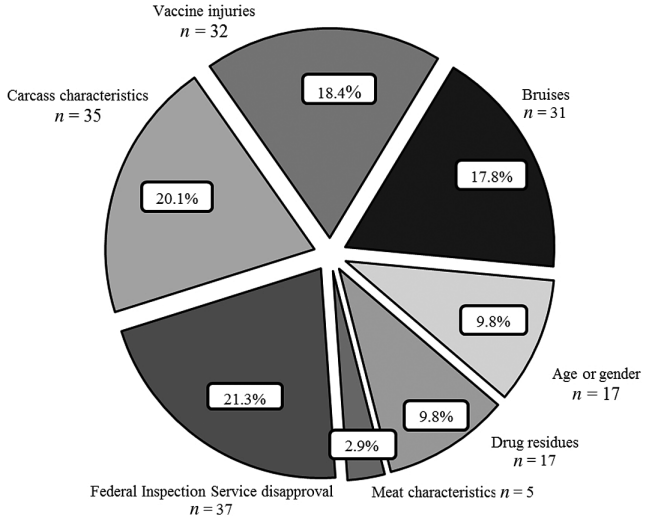


Fig. 5. Number of respondents (outside the pie chart) and percentage of responses (inside the pie chart) that indicated each criteria used to discount prices of carcasses.



the international market. Therefore, minimum domestic classification standards may further aid Brazilian beef exports. As mentioned above, the lack of marbling and ribeye measures in Brazilian packing plants may present an obstacle to this goal.

An additional factor driving cattle premiums was beef cattle genotypes. Studies have shown a strong association between meat quality (Crouse et al. 1989), tenderness, marbling, and breed (Wheeler et al. 1994). In Brazil, the Zebu genotype is predominant (Ferraz and Felício 2010; Oliveira and Millen 2014). However, some studies have reported that increased marbling, which is more pronounced in Angus and Hereford breeds than in Nellore cattle (Wheeler et al. 1996), generates a progressive increase in flavor intensity of cooked beef (Savell et al. 1987). Such factors, therefore, justify premiums that are associated with certain breeds.

Factors associated with fat thickness, weight, carcass fat, age, gender, and breed are related to the quantity and quality of the edible parts of the animal. Age characteristics are associated with the process in which collagen fibers become increasingly stable and cross-linked, and create a more rigid muscle matrix. This process appears to be followed by a change in collagen solubility that favors stiffening (Nishimura et al. 1999; Delgado and Santos 2010; Astruc 2014). Subcutaneous fat is important because it protects the carcass from rapid cooling and prevents excessive shortening of the sarcomere and consequent toughening of the meat cuts (Delgado and Santos 2010; Miller 2014).

Certifications were cited as being associated with carcass premiums, such as the Euro Retailer Produce Working Group for Good Agricultural Practices program ($n = 7$; 13.4%), organic certification ($n = 5$; 9.6%), and the ASSOCON quality program (PQA; $n = 2$; 3.8%), as well as proximity to the slaughterhouse ($n = 9$), as shown in Fig. 4.

Regarding carcass traits, ribeye area ($n = 3$; 5.7%), marbling ($n = 4$; 7.7%), meat cut weight ($n = 6$; 11.5%), meat tenderness ($n = 2$; 3.8%), meat flavor ($n = 3$; 5.7%), meat color ($n = 3$; 5.7%), and fatty acid profile (omega 3 and 6, $n = 2$; 3.8%) were less cited as factors for gaining carcass premiums. Some points should distinguish between the Yield and Quality grades of the USDA grading system and Brazilian system. All measures of ribeye area and marbling score depend upon sectioning the carcass between the 12th and 13th ribs. This practice is uncommon in Brazilian packing plants, due to loss of value of the rib primal cut. The lack of a national carcass classification system possibly inhibits implementation of a fair payment system. Thus, feeders who make major investments in their production systems are not always appropriately rewarded.

Carcass discounts

In terms of carcass discounts, bulls ($n = 16$; 30.7%) were more cited than cull cows ($n = 8$; 15.3%). Carcass characteristics related to the ribeye area ($n = 1$; 1.9%) and carcass fat ($n = 7$; 13.4%) were not mentioned frequently as a discount factor. Marbling ($n = 4$; 7.8%), meat cut weight ($n = 2$; 3.8%), and meat color ($n = 1$; 1.9%) were even less cited. Other criteria such as meat tenderness, fatty acid profile (omega 3 and 6), and meat flavor were not even mentioned. These characteristics (ribeye area all the way to meat flavor) are not measured in the slaughterhouse, so they would not constitute as discount factors.

The criteria most cited for causing discounts were lightweight carcasses ($n = 35$; 67.3%), an absence or low fat thickness ($n = 15$; 28.8%), carcass bruises ($n = 31$; 59.6%), injection site lesions ($n = 32$; 61.5%), Federal Inspection Service condemnation ($n = 37$; 71.1%), and drug residues in the carcass ($n = 17$; 32.7%; Fig. 5).

Sanitary carcass condemnations are relevant when associated with diseases such as brucellosis and tuberculosis, or with injuries caused by inadequate handling. Injection site lesions and bruises contribute to discounts because they imply the removal of damaged tissue and a reduction in meat cut value.

Only 5% of the respondents indicated meat quality contributing to premiums, and only 3% cited meat quality as a discount factor. Thus, meat quality is not relevant in promoting changes to the average price paid to producers. Meat quality is difficult to assess at the meatpacker and involves subjective measurements (Felício 2010), although some systems have successfully adopted measurements (Boykin et al. 2017). The Brazilian beef industry has the potential to establish itself through its brands (Ferraz and Felício 2010), rather than by the adoption of a national carcass and meat quality classification system.

Conclusion

In Brazil, the method for identifying the ideal moment for slaughter has room for improvement, as it is currently determined with great subjectivity and without the use of technological aids. National producers predominantly use visual and subjective criteria for defining the moment to slaughter. Currently, the industry has no incentive at a national level to define ideal slaughter time or prioritize meat quality as an important parameter in deciding slaughter endpoint.

Conflict of interest

The authors have no conflicts of interest to declare.

Acknowledgements

In memoriam of Geovani Bertochi Feltrin. We thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico do Brasil (CNPq, Brasilia, Brazil) for financial support.

References

Amer, P.R., Kemp, R.A., Buchanansmith, J.G., Fox, G.C., and Smith, C. 1994*a*. A bioeconomic model for comparing beef-cattle genotypes at their optimal economic slaughter end point. J. Anim. Sci. **72**(1): 38–50. doi:10.2527/1994.72138x.

Amer, P.R., Kemp, R.A., Fox, G.C., and Smith, C. 1994*b*. An economic comparison of beef-cattle genotypes for feedlot traits at their optimal slaughter end point. Can. J. Anim. Sci. **74**(1): 7–14. doi:10.4141/cjas94-002.

ANUALPEC. 2018. Anuário da pecuária Brasileira. Instituto FNP e Agra FNP Pesquisas Ltda, São Paulo, Brazil.

Astruc, T., 2014. Conective tissue: structure, function and influence on meat quality. Vol. 1. Pages 324 in M. Dikeman and C. Devine, eds. Encyclopedia of meat sciences. Academic Press, Cambridge, MA, USA.

BCNRM. 2016. National Academies of Science, Engineering, and Medicine (NASEM), Nutrient requirements of beef cattle, 8th ed. National Academies Press, Washington, DC, USA.

Boykin, C.A., Eastwood, L.C., Harris, M.K., Hale, D.S., Kerth, C.R., Griffin, D.B., et al. 2017. National beef quality audit — 2016: in-plant survey of carcass characteristics related to quality, quantity, and value of fed steers and heifers. J. Anim. Sci. **95**: 2993–3002. PMID:28727109.

Brasil. 1989. Sistema Nacional de Tipificação de Carcaças Bovinas. In Ministério da Agricultura, Portaria. Diário Oficial da União. http://www.cidasc.sc.gov.br/inspecao/files/2012/08/PORTARIA-MAPA-612-DE-05-10-1989.pdf [10 Oct. 1989].

Brasil. 2006. Sistema de Identificação e Certificação de Bovinos e Búfalos (SISBOV). In Ministério da Agricultura, Instrução Normativa. Diário Oficial da união. http://www2.agricultura.rs.gov.br/uploads/12754996131182539130IN_17_2006.pdf [13 July 2006].

Brasil. 2011. Alguns aspectos da rastreabilidade bovina e bubalina no Brasil. Boletim Técnico — Governo do Brasil, Universidade federal de lavras (UFLA), Lavras, Brasil. pp. 1–40.

Brasil. 2019. Ministério da Agricultura, Pecuária e Abastecimento, MAPA. Lista de fazendas aptas a exportar gado à Europa será atualizada a cada 15 dias. http://www.agricultura.gov.br/assuntos/sanidade-animal-e-vegetal/saude-animal/rastreabilidade-animal [08 Mar. 2019].

Cavalcanti, M., Camargo, A., and Zulini, T. 2011. Pesquisa Top 50 BeefPoint de confinamentos. [Online]. Available from https://www.beefpoint.com.br/pesquisa-top-50-beefpoint-de-confinamentos-2010-2011-74186/ [10 Oct. 2019].

Costa, C., Jr., Goulart, R.S., Albertini, T.Z., Feigl, B.J., Cerri, C.E.P., Vasconcelos, J.T., et al. 2013. Brazilian beef cattle feedlot manure management: a country survey. J. Anim. Sci. **91**(4): 1811–1818. doi:10.2527/jas.2012-5603. PMID:23345562.

Crouse, J.D., Cundiff, L.V., Koch, R.M., Koohmaraie, M., and Seideman, S.C. 1989. Comparisons of Bos indicus and Bos taurus inheritance for carcass beef characteristics and meat palatability. J. Anim. Sci. **67**(10): 2661–2668. doi:10.2527/jas1989.67102661x.

Delgado, E.F., and Santos, C.C. 2010. Fatores anteriores e posteriores ao abate que influenciam a qualidade de carne. Vol. 2. Pages 1283–1304 in A.V. Pires, ed. Bovinocultura de corte, Piracicaba, Brazil.

Felício, P.E. 2010. Classificação e tipificação de carcaças bovinas. Vol. 2. Pages 1257–1276 in A.V. Pires, ed. Bovinocultura de corte, Piracicaba, Brazil.

Ferraz, J.B.S., and Felício, P.E. 2010. Production systems — an example from Brazil. Meat Sci. **84**(2): 238–243. doi:10.1016/j.meatsci.2009.06.006. PMID:20374781.

Fisher, A.V. 1997. A review of the technique of estimating the composition of livestock using the velocity of ultrasound. Comput. Electron. Agric. **17**: 217–231. doi:10.1016/S0168-1699(96)01306-3.

Flores, H., Meneses, C., Villalobos, J.R., and Sanchez, O., 2017. Improvement of feedlot operations through statistical learning and business analytics tools. Comput. Electron. Agric. **143**: 273–285. doi:10.1016/j.compag.2017.10.026.

Gray, G.D., Moore, M.C., Hale, D.S., Kerth, C.R., Griffi, D.B., Savell, J.W., et al. 2012. National beef quality audit — 2011: survey of instrument grading assessments of beef carcass characteristics. J. Anim. Sci. **90**: 5152–5158. doi:10.2527/jas.2012-5551. PMID:22952354.

Herd, R.M., 1992. A computerised individual feeding system for beef cattle. Comput. Electron. Agric. **7**: 261–267. doi:10.1016/S0168-1699(05)80024-9.

Kempster, A.J., and Owen, M.G., 1981. A note on the accuracy of an ultrasonic technique for selecting cattle of different breeds for slaughter at equal fatness. Anim. Sci. **32**(1): 113–115. doi:10.1017/S0003356100024855.

Lanna, D.P.D., Boin, C., Alleoni, G.F., and Leme, P.R., 1995. Estimation of carcass and empty body composition of zebu bulls using the composition of rib cuts. Sci. Agric. **52**(1): 189–197. doi:10.1590/S0103-90161995000100032.

Lanna, D.P.D., Tedeschi, L.O., and Beltrame Filho, J.A., 1999. Modelos lineares e não-lineares de uso de nutrientes para

formulação de dietas de ruminantes. Sci. Agric. **56**: 479–488. doi:10.1590/S0103-90161999000200031.

Medeiros, S.R., Barioni, L.G., and Gomes, C., 2014. Ferramentas de pecuária de precisão voltadas à nutrição de bovinos de corte. Pages 22 in Simpósio brasileiro de pecuária de precisão aplicada à bovinocultura de corte. Anais. Embrapa Gado de Corte, Campo Grande, Brazil.

Mello, R., Resende, F.D., Queiroz, A.C., Faria, M.H., Oliveira, A.S., and Siqueira, G.R. 2009. Bio-economicity of the finishing phase on feedlot of crossbred young bulls slaughtered at different body weights. Rev. Bras. Zootec. **38**: 109–121. doi:10.1590/S1516-35982009000100015.

Mendez, R.D., Meza, C.O., Berruecos, J.M., Garces, P., Delgado, E.J., and Rubio, M.S., 2009. A survey of beef carcass quality and quantity attributes in Mexico. J. Anim. Sci. **87**(11): 3782–3790. doi:10.2527/jas.2009-1889. PMID:19648507.

Miller, R.K. 2014. Chemical and physical characteristics of meat. Pages 256 in M. Dikeman and C. Devine, eds. Encyclopedia of meat sciences. Academic Press, Cambridge, MA, USA.

Nishimura, T., Hattori, A., and Takahashi, K. 1999. Structural changes in intramuscular connective tissue during the fattening of Japanese Black cattle: effect of marbling on beef tenderization. J. Anim. Sci. **77**(1): 93–104. doi:10.2527/1999.77193x. PMID:10064032.

Oliveira, C.A., and Millen, D.D. 2014. Survey of the nutritional recommendations and management practices adopted by feedlot cattle nutritionists in Brazil. Anim. Feed Sci. Technol. **197**: 64–75. doi:10.1016/j.anifeedsci.2014.08.010.

Pazdiora, R.D., Resende, F.D., Faria, M.H., Siqueira, G.R., Almeida, G.B.D., Sampaio, R.L., et al. 2013. Animal performance and carcass characteristics of Nellore young bulls fed coated or uncoated urea slaughtered at different weights. Rev. Bras. Zootec. **42**(4): 273–283. doi:10.1590/S1516-35982013000400007.

Peltier, M.R., Wilcox, C.J., and Sharp, D.C. 1998. Technical note: application of the Box-Cox data transformation to animal science experiments. J. Anim. Sci. **76**(3): 847–849. doi:10.2527/1998.763847x. PMID:9535346.

Pinto, A.C.J., and Millen, D.D. 2018. Nutritional recommendations and management practices adopted by feedlot cattle nutritionists: the 2016 Brazilian survey. Can. J. Anim. Sci. **99**(2): 392–407. doi:10.1139/cjas-2018-0031.

Samuelson, K.L., Hubbert, M.E., Galyean, M.L., and Loest, C.A. 2016. Nutritional recommendations of feedlot consulting nutritionists: the 2015 New Mexico State and Texas Tech University survey. J. Anim. Sci. **94**(6): 2648–2663. doi:10.2527/jas.2016-0282. PMID:27285940.

Santos, D.O.S., Aurélio, M., Vieira, D.E.C., Silva, I.S., Borges, F., and Filho, B. 2015. Variação do Preço do Boi Gordo no período de 2010 Aa 2015 : uma análise econométrica. In VIII Congresso Virtual Brasileiro – Administração. [Online]. Available from http://www.convibra.com.br/upload/paper/2017/147/2017_147_13596.pdf [25 Jan. 2018].

Sartorello, G.L., Bastos, J.P.S.T., and Gameiro, A.H. 2018. Development of a calculation model and production cost index for feedlot beef cattle. Rev. Bras. Zootec. **47**: e2017215. doi:10.1590/rbz4720170215.

Savell, J.W., Branson, R.E., Cross, H.R., Stiffler, D.M., Wise, J.W., Griffin, D.B., and Smith, G.C. 1987. National consumer retail beef study — palatability evaluations of beef loin steaks that differed in marbling. J. Food Sci. **52**(3): 517–519. doi:10.1111/j.1365-2621.1987.tb06664.x.

Tatum, J.D., Belk, K.E., Field, T.G., Scanga, J.A., and Smith, G.C. 2006. Relative importance of weight, quality grade, and yield grade as drivers of beef carcass value in two grid-pricing systems. Prof. Anim. Sci. **22**: 41–47. doi:10.15232/S1080-7446(15)31059-7.

USDA, Foreign Agricultural Service. 2019. Livestock and poultry: world markets and trade. United States Department of Agriculture, Washington, DC, USA. [Online]. Available from https://apps.fas.usda.gov/psdonline/circulars/livestock_poultry.pdf [29 Aug. 2019].

Wheeler, T.L., Cundiff, L.V., and Koch, R.M. 1994. Effect of marbling degree on beef palatability in Bos taurus and Bos indicus cattle. J. Anim. Sci. **72**(12): 3145–3151. doi:10.2527/1994.72123145x. PMID:7759364.

Wheeler, T.L., Cundiff, L.V., Koch, R.M., and Crouse, J.D. 1996. Characterization of biological types of cattle (cycle IV): carcass traits and longissimus palatability. J. Anim. Sci. **74**(5): 1023–1035. doi:10.2527/1996.7451023x. PMID:8726734.

Wolfger, B., Schwartzkopf-Genswein, K.S., Barkema, H.W., Pajor, E.A., Levy, M., and Orsel, K., 2015. Feeding behavior as an early predictor of bovine respiratory disease in North American feedlot systems. J. Anim. Sci. **93**: 377–385. doi:10.2527/jas.2013-8030. PMID:25568380.