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The 2019 Brazilian survey on nutritional practices provided by feedlot cattle consulting nutritionists

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ABSTRACT - This survey aimed to provide a current outlook of nutritional recommendations and management practices adopted by feedlot nutritionists in Brazil. The survey questionnaire consisted of 96 questions that included general information on nutritionists, animals, ingredients utilized in finishing diets, management and formulation practices, feeding management, and challenges associated with applying nutritional recommendations in practice. Thirty-six nutritionists, responsible for 4,671,062 animals in Brazil, responded our questionnaire. An increase in the percentage of nutritionists (38.9%) recommending 66% or more grain inclusion in the diets was observed. Fine grinding remained the preferred grain processing method by nutritionists (44.4%); however, more than 50% of nutritionists recommended high-moisture harvest and storage as the secondary grain processing method of choice. The average level of concentrate in the diets was 83.3%, which is higher compared with past surveys. The preferred fiber analysis method by 80.6% respondents was physically effective neutral detergent fiber (peNDF), and corn silage remained the main roughage source in finishing diets (69.4%). Improvements in diet mixing and distribution were also noted. While 79.0% of nutritionists' clients use a truck-mounted mixer and 69.5% of them also use programmed delivery per pen, 44.4% of the nutritionists reported that their clients use clean-bunk management. Respiratory diseases and acidosis (reported by 71.4 and 27.6% of the respondents, respectively) are among the main health problems. The present survey provides an overview of nutritional practices currently adopted by feedlot nutritionists, who played an important role on the improvement of feeding management in Brazil over the last 10 years.

Keywords: beef cattle, Brazil, energy, recommendation

1. Introduction

Brazil is the world largest beef exporter (FAO, 2019), which has increased the international market demand for Brazilian beef. As a result, the number of cattle finished in feedlots in Brazil increased approximately 100% from 2009 to 2019 [from 2,757,000 (ANUALPEC, 2009) to 6,090,000 (ABIEC, 2020)] as well as the percentage of feedlot animals slaughtered in relation to the total number of slaughtered heads: 14.06% (IBGE, 2019). However, when compared with American industries, the feedlot industry in Brazil is relatively recent, and based on a previous survey conducted in 2015 by Pinto and Millen (2019), it is still evolving.

Surveys with feedlot cattle nutritionists in the US (Vasconcelos and Galyean, 2007; Samuelson et al., 2016) and Brazil (Millen et al., 2009; Oliveira and Millen, 2014; Pinto and Millen, 2019), as well as

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with dairy nutritionists (Silva et al., 2019), have become popular in the last 15 years to describe nutritional recommendations and management practices currently adopted by feedlots, indicating critical changes over time, and also to show the evolution of the feedlot industry. Our previous survey (Pinto and Millen, 2019) showed a broader range of technology adoption, allowing an increase in the number of feedlots with programmed feed delivery, and resulted in an energy level increase for finishing diets, which was identified by the increased levels of grain and fat, improved grain processing, and utilized feeding with a better roughage source (corn silage). In addition, it was observed that feedlot cattle nutritionists in Brazil were more experienced and highly educated, which has certainly been contributing to the evolution of the Brazilian feedlot industry. Thus, this survey was designed to present an overview of the evolution of feedlot operations over the last 10 years in Brazil, especially focusing on the past four years.

Thus, our survey aimed to: provide a current outlook of the nutritional recommendations and management practices adopted by feedlot cattle nutritionists in Brazil; identify critical issues on feedlot operations at national level and compare their evolution with previous surveys conducted by Millen et al. (2009), Oliveira and Millen (2014) and Pinto and Millen (2019); and collaborate and provide insights for the research development to improve the Brazilian feedlot systems.

2. Material and Methods

This survey was planned and conducted at the College of Technology and Agricultural Sciences, São Paulo State University, campus of Dracena, Brazil. The approval of this study by the Animal Care and Use Committee was not required since no animals were used. Furthermore, according to Article 1, sole paragraph from the Resolution 510/16, National Health Council of the Ministry of Health in Brazil: "there is no need to submit a project to Ethics Committee when interviewed participants are not identified and the survey has public access".

2.1. Nutritionists and data collection

Data collection was carried out according to Pinto and Millen (2019). Based on a list of contacts provided by the authors, 54 consulting feedlot cattle nutritionists were invited to participate in the survey. These nutritionists were selected because they represent typical cattle feeding practices in different geographical locations of Brazil. The first contact was made by email where each of them received a brief description of the project, instructions to access the survey, and a unique personal identification number to guarantee anonymity. Forty-five nutritionists agreed to participate, and 36 ultimately completed the survey. The questionnaire was posted on the web (https://www.typeform.com) and was available for two months (between December 2, 2019 and January 25, 2020).

2.2. Survey questions

Based on the evolution of the feedlot industry reported by Pinto and Millen (2019), 13 additional questions were included in this survey, which had 96 questions divided as follows: general information about the participating nutritionists (n = 11), general commodity information (n = 14), use of concentrate coproducts (n = 5), roughage sources and levels (n = 5), adaptation methods and receiving programs (n = 7), mixers (n = 6), feeding management (n = 5), cattle management and information (n = 17), formulation practices (n = 17), information on resources used for nutritional recommendations (n = 2), major health problems (n = 6), and challenges faced by the nutritionists in the field to put their nutritional recommendations into practice. The terms "primary" and "secondary" were used to describe the most often and second most often used feedstuffs, feed additives, and grain processing methods.

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2.3. Data analyses

Data were tabulated in an Excel (Microsoft, Redmond, WA, USA) spreadsheet, and the number of responses, mean, minimum value, maximum value, and mode were calculated for the responses to all questions. Statistical analyses were conducted according to Pinto and Millen (2019). Correlation analyses were performed between all variables, when appropriate, by the CORR procedure of SAS, (Statistical Analysis System, version 9.4). Seventeen correlations between the following variables were reported in this study because of their significant response and also for being reported previously by Pinto and Millen (2019): feedlot size vs. feeding frequency, feedlot size vs. percentage of clients who do not use any mixer, feedlot size vs. inclusion level of concentrate, feedlot size vs. inclusion level of grains, feedlot size vs. bunk space, feedlot size vs. percentage of clients who adopted continuous delivery, feedlot size vs. bunk management, inclusion level of concentrate vs. percentage of clients who add water to the mixed diets, feeding frequency vs. inclusion level of concentrate, feeding frequency vs. bunk space, inclusion level of forage vs. bunk space, bunk space vs. percentage of clients who adopted continuous delivery, total digestible nutrients (TDN) content of finishing diets vs. percentage of clients who used coproducts, TDN content of finishing diets vs. bunk management, TDN content of finishing diets vs. percentage of clients who added water to diets, physically effective neutral detergent fiber (peNDF) content vs. fat content of finishing diets, and percentage of clients who do not use any mixer vs. percentage of clients who adopted continuous delivery. The results were considered significant at P<0.05 level.

3. Results

3.1. General information

All 36 participants who answered this survey were responsible for a total of 5,190,051 animals; however, eleven nutritionists also practiced in other countries, including Paraguay (n = 9), Uruguay (n = 2), Bolivia (n = 4), and Russia, Nicaragua, Argentina, and the United States (n = 1), and reported a total of 518,989 animals assisted in foreign countries, which were also included in the data reported in this survey because separation was not possible based on the way data were collected. As a result, the nutritionists interviewed in this survey were responsible for 4,671,062 animals in Brazil. Most surveyed nutritionists declared having clients in the state of São Paulo (75.0%), 69.4% reported that most of their clients were in Mato Grosso, 61.1% serviced most of their clients in Mato Grosso do Sul, 58.3% responded in Goiás, 44.4% in Pará, 41.7% in Minas Gerais, 36.1% in Tocantins, 33.3% in Paraná, 13.9% in Bahia, 11.1% in Rondônia, 8.3% in Rio Grande do Sul, 2.8% in Alagoas, 2.8% in Sergipe, and 2.8% in Espírito Santo. The sum of nutritionists is higher than 100% because most of them have clients in more than one state. Furthermore, the interviewed consulting nutritionists reported visits to their clients every 34.2 days, on average.

Out of the 36 surveyed nutritionists, 47.2% were representatives of a corporate feed manufacturing company, 36.1% worked for a nutritional consulting company, 5.6% were associated with a university, 5.6% were independent consultants, 2.8% worked for a state research corporation, and 2.8% was a distributor and representative. Regarding their practice time, 83.3% of participants had been practicing for more 10 years, 11.1% from 8 to 10 years, and 5.6% from 5 to 8 years.

When asked about their terminal degree, 33.3% nutritionists reported a Bachelor of Science degree (agronomy, animal science, or veterinary medicine) with graduate certificate courses in cattle nutrition, 30.6% declared having a Ph.D degree, 25.0% a Master of Science degree, and 11.1% a Bachelor of Science degree. Most of the participating nutritionists (42.3%) reported that their degree was obtained in universities of the state of São Paulo, whereas the others declared that their degree were from universities from states of Minas Gerais (19.2%), Goiás (13.5%), Paraná (11.5%), Mato Grosso do Sul (7.7%), and Mato Grosso (5.8%).

Furthermore, nutritionists were asked about the average number of cattle in feedlot operations their practices serviced, 11.1% reported having clients that feed <1,000 animals, 52.8% had clients who

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feed from 1,001 to 5,000 animals, 19.4% responded assisting feedlots ranging from 5,001 to 10,000 animals, 11.1% reported having clients who feed from 10,001 to 20,000 animals, and 5.6% assisted only feedlots with a capacity of more than 20,000 animals on feed.

3.2. Information on grains and energy levels

3.2.1. Grains

Corn was the most utilized grain, reported by 97.2% of the nutritionists (Table 1), followed by sorghum (2.8%). In addition, flint type (100%) was the most fed corn in feedlot operations in Brazil. The secondary grain choice for 79.4% of the nutritionists was sorghum.

3.2.2. Grain processing methods

Fine grinding was the primary grain processing method adopted by feedlot nutritionists in Brazil (16, 44.4%), followed by coarse grinding (36.1%) and high-moisture harvesting and storage (13.9%; Table 1). The secondary preferred grain processing method by the participating nutritionists was high-moisture harvesting and storage (52.8%). Nutritionists were also questioned about corn granulometry used in Brazilian feedlots, and 29 of them reported an average of 3.2 mm.

3.2.3. Average inclusion level of grain and concentrate

About 50% of the consultants included from 51 to 65% (Table 1) of grain in the finishing diet (dry matter (DM) basis). Although the correlation between feedlot size and inclusion level of grains in finishing diets was not significant (r = 0.14, P = 0.41), the inclusion levels of grain in finishing diets of feedlot operations in Brazil have been increasing in the last decade based on the percentage of nutritionists who include more than 66% grains in finishing diets (Figure 1). Likewise, the inclusion level of concentrate in the diets also increased over the last decade, with 97.2% of the participants recommending from 71 to 90% per kg of diet DM (Figure 2). As for grain level, the correlation between feedlot size and inclusion level of concentrate in finishing diets was not significant (r = 0.23, P = 0.17).

3.3. Sources of information on feed energy values

The most common measure of energy unit utilized for diet formulation by the consulting nutritionists was total digestible nutrients (TDN; 52.8%), followed by net energy for gain (NEg; 16.7%), metabolizable energy (ME; 22.2%), and non-fibrous carbohydrates (8.3%; Table 2). The main source of information for feed energy values was the RLM (Ração de Lucro Máximo, 2014), which was the choice of 36.1% surveyed nutritionists, followed by Cornell Net Carbohydrate and Protein System (CNCPS; 19.4%), NRC (1996; 13.9%), NASEM (2016; 11.1%), and BR-Corte (Valadares Filho et al., 2016; 8.3%). In addition, 5.6% of the participants responded that they use the Cargill System for information on feed energy values, whereas 2.8% used their own information, and another 2.8% preferred the Agricultural and Food Research Council (AFRC).

3.4. Use of coproducts

Whole cottonseed was indicated by 52.8% of the participants as the primary coproduct used in finishing diets, followed by citrus pulp pellets (30.6%), dried distillers grains (DDG; 8.3%), soybean hulls (2.8%), wet distillers grains (2.8%), and cotton cake (2.8%; Table 3). The average inclusion level of whole cottonseed was of 14.6% of diet DM, whereas citrus pulp pellets were included at 27.8%. Most of the clients served by the interviewed nutritionists included some type of coproduct in finishing diets. In addition, the correlation between TDN content of finishing diets and percentage of clients who used some sort of coproducts, analyzed in this study, was not significant (r = 0.34, P = 0.16).

3.5. Roughage sources, levels, and methods of fiber analysis

3.5.1. Roughage sources and levels

The typical level of roughage inclusion in finishing diets recommended by the surveyed nutritionists was 16.8% of diet DM (Table 4), which represented approximately a 42% decrease when compared with the very first Brazilian feedlot survey conducted in 2009 (Millen et al., 2009; Figure 3). Corn silage was the primary roughage source in finishing diets, which was used by 69.4% of the respondents, followed by sugarcane bagasse (11.1%), grass silage (8.3%), hay (5.6%), cottonseed pod (2.8%), and sugarcane silage (2.8%). The secondary roughage recommended by 36.1% of the participants was sugarcane

Table 1 - General commodity information recommended for finishing diets by the surveyed Brazilian consulting nutritionists

Information	No. of responses[1]	% of responses
Primary source of used grain		
Corn	35	97.22
Sorghum	1	2.78
Secondary source of used grain (n = 34)		
Sorghum	27	79.41
Corn	6	17.65
Millet	1	2.94
Type of used corn (n = 35)		
Flint	35	100.00
Dent	0	0.00
Primary grain-processing method		
Finely ground	16	44.44
Coarsely ground	13	36.11
High-moisture harvesting and storage	5	13.89
Only cracked	1	2.78
Reconstituted grain	1	2.78
Secondary grain-processing method		
High-moisture harvesting and storage	19	52.78
Finely ground	9	25.00
Coarsely ground	5	13.89
Whole-shelled corn grain	2	5.56
Steam-flaking	1	2.78
Inclusion level of grains in finishing diet (% of dry matter)		
20 to 35	2	5.56
36 to 50	2	5.56
51 to 65	18	50.00
66 to 80	12	33.33
81 or more	2	5.56
Inclusion level of concentrate in finishing diet (% of dry matter)		
Less than 55	1	2.78
56 to 70	0	0.00
71 to 80	12	33.33
81 to 90	23	63.89
91 or more	0	0.00

[1] Number of responses when nutritionists chose only one answer for a question.
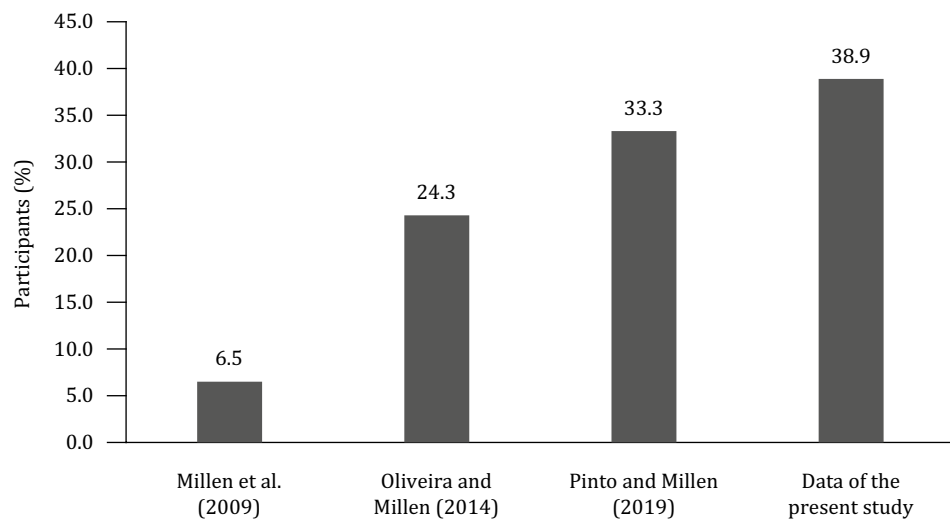
Figure 1 - Percentage of Brazilian nutritionists who recommended more than 66% of grains per kg of diet DM.
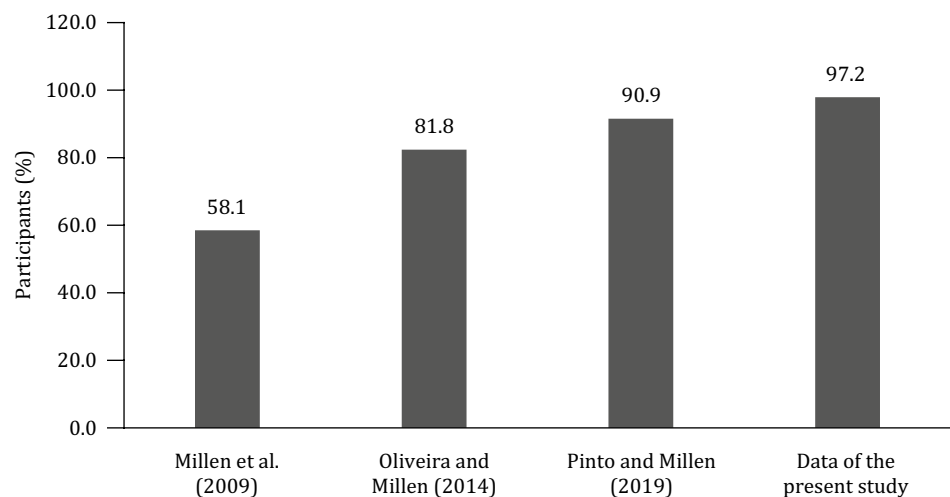

Figure 2 - Percentage of Brazilian nutritionists who recommended from 71 to 90% concentrate ingredients per kg of diet DM.

bagasse, 27.8% reported the use of grass silage, 13.9% used sorghum silage, 11.1% sugarcane silage, 8.3% corn silage, and 2.8% fresh-chopped sugarcane.

3.5.2. Methods of fiber analysis

The preferred fiber analysis method for finishing diets reported by 80.6% of the respondents (Table 4) was dietary peNDF followed by dietary neutral detergent fiber (NDF; 11.1%), roughage NDF (5.6%), and dietary acid detergent fiber (2.8%). The average dietary peNDF inclusion level reported by the surveyed nutritionists was 14.3% of diet DM. For nutritionists who reported the use of dietary NDF, the recommendation of dietary NDF content in finishing diets was 21.8%.

3.6. Receiving programs and adaptation methods for cattle

3.6.1. Receiving programs

The most adopted receiving program by nutritionists was a feedlot bunk containing a mix of roughage and concentrate (44.4%; Table 5). The pasture plus a bunk containing concentrate was the second most

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Table 2 - Information on energy values and types of energy units used to formulate diets adopted by the interviewed consulting nutritionists

Information	No. of responses[1]	% of responses	Average level	Maximum	Minimum	Mode
Type of energy unit used to formulate finishing diets						
Total digestible nutrients (%)	19	52.78	74.66 (n = 19)	79.00	70.00	75.00
Net energy for gain (Mcal/kg DM)	6	16.67	1.33 (n = 5)	1.48	1.20	
Metabolizable energy (Mcal/kg DM)	8	22.22	2.89 (n = 8)	3.2	2.60	2.87
Non-fibrous carbohydrates (%)	3	8.33	52.67 (n = 3)	54.00	50.00	54.00
Source of information on energy values						
RLM	13	36.11				
CNCPS 2000	7	19.44				
NRC 1996	5	13.89				
NASEM 2016	4	11.11				
BR-Corte 2016	3	8.33				
Cargill System	2	5.56				
Own information	1	2.78				
AFRC	1	2.78				

DM - dry matter; RLM - Ração de Lucro Máximo; CNCPS - Cornell Net Carbohydrate and Protein System; NRC - National Research Council; NASEM - National Academies of Sciences, Engineering, and Medicine; AFRC - Agricultural and Food Research Council.
[1] Number of responses when nutritionists chose only one answer for a question.

Table 3 - Concentrate coproducts used in finishing diets by the surveyed Brazilian consulting nutritionists

Coproduct	No. of responses[1]	% of responses	Average level	Maximum	Minimum	Mode
Primary used concentrate coproduct						
Whole cottonseed	19	52.78	14.64 (n = 18)	20.00	8.00	15.00
Citrus pulp pellets	11	30.56	27.75 (n = 10)	35.00	20.00	35.00
Dried distillers grains	3	8.33	15.00 (n = 3)	15.00	15.00	15.00
Soybean hulls	1	2.78	10 (n = 1)	10.00	10.00	-
Wet distillers grains	1	2.78	30 (n = 1)	30.00	30.00	-
Cotton cake	1	2.78	25 (n = 1)	25.00	25.00	-
Secondary used concentrate coproduct						
Soybean hulls	10	27.78	17.70 (n = 10)	30.00	7.00	15.00
Whole cottonseed	10	27.78	11.55 (n = 10)	15.00	5.00	15.00
Dried distillers grains	6	16.67	14.49 (n = 6)	30.00	3.50	-
Citrus pulp pellets	6	16.67	29.42 (n = 6)	35.00	23.00	35.00
Cotton cake	2	5.56	15.00 (n = 2)	15.00	15.00	15.00
Corn gluten feed	1	2.78	17.50 (n = 1)	17.50	17.50	-
Brewery wet residue	1	2.78	15.00 (n = 1)	15.00	15.00	-
Percentage of clients that use some type of coproduct in finishing diets						
Mean			82.28			
Maximum			100.00			
Minimum			5.00			
Mode			100.00			

[1] Number of responses when nutritionists chose only one answer for a question.

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used receiving program reported by the participants in this survey (30.6%). For all 35 nutritionists who recommended receiving programs to their clients, 9.7 days was the average number of days that the cattle spent in this program.

Table 4 - Roughage sources and levels and fiber analysis methods used by the Brazilian consulting nutritionists surveyed

Roughage	No. of responses[1]	% of responses
Primary roughage source		
Corn silage	25	69.44
Sugarcane bagasse	4	11.11
Grass silage	3	8.33
Hay	2	5.56
Cottonseed pod	1	2.78
Sugarcane silage	1	2.78
Secondary roughage source		
Sugarcane bagasse	13	36.11
Grass silage	10	27.78
Sorghum silage	5	13.89
Sugarcane silage	4	11.11
Corn silage	3	8.33
Fresh-chopped sugarcane	1	2.78
Preferred method of fiber analysis		
peNDF	29	80.56
NDF	4	11.11
Roughage NDF	2	5.56
ADF	1	2.78
Typical range of inclusion of roughage in finishing diets (% of DM)		
Mean		16.75
Maximum		35.00
Minimum		7.17
Mode		15.00

[1] Number of responses when nutritionists chose only one answer for a question.
DM - dry matter; peNDF - physically effective neutral detergent fiber; NDF - neutral detergent fiber; ADF - acid detergent fiber.
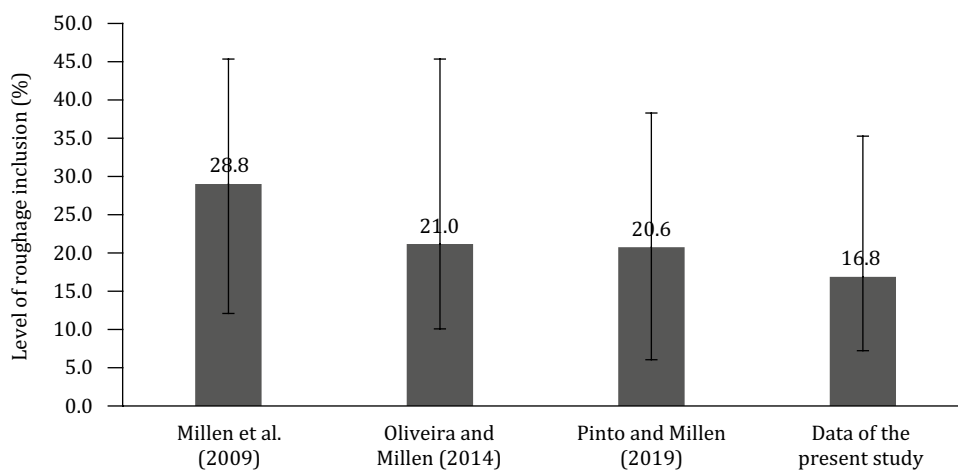

Figure 3 - Typical level of roughage inclusion in finishing diets recommended by Brazilian nutritionists surveyed over the last 10 years.

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3.6.2. Adaptation methods

Multiple step-up diets were the preferred adaptation method reported by 61.1% of the participants. Nevertheless, 19.4% of the nutritionists reported the use of only one diet containing less energy than the finishing diet, followed by blending of two diets (13.9%), final diet limited by quantity fed (2.8%), and multiple step-up diets associated with restriction by quantity fed (2.8%; Table 5). Regarding multiple step-up diets, the nutritionists reported an average of 2.9 diets used within the adaptation period (average of 7.1 days per diet), which resulted in an average number of days for the entire adaptation period of 19.2 (Table 6). When questioned about the average initial roughage concentration, participants recommended 36.9% of diet DM.

Table 5 - Cattle adaptation and receiving program methods used by the Brazilian consulting nutritionists surveyed

Program method	No. of responses[1]	% of responses
Methods used for adapting cattle to finishing diet		
Multiple step-up diets	22	61.11
Only one diet containing less energy than final diet	7	19.44
Blending of two diets	5	13.89
Final diet limited by quantity	1	2.78
Multiple step-up diets associated with restriction	1	2.78
Receiving program		
Feedlot bunk containing roughage and concentrate	16	44.44
Pasture plus bunk containing concentrate	11	30.56
Feedlot bunk containing only roughage	5	13.89
Pasture	3	8.33
None	1	2.78
Average number of days in the receiving program (n = 35)		
Mean	9.68	
Maximum	60	
Minimum	2	
Mode	3	

[1] Number of responses when nutritionists chose only one answer for a question.

Table 6 - Recommendations for each adaptation method used by the surveyed Brazilian consulting nutritionists

Recommendation	Mean	No. of respondents[1]	Minimum	Maximum	Mode
Multiple step-up diets					
Number of step-up diets used	2.88	21	2	4	3
Number of days per diet	7.14	20	3	14	5
Average number of days to the final diet	19.22	20	8	35	10
Initial level of roughage (% of DM)	36.89	22	18	50	40
Final diet limited by quantity					
Average number of days to the final diet	40.00	1	40	40	-
Initial level of roughage (% of DM)	15.00	1	15	15	-
Only one diet containing less energy than final diet					
Average number of days to the final diet	24.71	7	12	60	15
Initial level of roughage (% of DM)	37.79	7	22	45	45
Blending of two diets					
Average number of days to the final diet	14.67	3	6	21	-
Initial level of roughage (% of DM)	36.50	5	27.5	40	40

DM - dry matter.
[1] All nutritionists had either an answer for all possible choices or more than one answer per question.

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3.7. General feeding and bunk management

3.7.1. Mixers

The surveyed nutritionists reported that 79.0% of their clients used truck-mounted mixers, 16.3% used a combination of stationary mixer/delivery trucks, and 4.9% utilized only delivery trucks (Table 7). In addition, the participants indicated that 81.6% of their clients used horizontal mixers.

Table 7 - Mixers and feeding management information provided by the surveyed Brazilian consulting nutritionists

Item	No. of respondents[1]	Mean	Minimum	Maximum	Mode
Mixer (%)					
Truck-mounted mixer	36	79.01			
Stationary mixer and delivery truck	36	16.33			
Delivery truck	36	4.89			
Does not use any mixer	36	1.72			
Feed delivery (%)					
Programmed delivery per pen	36	69.47			
Continuous delivery	36	30.53			
Type of mixer used (%)					
Horizontal mixer	34	81.55			
Vertical mixer	34	8.43			
No mixer	34	10.01			
Feeding management					
Daily feeding interval (h)	36	3.01	1.5	6	3
Bunk space per animal (cm)	36	0.36	0.275	0.5	0.35
Area per animal in a pen (m^2)	36	15.18	10	20.5	15
Average mixing time for finishing diets (min)	36	6.11	4	15	5
Clients who add water to finishing diets (%)	36	45.08	0	100	0
Water added to finishing diets (%)	31	12.00	0	30	10
Dry matter in finishing diets (%)	36	65.42	55	80	65

	No. of responses[2]	Percentage of responses			
Feeding					
Cattle are fed one time daily	0	0.00			
Cattle are fed two times daily	2	5.56			
Cattle are fed three times daily	6	16.67			
Cattle are fed four times daily	24	66.67			
Cattle are fed five times daily or more	4	11.11			
Bunk management					
Clean bunk	16	44.44			
1 to 3% orts	15	41.67			
3 to 5% orts	5	13.89			
Water trough cleaning					
Once a week	11	30.56			
Twice a week	7	19.44			
Thrice a week	17	47.22			
Daily	1	2.78			
Use of sprinklers in the pen					
Yes	16	44.44			
No	20	55.56			

[1] All nutritionists had either an answer for all possible choices or more than one answer per question.
[2] Number of responses when nutritionists chose only one answer for a question.

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The percentage of nutritionists' clients not using any mixer in this survey was 10%; however, this data was not significantly correlated with feedlot size (r = −0.24, P = 0.15).

3.7.2. Feed delivery and mixing

The percentage of nutritionists' clients using a programmed delivery per pen (69.5%) increased over the last decade (Figure 4); however, 30.5% of clients still adopt continuous delivery (Table 7). In this survey, the correlation between the percentage of clients who did not use any mixer and percentage of clients who adopted continuous delivery was significant (r = 0.32, P = 0.05) as well as the correlation between feedlot size and percentage of clients who adopted continuous delivery (r = −0.37, P<0.05). The correlation is not causation, and based on this fact, nutritionists should make their recommendations considering unique aspects related to each client.

The surveyed nutritionists reported that 45.1% of their clientele added water to the finishing diet at 12.0% of diet DM (Table 7) during the process of mixing diets. Furthermore, the correlation between the percentage of clients who added water to the finishing diet and TDN content of the finishing diets was significant (r = 0.66, P<0.01), showing that nutritionists consider the energy content of finishing diets as one of factors to make the decision of adding water to diets. The inclusion level of concentrate was not correlated with the percentage of clients who added water to the finishing diet (r = 0.19, P = 0.26). With respect to the average mixing time, the nutritionists recommended 6.1 min.
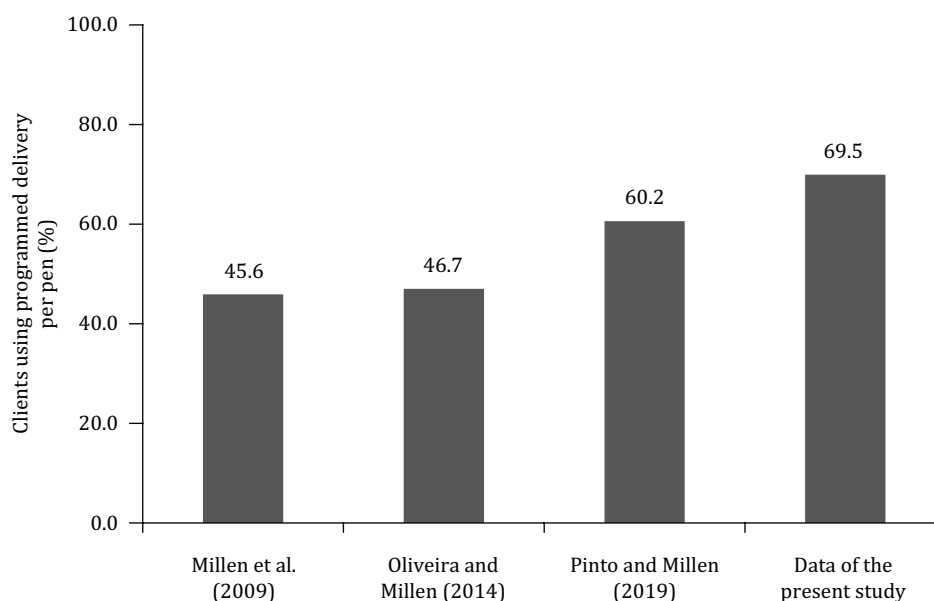
This figure depicts the percentage of nutritionists' clients using programmed delivery per pen over the last decade.

Figure 4 - Evolution of the use of programmed delivery per pen in feedlot operations in Brazil.

3.7.3. Water trough cleaning and sprinklers

About 47% of the participants reported that their clients cleaned water troughs three times a week, followed by once a week (30.6%), twice a week (19.4%), and daily (2.8%). The use of sprinklers in feedlot pens was reported by 44.4%, but 55.6% did not report the use of sprinklers by their clients (Table 7).

3.8. Management of newly received cattle

Our respondents indicated that 91.1% of their clients used some method to sort cattle upon arrival at the feedlot. Most of nutritionists' clients (73.9%) sorted cattle based only on body weight (BW),

16.2% sorted cattle by BW and body condition score, 1.5% used only body condition score, 1.3% sorted cattle by using real-time ultrasound, and 7.1% used a combination of either BW and breed, BW and frame, or origin source (data not shown).

3.9. Cattle performance information

Bulls were the predominant type of cattle fed in Brazilian feedlots (by 87.5% of the clients), followed by heifers (26.4%), calves (15.3%), cull cows (14.7%), and steers (6.6%) (Table 8). All animals that were less than 12 months old were considered calves. In addition, about 85% of the nutritionists' clients fed Nellore cattle, and approximately 52% fed some sort of crossbred animals.

When asked about how their clients marketed their cattle, participants (n = 35) responded that 70% of their clients' market animals as a commodity, and 30% had an agreement with beef programs. Moreover, 57.9% of the livestock fed by nutritionists' clients were from traceability programs (data not shown).

Table 8 - Cattle performance information provided by the surveyed consulting nutritionists in Brazil

	Calf	Bull	Steer	Heifer	Cull cow	Nellore	Crossbred
Average initial age (mo)	9.82 (n = 25)	36.69 (n = 35)	20.85 (n = 20)	16.92 (n = 33)	55.83 (n = 23)		
Average initial BW (kg)	236.67 (n = 27)	376.09 (n = 36)	371.82 (n = 22)	292.21 (n = 34)	386.42 (n = 26)		
Average final BW (kg)	460.43 (n = 23)	555.77 (n = 35)	516.19 (n = 21)	423.78 (n = 32)	474.28 (n = 25)		
Days on feed	158.20 (n = 25)	106.82 (n = 36)	98.86 (n = 22)	88.71 (n = 34)	65.42 (n = 26)		
ADG (kg)	1.33 (n = 25)	1.58 (n = 36)	1.41 (n = 22)	1.29 (n = 33)	1.31 (n = 25)		
Feed-to-gain ratio	6.53 (n = 23)	6.99 (n = 31)	8.02 (n = 19)	7.66 (n = 26)	8.79 (n = 22)		
DMI (kg)	8.21 (n = 22)	10.68 (n = 34)	10.39 (n = 20)	8.61 (n = 29)	10.82 (n = 23)	10.52 (n = 26)	11.45 (n = 25)
DMI (% of BW)	2.39 (n = 25)	2.32 (n = 36)	2.28 (n = 21)	2.36 (n = 31)	2.51 (n = 25)	2.26 (n = 29)	2.43 (n = 28)
Clients who feed (%)	15.29 (n = 29)	87.52 (n = 35)	6.64 (n = 31)	26.37 (n = 35)	14.65 (n = 31)	85.76 (n = 34)	52.73 (n = 34)

BW - body weight; ADG - average daily gain; DMI - dry matter intake.

3.10. Recommended nutrient composition for finishing diets

3.10.1. Fat

The participants reported that the average dietary fat concentration in finishing diets (DM basis) was 5.22% (Table 9). Likewise, the maximum dietary fat concentration recommended (DM basis) by the nutritionists was 6.64% in the current survey. In addition, the relationship between fat and peNDF contents of finishing diets was not significantly correlated (r = −0.28, P = 0.15) in this study. Whole cottonseed was the main source of fat in Brazilian feedlot diets (75.0%), followed by cottonseed hulls, high oil (19.4%), rumen-protected fat (2.8%), and soybean sauce residue (2.8%).

3.10.2. Protein

The consulting nutritionists recommended 13.7, 8.9, and 1.1% (DM basis) for average concentrations of crude protein (CP), rumen degradable protein (RDP), and urea, respectively (Table 9). In the current survey, 86.1% of Brazilian consultants also declared to formulate diets for RDP. Soybean meal was the primary source of plant-based protein used by 55.6% of participants, followed by cottonseed meal

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(13.9%), whole cottonseed (11.1%), dried distillers grains (11.1%), cotton cake (5.6%), and whole cottonseed plus DDG (2.8%). The second most commonly used source of plant-based protein included in finishing diets and used by the surveyed nutritionists was whole cottonseed (34.3%), followed by cottonseed meal (25.7%), peanut meal (11.4%), DDG (11.4%), soybean meal (8.6%), wet distillers grains (2.9%), brewery wet residue (2.9%), and cotton cake (2.9%).

Table 9 - Fat and protein recommendations for finishing diets used by the surveyed Brazilian consulting nutritionists

Recommendation	Mean	No. of respondents[1]	Minimum	Maximum	Mode
Recommended dietary fat (% of DM)	5.22	36	2.00	10.00	5.00
Maximum dietary fat recommended (% of DM)	6.64	35	3.00	9.00	6.00
Recommended level of CP (% of DM)	13.69	36	12.00	15.80	14.00
Recommended level of urea (% of DM)	1.07	36	0.50	1.30	1.20
Nutritionists who formulate for RDP (n = 36)	31 (86.11%) = Yes	5 (13.89%) = No			
RDP recommended for finishing diets (% of DM)	8.93	29	0.0	13.2	10
	% of responses	No. of responses[2]			
Main source of fat					
Whole cottonseed	75.00	27			
Cottonseed hulls, high oil	19.44	7			
Rumen-protected fat	2.78	1			
Soybean sauce residue	2.78	1			
Primary source of protein					
Soybean meal	55.56	20			
Cottonseed meal	13.89	5			
Whole cottonseed	11.11	4			
Dried distillers grains	11.11	4			
Cotton cake	5.56	2			
Whole cottonseed and dried distillers grains	2.78	1			
Secondary source of protein (n = 35)					
Whole cottonseed	34.29	12			
Cottonseed meal	25.71	9			
Peanut meal	11.43	4			
Dried distillers grains	11.43	4			
Soybean meal	8.57	3			
Wet distillers grains	2.86	1			
Brewery wet residue	2.86	1			
Cotton cake	2.86	1			

DM - dry matter; CP - crude protein; RDP - rumen degradable protein.
[1] All nutritionists had either an answer for all possible choices or more than one answer per question.
[2] Number of responses when nutritionists chose only one answer for a question.

3.10.3. Macro minerals

The average Ca concentration recommended by the surveyed nutritionists for finishing diets was 0.63% of diet DM (Table 10). Regarding P, K, and S concentrations, participants recommended 0.30, 0.75, and 0.19% of diet DM, respectively. Finally, the nutritionists' recommendations for Mg and Na in finishing diets were, on average, 0.18% of diet DM.

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3.10.4. Trace minerals

The recommended concentrations of trace minerals provided by the interviewed nutritionists were 15.5, 63.0, 33.0, 0.7, and 55.1 mg/kg of diet DM for Cu, Fe, Mn, I, and Zn, respectively (Table 10).

3.10.5. Vitamins

The average recommended vitamin A, D, and E concentrations were 2,583.5, 291.6, and 24.2 IU/kg, respectively (Table 10).

Table 10 - Feed additives and major and trace mineral recommendations by the surveyed Brazilian consulting nutritionists (DM basis)

Item	Mean	No. of respondents[1]	Minimum	Maximum	Mode
Major mineral (% of diet)					
Ca	0.63	28	0.00	1.40	0.80
P	0.30	28	0.14	0.60	0.30
K	0.75	26	0.49	1.20	0.80
Na	0.18	28	0.00	1.00	0.20
Cl	0.21	15	0.00	0.50	0.25
S	0.19	26	0.04	0.75	0.20
Mg	0.18	25	0.08	0.50	0.20
Trace mineral (mg/kg of diet)					
Fe	63.00	16	18.00	150.00	50.00
Zn	55.08	24	22.00	90.00	40.00
Cu	15.50	23	5.00	25.00	15.00
I	0.66	22	0.50	1.00	0.50
Mn	33	23	6.00	60.00	30.00
Vitamin (IU/kg)					
A	2583.50	20	0.00	5000.00	2200.00
D	291.59	17	0.00	625.00	0.00
E	24.20	19	0.00	50.00	30.00

[1] All nutritionists had either an answer for all possible choices or more than one answer per question.

3.10.6. Feed additives

The nutritionists interviewed in this survey declared that 99.8% of their clients utilized some type of additive in finishing diets (Table 11). With respect to the primary feed additive used in finishing diets, 86.1% of the participants reported sodium monensin, with the recommended inclusion level of 24.6 mg per kg (DM basis), on average. Other feed additives cited by the nutritionists included virginiamycin (5.6%), followed by salinomycin (5.6%) and a combination of monensin and virginiamycin (2.8%). When asked about the secondary feed additive used by their clients in finishing diets, 65.7% of the nutritionists responded virginiamycin, 8.6% reported the use of lasalocid, 5.7% responded monensin, 5.7% used functional oils, 2.9% reported using salinomycin, 2.9% yeast, 2.9% tannin, 2.9% sodium bicarbonate, and 2.9% flavomycin. An additional question was asked in this survey related to mycotoxin adsorbents, and the participants responded that only 18.8% of the clients used some type of adsorbent.

3.11. Sources of information

When asked about nutritional models they used, 30.6% of the Brazilian nutritionists interviewed responded RLM (Ração de Lucro Máximo, 2014), which was followed by NRC (1996; 13.9%),

Table 11 - Feed additive recommendations for finishing diets used by the surveyed Brazilian consulting nutritionists

Recommendation	No. of responses[1]	Mean (%)	Recommended level	Minimum	Maximum	Mode
Clients who use mycotoxin adsorbents (%)	35	18.77				
Clients who use some kind of feed additive (%)	36	99.78				
Primary feed additive used						
Monensin (mg/kg of DM)	31	86.11	24.58	18.00	30.00	25.00
Virginiamycin (mg/kg of DM)	2	5.56	25.00	25.00	25.00	25.00
Salinomycin (mg/kg of DM)	2	5.56	13.00	13.00	13.00	13.00
Monensin and virginiamycin (mg/kg of DM)	1	2.78	23.00	-	-	-
Secondary feed additive used (n = 35)						
Virginiamycin (mg/kg of DM)	23	65.71	20.30	15.00	25.00	20.00
Lasalocid (mg/kg of DM)	3	8.57	25.00	16.00	35.00	-
Monensin (mg/kg of DM)	2	5.71	21.00	20.00	22.00	-
Functional oils (mg/kg of DM)	2	5.71	50.00	-	-	-
Salinomycin (mg/kg of DM)	1	2.86	12.00	-	-	-
Yeast (g/kg of DM)	1	2.86	1.00	-	-	-
Tannin (g/kg of DM)	1	2.86	7.00	-	-	-
Sodium bicarbonate (g/kg of DM)	1	2.86	6.00	-	-	-
Flavomycin (mg/kg of DM)	1	2.86	4.00	-	-	-

DM - dry matter.
[1] Number of responses when nutritionists chose only one answer for a question.

CNCPS (13.9%), NASEM (2016; 13.9%), private company source (8.3%), own information (5.6%), BR-Corte (Valadares Filho et al., 2006; 5.6%), NRC (1984; 2.8%), LRNS (2.8%), and AFRC/NRC/ own information (2.8%).

Regarding the source of scientific or general information used by the consulting nutritionists (91.7%), the Journal of Animal Science was the most common answer (81.8%), followed by the Brazilian Journal of Animal Science (6.1%), articles from agriculture and livestock magazines (6.7%), conferences proceedings (3.0%), and technical company bulletin (3.0%; data not shown).

3.12. Problems reported by the nutritionists

3.12.1. Health problems

The main health problems indicated by the nutritionists were respiratory diseases (71.4%), followed by acidosis (11.4%), laminitis (11.4%), injuries resulting from transport (2.9%), and clostridiosis and mycotoxins (2.9%, Table 12).

All participants reported that their clients used vermifuge (an anthelmintic medicine), whereas 97.2 and 66.7% declared that their clients vaccinated animals against clostridium and pneumonia, respectively. Vaccination against acaricide (ticks and mites) was cited only by 37.1% of the interviewees (Table 12). The average mortality rate reported by the nutritionists at the feedlots they serviced was 0.57%.

3.12.2. Major challenges

In this survey, the nutritionists indicated (61.1% of the responses) administration and management as the most challenging issue to put their nutritional recommendations into practice. Other challenges cited by the nutritionists included lack of trained employees (30.6%), equipment precision and availability (5.6%), and logistics (2.8%; Table 12).

Table 12 - Major health problems and challenges faced by the surveyed Brazilian consulting nutritionists

Item	No. of responses[1]	% of responses
Major health problems (n = 35)		
Respiratory diseases in general	25	71.43
Acidosis	4	11.43
Laminitis	4	11.43
Injuries resulting from transport	1	2.86
Clostridiosis and mycotoxins	1	2.86
Vaccination against clostridium		
Yes	35	97.22
No	1	2.78
Vaccination against pneumonia		
Yes	24	66.67
No	12	33.33
Cattle vermifuge		
Yes	36	100.00
No	0	0.00
Vaccination against acaricide (n = 35)		
Yes	13	37.14
No	22	62.86
Average mortality rate reported	35	0.57
Major challenge		
Administration and management	22	61.11
Lack of trained employees	11	30.56
Equipment precision and availability	2	5.56
Logistics	1	2.78

[1] Number of responses when nutritionists chose only one answer for a question.

4. Discussion

4.1. General information

The 4,671,062 animals serviced by the nutritionists interviewed in this survey represented close to 75% of the cattle finished in a feedlot in Brazil in 2019 based on estimation of ABIEC (ABIEC, 2020). The interviewed consulting nutritionists reported visits to their clients every 34.2 days, on average, which is close to the interval of 38.2 days reported by Pinto and Millen (2019), but longer than the one of 26.3 days reported by Oliveira and Millen (2014). When compared with the first survey (Millen et al., 2009) conducted 10 years ago, the percentage of nutritionists serving feedlots that fed <5000 animals annually decreased (71.0% vs. 63.9%). In addition, it was the first time that nutritionists reported servicing feedlots with more than 20,000 heads capacity, on average, which is an evidence that feedlot operations still have been growing in Brazil since the first survey was conducted (Millen et al., 2009).

Out of the 36 surveyed nutritionists, 47.2% were representatives of a corporate feed manufacturing company, which is in agreement with previous surveys (Pinto and Millen, 2019; Oliveira and Millen, 2014), in which most of the participants were from corporate feed manufacturing companies (45.5 and 45.4% respectively). Furthermore, the percentage of nutritionists who work with feedlot cattle with for more than 10 years of practice rose from 42.4% (Oliveira and Millen, 2014) to 83.3%. It is noteworthy that 48% of the nutritionists interviewed in this survey participated at least in one of the three previous surveys (Millen et al., 2009; Oliveira and Millen, 2014; Pinto and Millen, 2019). However,

unlike previous surveys (Millen et al., 2009; Oliveira and Millen, 2014; Pinto and Millen, 2019), there was no interviewee with less than five years of practice.

In agreement with the first (Millen et al., 2009) and second Brazilian surveys (Oliveira and Millen, 2014), a Bachelor degree with graduate certificate courses in cattle nutrition was the most common terminal degree among the nutritionists surveyed, which is differently from what was reported in the previous survey by Pinto and Millen (2019), in which nutritionists with a Bachelor degree with graduate certificate courses in cattle nutrition represented only 15.1%. Most of the participating nutritionists (42.3%) in the current survey reported that their degree was obtained in universities of the state of São Paulo.

4.2. Information on grains and energy levels

Corn was the most utilized grain (97.2%), as reported previously (Millen et al., 2009; Oliveira and Millen, 2014; Pinto and Millen, 2019). In agreement with previous surveys by Millen et al. (2009) and Pinto and Millen (2019), fine grinding remained the primary grain processing method adopted by feedlot nutritionists in Brazil (44.4%). On the other hand, the percentage of nutritionists who adopted only grain cracking has drastically reduced over the years, from 57.6% (Oliveira and Millen, 2014) to only 2.8% of nutritionists in this survey.

The average granulometry of 3.2 mm for corn in Brazilian feedlots, reported by the interviewed nutritionists, showed a slightly reduction when compared with the one of 3.6 mm reported by Oliveira and Millen (2014). It seems that grain-processing methods improved over the years in feedlot operations in Brazil, showing that nutritionists and feedlot owners were determined to increase starch availability and also the energy content of finishing diets in Brazil. In this survey, high-moisture harvesting and storage was the secondary preferred grain processing method by more than 50.0% of the participating nutritionists. However, Brazilian feedlots still have a long road to improve efficiency of grain processing, and adopt a more extensive method, as first their option, such as steam-flaking or high-moisture, the primary choices of grain processing methods for 87.5% of the nutritionists (70.6 and 16.7%, respectively) in the US (Samuelson et al., 2016). As described before, flint type was the most fed corn in Brazil, and the greater adoption of steam-flaking and high-moisture processing methods would increase the proportion of starch that becomes available for ruminal fermentation at similar levels of dent corn (Zinn et al., 2002).

The average inclusion level of grains from 51 to 65% was close to the ones of 51.5, 51.6, and 51.5% reported by Millen et al. (2009), Oliveira and Millen (2014), and Pinto and Millen (2019), respectively. The percentage of nutritionists reporting inclusion levels of grains from 36 to 50% decreased over the last 10 years from 22.6% (Millen et al., 2009) to 5.6% in this survey; however, the percentage of consulting nutritionists reporting that their finishing diets contained more 66% of grains increased from 6.5 to 38.9% (Figure 1), showing that inclusion levels of grains in finishing diets in Brazil increased over the last decade.

Regarding the inclusion level of concentrate in the diets, 97.2% of the participants recommended from 71 to 90% per kg of diet DM, which was 9.3% higher than the value reported in the previous survey by Pinto and Millen (2019), and 39.1% higher than those reported in the very first Brazilian survey (Millen et al., 2009) 10 years ago (Figure 2). Unlike the data for feedlots covered by the American survey, in which 78.2% of nutritionists recommended inclusions higher than 60% of grains (Samuelson et al., 2016), mostly steam-flaked grains (70.8%), in the finishing diets, the present survey indicated that there is still a window for improvement, not only in the extent of grain processing, but also in the inclusion of grains in the finishing diets in Brazil. The increasing levels of grains in finishing diets, as well as the slight improvement on grain processing methods, were indicators that the energy content of finishing diets has increased over the last 10 years in Brazil.

4.3. Sources of information on feed energy values

As in previous surveys, TDN was the most recommended energy unit (52.8%); however, the use of TDN by feedlot cattle nutritionists decreased over the years (83.8%, Millen et al., 2009; 78.8%, Oliveira and Millen, 2014; 69.7%, Pinto and Millen, 2019). Furthermore, the use of NEg became more popular among feedlot nutritionists, as its utilization increased about 10% over the last 10 years (16.7 vs. 6.5%; Millen et al., 2009). Nevertheless, despite the increasing inclusion level of grains in the finishing diets, as well as the improvement of the grain processing methods, the energy content of finishing diets in Brazil is still 12.5% lower than the recommended by the US consulting nutritionists (1.33 vs. 1.52 Mcal of NEg/kg of diet DM; Samuelson et al., 2016) when considering the 16.7% of the nutritionists who used NEg as preferred energy unit to formulate their diets.

Regarding the main sources of information on feed energy values, RLM (Ração de Lucro Máximo, 2014) remained as the most cited source by 36.1% of the surveyed nutritionists. The RLM was also reported by Oliveira and Millen (2014) and Pinto and Millen (2019) as the most popular source of information for feed energy values among nutritionists in Brazil. The eighth revised version of the NRC (NASEM, 2016) was cited by 11.1% of the surveyed nutritionists, despite its relatively recent publication.

4.4. Use of coproducts

Whole cottonseed remained as the primary coproduct included in finishing diets in Brazil, as reported by Millen et al. (2009), Oliveira and Millen (2014), and Pinto and Millen (2019). The inclusion level of whole cottonseed decreased 0.4% (14.6 vs. 15.0%) when compared with the survey conducted 10 years ago (Millen et al., 2009). In addition, the inclusion level of citrus pulp pellets was 27.8% (Table 3), which was lower when compared with inclusions reported in previous surveys (33.8%, Millen et al., 2009; 40.0%, Oliveira and Millen 2014; 29.2%, Pinto and Millen, 2019). In this survey, it was reported for the first time the inclusion of DDG into feedlot diets (at 15.0% of diet DM, on average) due to the expansion of the grain milling industry for ethanol. Although the percentage of customers using some type of coproduct increased when compared with the last survey (82.3 vs. 70.6%; Pinto and Millen, 2019), the level of inclusion of these ingredients decreased slightly.

4.5. Roughage sources and levels and fiber analysis methods

The typical level of roughage inclusion in finishing diets recommended by the nutritionists surveyed was 16.8% of diet DM (Table 4), which shows a 3.8% decrease when compared with the previous survey conducted by Pinto and Millen (2019), confirming that the level of roughage inclusion decreased, since the first survey was conducted 10 years ago (Millen et al., 2009; Figure 3). The current level of roughage inclusion recommended by feedlot nutritionists in Brazil was still above the levels used by US feedlot-consulting nutritionists (Samuelson et al., 2016), in which 50 and 41.7% of nutritionists reported the use of inclusion levels between 8 to 10% in summer and winter, respectively. As reported earlier, finishing diets changed consistently in Brazil over the last 10 years, where roughage and coproducts were partially replaced by cereal grains. Corn silage remained as the primary source of roughage in finishing diets (Pinto and Millen, 2019). Samuelson et al. (2016) also reported that corn silage was the roughage of choice of 37.5% of the nutritionists surveyed, followed by Alfalfa hay (20.8%), for finishing diets in US. Since large feedlot operations are still expanding in Brazil, fresh feeds, such as chopped sugarcane and sugarcane bagasse, were gradually replaced by conserved feeds, e.g., corn silage, as reported in this survey. Furthermore, the greater use of corn silage contributed for increasing the energy content of finishing diets in Brazil since it presents the highest energy value among the roughages cited in this survey (Table 4; Valadares Filho et al., 2016).

The methods of fiber analysis preferred by nutritionists in this survey was peNDF, which was in agreement with Pinto and Millen (2019), who reported peNDF as the preferred method as well. However, Millen et al. (2009) and Oliveira and Millen (2014) reported in the past that NDF was the

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method of choice of most nutritionists in Brazil, which was a significant change. Since energy content in finishing diets have increased in the last 10 years, the use of peNDF is more accurate than NDF to monitor the particle size of feedlot diets, which is mandatory to assure a minimum level of fiber to stimulate rumination and rumen buffering (NASEM, 2016). In addition, the use of peNDF allows the nutritionist to identify and prevent particle sorting, which may negatively impact health and performance of feedlot cattle (Rivera et al., 2005).

The average dietary peNDF inclusion level of 14.3% was close to the 14.4% reported by Pinto and Millen (2019) four years ago. This result agrees with Goulart and Nussio (2011), who recommended finishing diets containing from 10 to 18% dietary peNDF for Nellore cattle in Brazil. For nutritionists who reported the use of dietary NDF, the current recommendation of dietary NDF content in finishing diets was 21,8%, on average, which was 1.9% lower when compared with the previous survey conducted by Pinto and Millen (2019).

4.6. Cattle adaptation methods

Receiving programs became more popular among feedlot nutritionists, based on the fact that 10 years ago, 35.5% of the nutritionists interviewed did not adopt any type of receiving program (Millen et al., 2009), which was really different compared with this survey, in which only one nutritionist (2.8%, Table 5) did not recommend receiving programs. The use of receiving programs is important so that cattle can recover from psychological agents and physical stressors associated with management procedures and transporting (Marques et al., 2012), such as feed and water deprivation (Swanson and Morrow-Tesch, 2001) that often lead to impaired health and productivity during feedlot receiving (Araujo et al., 2010).

In agreement with previous surveys (Millen et al., 2009; Oliveira and Millen, 2014; Pinto and Millen, 2019), including US surveys (Vasconcelos and Galyean, 2007; Samuelson et al., 2016), multiple step-up diets were the preferred adaptation method reported by 22 (61.1%) participants. Millen et al. (2009), Oliveira and Millen (2014), and Pinto and Millen (2019) reported that when the multiple step-up diets program was the choice of the nutritionists, cattle spent, on average, 17.1, 18.6, and 16.2 days, respectively, to adapt to finishing diets. However, in the current survey, probably due to increasing energy contents of finishing diets reported earlier, nutritionists were recommending an extended stay on adaptation to high-concentrate diets, which were, on average, 19.2 days. Since the level of roughage inclusion in finishing diets has been decreasing over the years, cattle may take a little longer to reach the expected dry matter intake to receive the finishing diet (NASEM, 2016). However, this little increase in adaptation length when multiple step-up diets method was used, still falls into the recommendation that feedlot cattle, either in Brazil or US, should not be adapted in less than 14 days to high-energy diets (Brown et al., 2006; Parra et al., 2019), especially newly received cattle coming from either nutritional restriction or previously exposed to supplementation of concentrate feedstuffs (Pereira et al., 2020).

The average initial roughage concentration recommended by the nutritionists surveyed, when the multiple step-up diets method was adopted, was 36.9%, which was lower than previous recommendations made in the past: 54.7% (Millen et al., 2009), 50.5% (Oliveira and Millen, 2014), and 45.1% (Pinto and Millen, 2019). The greater level of grains inclusion, a longer adaptation to high-concentrate diets, as well as the consistent adoption of peNDF among feedlot cattle nutritionists in Brazil, may explain this reduction in the average initial level of roughage for the adaptation period.

4.7. General feeding and bunk management

The percentage of nutritionists' clients who used truck-mounted mixers and horizontal mixers increased 38.5% (79.0 vs. 40.5%; Millen et al., 2009) and 47.7% (81.6 vs. 33.9%; Millen et al., 2009), respectively, over the last 10 years. The percentage of nutritionists' clients not using any mixer was 10%, which was lower than the 33.4 and 16.2% reported by Millen et al. (2009) and Pinto and Millen (2019), respectively. Results obtained in the present survey showed that feedlot operations in Brazil evolved in terms of use

of mixers, but there is still window for growing, since some clients of the nutritionists still do not mix properly the feed delivered to cattle. Certainly, the quality of ration mixing is variable among mechanic mixers available in Brazil; however, it is reasonable to assume that the use of any mechanic mixer promotes better mixing when compared with manual mixing or simply to unmixed rations, which is the case of nutritionists' clients who did not use any mixer. Pinto and Millen (2019) reported a significant negative correlation between feedlot size and percentage of clients who did not use any type mixer; however, in this survey, this correlation was no longer significant (r = −0.24, P = 0.15), which may indicate that even small feedlot operations (<5,000 animals) are improving their feeding management by acquiring mixers that, in many cases, are equipped with scales and automated systems.

The increasing use of truck-mounted mixers allowed an increase in the percentage of nutritionists' clients using programmed delivery per pen, which increased 9.2% in the last four years (Pinto and Millen, 2019) and 23.9% in the last 10 years (Millen et al., 2009; Figure 4). In this survey, the correlation between the percentage of clients who did not use any mixer and percentage of clients who adopted continuous delivery was significant (r = 0.32, P = 0.05), as well as the correlation between feedlot size and percentage of clients who adopted continuous delivery (r = −0.37, P<0.05), showing that it is difficult to adopt a ration delivery system using a programmed delivery per pen at small operations and when no mixer is available. Therefore, nutritionists may be cautious to recommend diets containing higher energy content in feedlot operations that adopted continuous feed delivery, especially those that fed less than 1,000 animals. On the other hand, the greater use of truck-mounted mixers, peNDF, and programmed delivery per pen allowed nutritionists to increase the energy content of finishing diets in Brazil. As a result, consulting nutritionists are able to collect more accurate data related to feeding management and delivery from their client's operations, which helps consultants to make decisions and nutritional recommendations to improve performance and avoid digestive disturbances, such as acidosis (Owens et al., 1998).

The water added at 12% to finishing diets during the process of mixing represented a slight increase when compared with previous surveys (9.3%, Millen et al., 2009; 11.0%, Oliveira and Millen, 2014; 10.2%, Pinto and Millen, 2019), but the percentage of clients who added water to feed increased about fourfold (45.1 vs. 10.2%, Millen et al., 2009) over the last decade. The increasing percentage of clients that added water to finishing diet was associated with TDN content (r = 0.66, P<0.01), but not with inclusion level of concentrate (r = 0.19, P = 0.26), showing that the addition of water to finishing diets may be alternative to decrease diet DM content when needed. Despite this increase in the percentage of clients who added water to feed, DM in finishing diets increased from 59.9 (Millen et al., 2009) to 65.4% (Table 7), which was caused by a higher inclusion of grains. The average mixing time recommended by the nutritionists was 6.1 min, which is 2.4 min shorter when compared with the first survey conducted in Brazil 10 years ago (Millen et al., 2009) and may be related to the decreased level of roughage inclusion in the finishing diets reported in previous surveys (Millen et al., 2009; Oliveira and Millen, 2014; Pinto and Millen, 2019).

About 67% of the nutritionists surveyed reported that most of their clients fed cattle four times a day, which agrees with the survey conducted by Pinto and Millen (2019) four years ago. Apparently, the greater use of truck-mounted mixers, as well as programmed deliveries per pen and the lower roughage inclusion, makes the planning of feeding frequency more organized without requiring extra deliveries eventually. Ten years ago, Millen et al. (2009) reported that 36.8% of the nutritionists interviewed declared that their clients used to feed cattle five times a day or more. It has been reported in the literature that feedlot performance improved when Nellore cattle, the predominant breed at Brazilian feedlot, were fed from three to four times a day compared with one to two times daily (Silva et al., 2018). Furthermore, the correlation between feeding frequency and feedlot size was not significant (r = 0.07, P = 0.68), showing that feedlot size is not the main factor affecting feeding frequency planning. On the other hand, a correlation was found to be significant (r = 0.42, P<0.01) between feeding frequency and inclusion level of concentrate, which is excellent to avoid overconsumption of feed in some of the meals, which could possibly increase DMI fluctuation and lead to ruminal acidification (Schwartzkopf-Geinswein et al., 2004).

As energy content of the finishing diets has increased and level of roughage inclusion has decreased, bunk space per animal reported by nutritionists interviewed decreased 5 cm (Table 7) when compared

with previous survey (36 vs. 41 cm; Pinto and Millen, 2019). Moreover, a significant correlation (r = −0.50, P<0.01) was observed between feedlot size and bunk space, demonstrating that larger feedlot operations are adopting diets containing higher inclusions of grains, which allows them to provide a shorter bunk space per animal. Likewise, there was a correlation between bunk space and percentage of clients who adopted continuous delivery (r = 0.50, P = 0.02). However, the correlation between bunk space and feeding frequency, and bunk space and inclusion level of roughage, was not significant in this study (r = 0.02, P = 0.87; and r = 0.27, P = 0.12; respectively). The average area per animal in a pen reported by the nutritionists interviewed was 15.2 m^2.

With respect to bunk management, about 45% of nutritionists reported that their clients use clean-bunk management, which was an evolution when compared with Pinto and Millen (2019), in which nutritionists reported that most of their clients left 1-3% orts. Furthermore, a correlation was found between bunk management and feedlot size (r = −0.30, P = 0.05), confirming that shifting to a clean-bunk management was a required evolution when feedlot operations became larger. However, bunk management was not directly associated to the energy content of finishing diet, as the correlation between TDN content and bunk management was not significant (r = −0.24, P = 0.32).

The use of sprinklers in feedlot pens was reported by 44.4% (n = 16) of the nutritionists, a 15.6% decrease when compared with the previous survey (Pinto and Millen, 2019). However, if this decreased use of sprinklers is associated with increasing respiratory diseases issues, it remains unknown; since nutritionists were not questioned about it.

4.8. Management of newly received cattle

The use of only BW to sort cattle at feedlot arrival was the primary method adopted by 73.9% of the participants' clients in this survey, and in past surveys as well (Millen et al., 2009; Oliveira and Millen, 2014; Pinto and Millen, 2019), including the US survey (56.3%; Samuelson et al., 2016).

4.9. Cattle performance information

As reported in past surveys (Millen et al., 2009; Oliveira and Millen, 2014; Pinto and Millen, 2019), bulls remained as the predominant type of cattle fed in Brazilian feedlots (by 87.5% of the clients; Table 8). In addition, the final weight of bulls increased about 30 kg when compared with the previous survey (Pinto and Millen, 2019), and 55 kg over the last 10 years (Millen et al., 2009). Heavier final weights were also observed for heifers, calves, cull cows, and steers. However, the initial weights remained practically unaltered over the last 10 years (Millen et al., 2009). Considering that the mature weight of Nellore cattle, which is the predominant breed in Brazil and also in Brazilian feedlots (fed by 75.3% of nutritionists' clients), ranges between 560 and 580 kg (Fox et al., 1992), nutritionists have been taking advantage of feed efficiency of cattle slaughtered at lighter weights when compared with mature weight of Nellore animals (Owens et al., 1995) to explore carcass deposition and increase dressing percentage. Certainly, the increasing energy content in finishing diets in Brazil was one of the factors that led to heavier weights at slaughter. In addition, bulls, and heifers, calves, cull cows, and steers, have been fed for longer periods, which also contributes to increase slaughter weights. The number of days on feed increased about 23 days for bulls and 21 for heifers when compared with the first Brazilian survey conducted 10 years ago (Millen et al., 2009). In the last four years, the Brazilian markets and the packing plants increased the requirement for minimum fat cover (5 mm on backfat of carcasses) and started paying bonuses for it. However, there is no national grading system established by the Ministry of Agriculture and Livestock, and each packing plant has developed its own system for carcass grading according to their markets.

4.10. Recommended nutrient composition for finishing diets

The average dietary fat concentration in finishing diets (DM basis) was 5.22%, which is greater than the 5.0% reported by Pinto and Millen (2019), and even greater than the 4.7% observed by Millen et al.

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(2009) ten years ago. For maximum inclusion of dietary fat, nutritionists interviewed in this survey recommended 6.64%, which represents an 8.8% increase in the last decade (Millen et al., 2009). Levels of dietary fat higher than 7.0% (DM basis) may negatively impact fiber digestion in the rumen (Oldick and Firkins, 2000); however, it seems that Brazilian nutritionists were aware of this fact by recommending both average and maximum dietary fat concentrations below 7% of diet DM. Along with increasing levels of both grains and concentrate, the greater dietary fat concentration recommended in the current survey is also contributing to increase energy content of finishing diets in Brazil.

Protein recommendations did not change much on the course of the last ten years, and values reported in this survey were similar to previous ones (Millen et al., 2009; Oliveira and Millen, 2014; Pinto and Millen, 2019). As discussed earlier, Brazilian cattle has typically been slaughtered before reaching the mature weight, which supports the unaltered nutritionists' recommendations of protein over the last decade, since this type of cattle requires more metabolizable protein for muscle protein synthesis (NASEM, 2016). Moreover, in US feedlot system, the average CP concentration recommended by consulting nutritionists was 13.4% (DM basis; Samuelson et al., 2016), which is quite similar to the 13.7% reported in this survey. In the last and eighth revised version of the NRC (NASEM, 2016), the requirements of RDP have been revisited, and from now on, nutritionists in US and Brazil may want to revise their protein recommendations to meet a lower ammonia and RDP requirements, based on the fact that the current model assumes that all RDP will be used for microbial protein synthesis. Feedlot performance is usually limited by energy, and adjustments in finishing diets in that direction (less protein and more energy) may increase slaughter weights beyond maturity, and positively impact fat cover of carcasses of feedlot cattle in Brazil (NASEM, 2016). In this case, formulation of diets for RDP would be less important, and this may explain why only one-third of feedlot nutritionists in US formulated for RDP (Samuelson et al., 2016). It is noteworthy that soybean meal remained as the primary source of plant-based protein used in finishing diets in Brazil; however, it was the first time that distillers grains were cited among the main sources of plant-based protein used by the nutritionists (Table 9).

The average Ca concentration recommended by the surveyed nutritionists for finishing diets was 0.63% of diet DM, value that is greater than 0.58% (DM basis) reported by Millen et al. (2009); however, both values still met the NASEM (2016) recommendations. Furthermore, the 0.30% of diet DM recommended for P was similar to the value reported by Millen et al. (2009) 10 years ago and agreed with recommendations of NASEM (2016) and Samuelson et al. (2016). The K concentration decreased slightly after 10 years (0.75 vs. 0.83% of diet DM; Millen et al., 2009); however, S concentrations increased about 12% (0.19 vs. 0.17%; Millen et al., 2009), which was consistent with increasing levels of energy in finishing diets, since increased synthesis of microbial protein requires more S, especially for amino acids such as methionine, cysteine, and cystine (NASEM, 2016). Recommendations of nutritionists for Mg in finishing diets increased when compared with the reported by Millen et al. (2009) ten years ago (0.18 vs. 0.16%).

In this survey, the recommended concentrations of trace minerals values increased slightly (Table 10), but it still met NASEM (2016) recommendations, and were less than those reported by feedlot cattle nutritionists in US (Samuelson et al., 2016), which may be a result of the use of different feedstuffs and energy levels in finishing diets between Brazil and the US.

The values for vitamin concentrations in this survey (Table 10) were greater than those reported by Millen et al. (2009) and were in accordance with the recommendations of NASEM (2016), differently from what was reported in 2009, in which these values were below the recommendations (Millen et al., 2009). In terms of vitamin A, the American nutritionists recommended 4,715 IU/kg (Samuelson et al., 2016), which was 82% greater than the recommended by Brazilian nutritionists. The higher inclusion of roughages in finishing diets in Brazil compared with USA may explain these differences in vitamin A recommendations, since tropical roughages contain significant amount of this vitamin in their composition (Reynoso et al., 2004).

Sodium monensin, the most popular feed additive among feedlot consulting nutritionists (Table 10), is an ionophore, which has been cited in all past Brazilian (Millen et al., 2009; Oliveira and Millen, 2014;

Pinto and Millen, 2019) and American surveys (Samuelson et al., 2016) as the primary type of feed additive used in finishing diets. Virginiamycin has been cited as the secondary feed additive used by their clients in finishing diets, since the combination of monensin and virginiamycin in finishing diets has become popular in the past four years based on promising results related to increasing carcass weight (Rigueiro et al., 2020). However, we cannot guarantee, based on the results of this survey, that all nutritionists' clients that use virginiamycin as secondary feed additive also use sodium monensin as their primary feed additive.

4.11. Sources of information

When asked about nutritional models they used, the RLM was the most common nutritional model used by the nutritionists (30.6%), as also reported previously by Pinto and Millen (2019) four years ago (36.7% of the responses); however, considering new and old versions of the NRC publications, 33.4% of the nutritionists reported that they used some of its versions as the nutritional model of choice.

Regarding source of scientific or general information, the Journal of Animal Science remained as the most popular source among Brazilian nutritionists over the past 10 years (Millen et al., 2009; Oliveira and Millen, 2014; Pinto and Millen, 2019).

4.12. Problems reported by the nutritionists

Respiratory diseases in general, as well as acidosis, were already cited in previous surveys (Millen et al., 2009; Oliveira and Millen, 2014; Pinto and Millen, 2019) as the primary and secondary issues related to animal health in Brazilian feedlots. We point out that the percentage of the nutritionists reporting respiratory diseases as the major health problem increased 19.7% when compared with the last survey (Pinto and Millen, 2019). However, mortality rate reported by the nutritionists in the feedlots they serviced was a little lower (0.57 vs. 0.76%) than the reported by Pinto and Millen (2019).

Past surveys indicated the lack of trained employees (63.0%; Millen et al., 2009) and availability and accuracy of equipment (58.1%; Oliveira and Millen, 2014) as the major challenges; however, in this survey, nutritionists (61.1% of the responses) indicated administration and management as the most challenging issues to put their nutritional recommendations into practice. Due to the fact that Brazilian feedlots increased their investments on feeding technologies, we assumed that employees have been subjected to more rigorous training to operate machinery and computer-based devices; however, the major challenge now is to manage and organize all the processes present in the feedlot and coordinate these with nutritional recommendations, which include time of feeding, mixing time, feeding frequency, and so on.

5. Conclusions

The present survey provides an overview of nutritional and management recommendations currently adopted by feedlot nutritionists in Brazil. Brazilian feedlots have clearly improved feeding management over the last 10 years, which included a greater use of truck-mounted mixers, allowing about 70% of the nutritionists' clients to adopt programmed deliveries per pen. Moreover, the greater use of physically effective neutral detergent fiber and energy units based on calories, allowed nutritionists to monitor the amount of fiber and energy being offered more accurately, resulting in an increased energy content of finishing diets by including either more grains or fat. This has certainly contributed to increase the final weights of all types of cattle fed in Brazilian feedlots. Regarding the critical issues, utilization of starch has not yet been optimized in Brazilian feedlots after 10 years, because fine grinding remains the primary utilized grain-processing method. However, high-moisture harvesting and storage appeared as the secondary grain-processing method of use, possibly indicating that Brazilian nutritionists have been interested in improving starch utilization of finishing diets, as the inclusion levels of energy is closer to those reported by the American feedlot nutritionists than ever before. Dried and wet distillers grains were cited for the first time in a Brazilian survey among the concentrate coproducts used in

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finishing diets, and studies associating inclusion levels of distillers grains for Nellore cattle, as well as for typical feedlot diets in Brazil, are still scarce (Ferreira et al., 2020). In addition, cattle finished in Brazilian feedlots have been slaughtered at heavier weights, deserving further attention of scientists, as nutritional adjustments will be needed during the feeding period to achieve Brazilian market requirements for fat cover and carcass weight.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Data curation: A.M. Silvestre. Formal analysis: A.M. Silvestre and D.D. Millen. Methodology: D.D. Millen. Project administration: A.M. Silvestre and D.D. Millen. Supervision: D.D. Millen. Writing-original draft: A.M. Silvestre.

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