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Effects of maternal factors and season on health, growth and reproductive parameters in Holstein young heifers

[*Efeitos dos fatores maternos e da estação do ano sobre a saúde, o crescimento e os parâmetros reprodutivos de novilhas Holandesas jovens*]

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ABSTRACT

This observational study describes the short- and long-term effects of maternal factors in 226 Holstein heifers and their offspring. We obtained maternal data and information from the dairy register. Young heifers were assessed in the window of 60 to 105 days of life to perform the Calf Health Scoring System and performance index, and blood samples to measure inflammatory biomarkers. Prospective data on reproduction were obtained from dairy farm registers. The eutocic weight was higher than the dystocic calving heifers. Plasma total protein and weight were higher in the offspring of multiparous dams than in those of primiparous dams. Calves that were born lighter and in summer had lower concentrations of total protein and performance indices. The punctuation of the fecal score was higher in calves born in summer and cold months for BRD. Offspring from multiparous dams born at term exhibited greater precocity in terms of age at first artificial insemination and first parturition. Finally, seasonality at birth affected pregnancy loss and age at first calving. Heifers born in winter had lower rates of pregnancy loss than those born in summer. In addition, these animals were more precocious than animals born during the cold seasons.

Keywords: dairy calf, dystocia, prematurity, primiparous

RESUMO

Este estudo observacional descreve os efeitos de curto e longo prazo de fatores maternos em 226 novilhas Holandesas e suas proles. Foram obtidos dados maternos e informações do registro leiteiro. Novilhas jovens foram avaliadas, na janela de 60 a 105 dias de vida, com o escore de saúde, índice de desempenho e amostras de sangue para medir biomarcadores inflamatórios. Dados prospectivos sobre reprodução foram obtidos dos registros da fazenda. O peso das novilhas eutócicas foi superior ao das novilhas que nasceram de parto distócico. A proteína total plasmática e o peso foram maiores nas proles de vacas multíparas do que nas proles das primíparas. Bezerras que nasceram mais leves e no verão apresentaram menores concentrações de proteína total e índices de desempenho. A pontuação do escore fecal foi maior em bezerras nascidas no verão e nos meses frios para DRB. A prole de vacas multíparas nascidas a termo apresentou maior precocidade em relação à idade à primeira inseminação artificial e ao primeiro parto. Finalmente, a sazonalidade ao nascimento afetou a perda de prenhez e a idade ao primeiro parto. As novilhas nascidas no inverno tiveram menores taxas de perda de gestação do que as nascidas no verão. Além disso, esses animais eram mais precoces do que os nascidos nas estações frias.

Palavras-chave: bezerra leiteira, distocia, prematuridade, primípara

INTRODUCTION

Maternal effects can trigger a cascade of events that impact the development, health, and future production of offspring. These effects can also occur in the pre-calving period, exposing the fetus to various factors that may adversely affect different organ systems and result in long-term alterations in the structure and functioning of the organism (Funston e Summers, 2013; Abuelo, 2020). Adverse maternal phenotypic

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characteristics that put placental viability at risk include metabolic distress, reproductive and immunological dysfunction, and uterine exposure to stressors (Barker, 2007; Reynolds *et al*., 2010).

Placental development depends on maternal age, calving type, body size, and nutritional status (Osgerby *et al*., 2003). The first pregnancy in dairy cows often occurs during the period of the organic immaturity in heifers, which leads to an increased risk of dystocia due to maternal-fetal incompatibility (Coffey *et al*., 2006). In addition, primiparous dams tend to produce smaller calves with limited energy reserves, hypothermia, and less-developed immune systems (Wathes *et al*., 2008). In multiparous cows, the causes of dystocia are secondary to complications during gestation involving the fetus. These cows are more likely to gestate poorly positioned fetuses, leading to a higher incidence of premature births and underweight calves at birth (Lombard *et al*., 2007). Consequently, they face increased susceptibility to neonatal asphyxia, failure to acquire passive immunity (Barrier *et al*., 2013), and compromised milk intake, which adversely affects growth, development, and future performance. Late-developing calves suffer from delayed weaning and generally weigh approximately 80kg less (Wittum *et al*., 1994).

There is limited research available on the maternal effects on growth performance and their long-term impact on reproductive performance in heifers from large commercial dairy farms. Therefore, the objective of this study was to evaluate the effects of maternal and environmental factors on the health, performance, and reproductive indices in a population of Holstein heifers from the largest dairy farm in Brazil.

MATERIALS AND METHODS

This study was approved by the Animal Care and Use Committee of the University of São Paulo, number nº1658230119. This study was conducted on a commercial farm located at São Paulo - Brazil, between May to December 2017. The geographical coordinates are represented by latitude 22º21'25''S; longitude 47º23'03''W; and altitude of 629m.

In this study, 226 Holstein cows and their female offspring (n = 226). In the pre-calving period, 226 cows were transferred to the maternity barn, housed in a freestall with a sand bed and a cross-ventilation system, and continuously monitored to detect the exact moment of referral to the maternity pen and assistance at birth, if necessary. The housing and feeding system described in this study followed the management routines employed at the commercial farm selected for this experiment. The calves were born from February 19th up to August 16th, 2017.

After calving, neonates were transferred from the maternity barn to the calf housing system, where the individual suspended cages (1.0 x 1.3m^2) were distributed in a covered barn with lateral curtains. The heifers were maintained in the same individual housing for the first 10 days after calving. From this period, they were transferred to a collective housing system, composed of eight heifers, during the adaptation phase (up to seven days after the introduction of animals into the collective housing system). Subsequently, the number of animals per group doubled weekly until a maximum of 20 heifers were used.

The management of the first colostrum was based on the 3 Q principle: quantity (minimum volume of 3-4 liters), quality (IgG $\leq$ 50 g/dL), and speed (time of ingestion $\leq$ 6 hours after birth). The 2nd colostrum feeding session was offered between 12-18 hours after birth. Calves were fed waste milk supplemented with milk replacer (Nattimilk Emax®, Auster Nutrição Animal LTDA, Brazil) to achieve a total solid content of 14%, distributed in two meals. The neonates were fed from days 2 to 24 of life with seven liters of liquid diet, followed by a volume of eight liters offered from 25 days of life until weaning. Despite being fed a liquid diet, the calves had free access to water and concentrate. The heifers were gradually weaned when they reached an average weight of 101kg. The volume of the milk replacement was reduced every 48 h, and the amount of solid diet was fixed at 2 kg (Rumileite LS®, Guabi Nutrição e Saúde Animal S. A., Brazil). After weaning, the heifers had time to adapt to a solid diet composed of 20% crude protein, hay of Tifton-85 and corn flour in the first 15 days. Subsequently, the young heifers received concentrate and corn silage.

Data and information from dams were used to compose the experimental group such as type of calving (dystocic or eutocic), number of calving (primiparous or multiparous), length of gestation (premature or term) and the season of the births (summer = February 19 to March 13, 2017, fall = March 27 to June 1, 2017 and winter = June 25 to August, 2017) were recovered from the DairyComp Herd Management Software (Lactanet, Québec, Canada) according to the farm registration. According to farm classification, the type of calving is defined as with or without obstetric assistance, using only hands or forceps to manage the abnormal progress of parturition.

During the pre-weaning period, data regarding heifer health were recovered from the clinical records of the farm. For convenience, heifers were physically assessed from 60 to 105 days of life (defined as T0), followed by evaluations on 61-106 days (T1); 63-108 days (T3); 65-110 days (T5); 67-112 days (T7); 75-120 days (T15); 90-135 days (T30); and 120-165 days of life (T60).

Health scores and inflammatory blood marker levels were evaluated at T1, T3, T5, T7, T15, T30, and T60. Calf health was monitored following the procedures for the classification of diarrhea and Bovine Respiratory Disease (BRD) Scoring System described by McGuirk (2008). Blood samples were collected in 9 mL vacuum tubes containing EDTA or without anticoagulants by puncturing the external jugular vein. Total serum protein (TP) was determined by optical refractometry (g/dL), and haptoglobin (Hp) concentration (mg/dL) was determined based on its ability to bind to hemoglobin, according to the procedures described by Ramos *et al*. (2021).

The performance indices were evaluated at T0, T5, T15, T30, and T60. Heifers were measured with a scale weight flexible tape placed in the region of the thoracic perimeter (weight), an anthropometric ruler was used to measure the distance from the withers to the tip of the hooves (withers height), and the distance between the ileum (hip width) according to Heinrichs *et al*. (1987).

Reproductive data from the offspring, such as age at first insemination, age at the first calving and pregnancy loss, were recovered using the DairyComp Herd Management Software (Lactanet, Québec, Canada).

The timeline of this study is shown in Fig. 1. Briefly, maternal data were recovered from the farm using the DairyComp Herd Management Software (Lactanet, Québec, Canada) to compound the experimental groups.

The data from the pre-weaning period was excluded from the analysis due to the manual system employed for managing young heifer categories on the farm. Convenience data from a previous experiment were used to analyze the health and development of young heifers from weaning to the 60^{th} day. Long-term reproductive performance was analyzed using farm data recovered using DairyComp Herd Management Software (Lactanet, Québec, Canada).

Maternal factors were classified as independent variables and categorized according to parity (primiparous [n = 113] and multiparous [n = 113]), length of gestation (premature [n = 39] ≤ 270 days and term [n = 187] > 270 days), and calving type (eutocic [n = 174] and dystocic [n = 52]). Calving season was also considered an independent variable, where the birth date was classified according to the Brazilian season into three categories: x (n= 79), y (n= 88), and z (n= 59). Offspring measurements were classified as dependent variables: weight at birth, age at weaning, weight at weaning, rump width, height at withers, fecal score, BRD score, serum protein level, serum acute-phase protein (haptoglobin) level, and reproductive index.

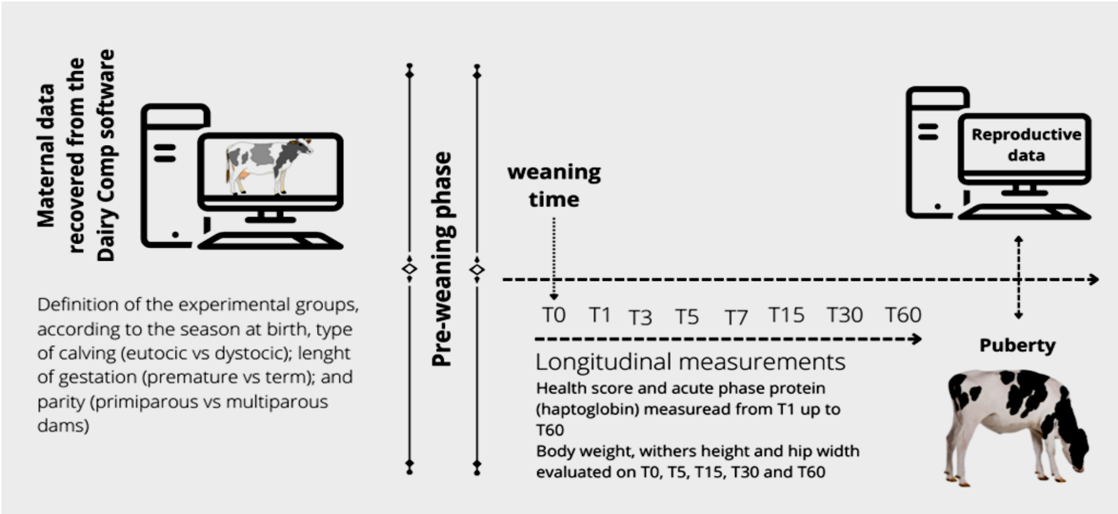

Figure 1. Timeline of the study design showing the following of the young heifer at short and long-term.

Data were analyzed using the Statistical Analysis System for Windows (SAS® version 9.4), except for logistic regression, which was performed using SPSS version 18 (IBM Corporation). Health scores and quantitative variables were evaluated for Gaussian distribution using a Guided Data Analysis function. Some data presented no normal distribution and were subjected to logarithmic transformation using $\log_{10}$, square root, or inverse analysis to obtain a normal distribution of the variables. Descriptive data were defined using the command PROC MEANS MEAN STDERR after these variables were tested for fixed effects of maternal factors, seasonality, and time as well as the interaction between groups and times using the MIXED procedure. A significance level of $P \leq 0.05$ was used to determine the presence of interactions, indicating the need to compare maternal factors and seasonality groups at each evaluation time. Parametric dichotomous variables were evaluated using Student's t-test, and non-parametric dichotomous variables were compared using the Wilcoxon test. Differences between groups for variables with three categories were evaluated by Tukey's test using the PROC GLM command. The effects of maternal factors on reproductive parameters were evaluated using the chi-square test.

RESULTS

The influence of maternal factors and seasonality on weight at birth and age at weaning in young Holstein heifers is shown in Table 1. It was possible to detect the effect of the length of gestation on weight at birth by observing lighter calves from premature births. This maternal effect on weight at birth progressed until the post-weaning phase the supplementary Table 1. Dystocia did not affect weight at birth, although some differences were detected in the final post-weaning phase (T60) measured in this study (Supplementary Table 1). Calves born during fall were slightly lighter than those born in winter. Young heifers born in the cold seasons (fall and winter) developed slowly, represented by a lower body weight in the post-weaning phase (T0–T60), as presented in Supplementary Table 1.

The effects of maternal factors on the health and performance of Holstein heifers from weaning to the 60th day are shown in Tables 2 and 3. In the present study, the prevalence of dystocia was 23% (52/226). Dystocia did not have an impact on fecal and BRD score punctuation. No significant differences were observed in the concentrations of total protein and haptoglobin between calves born via eutocic and dystocic deliveries. The length of gestation differed only between the groups (term vs. premature), and the interaction between group and time for haptoglobin level at the post-weaning phase; however, no differences were detected between the groups at each time point after weaning.

Table 1. Influence of maternal factors and seasonality on weight at birth and age at weaning in young Holstein heifers

Independent variables	Categories	Sample size	Weight at birth (kg)	Age at weaning (days of life)
Maternal factors	Eutocic	174	39.09±0.26	88.09±0.57
	Dystocic	52	39.82±0.60	88.29±1.01
	P-value	-	0.27	0.59
	Primiparous	113	39.09±0.33	88.44±0.69
	Multiparous	113	39.43±0.36	87.84±0.71
	P-value	-	0.50	0.99
	Term	187	39.77±0.26	88.11±0.55
	Premature	39	36.82±0.52	88.26±1.55
	P-value	-	<0.0001*	0.55
Seasons at birth time	fall	79	37.97±0.48[b]	87.93±0.98[b]
	winter	88	39.70±0.33[a]	83.94±0.67[c]
	spring	59	39.45±0.50[ab]	96.75±0.97[a]

Descriptive analysis using PROC MEANS MEAN STDERR; Dichotomous variables were considered when P≤0.05 by the chi-square test. TUKEY indicated different letters for categorical variables when thought. * Indicates difference (p≤0.05). [a], [b]: Letters indicate statistical differences.

Table 2. Effect of calving type and gestation length on health and performance index in Holstein heifers from 1st up to 60th day after weaning

Variable 1	Eutocic	Dystocic	Type of calving	Times	TC*Times
Fecal score	0.25±0.01	0.24±0.02	0.9208	<0.0001	0.9208
BRD score	3.58±0.03	3.61±0.06	0.7168	<0.0001	0.4537
(g/dL)	6.56±0.01	6.57±0.02	0.9677	0.0012	0.7939
Hp (mg/dL)	31.41±0.17	31.41±0.31	0.5836	<0.0001	0.8689
Weight (kg)	119.83±0.81	116.50±1.53	0.0049	<0.0001	0.8955
WH (cm)	90.21±0.16	89.90±0.34	0.3036	<0.0001	0.9453
HW (cm)	27.84±0.07	27.62±0.15	0.1144	<0.0001	0.9518
Variable 2	**Term**	**Premature**	**Length of gestation**	**Times**	**LG*Times**
Fecal score	0.25±0.01	0.24±0. 03	0.8932	<0.0001	0.5255
BRD score	3.58±0.03	3.63±0.07	0.6054	<0.0001	0.1858
Protein (g/dL)	6.58±0.01	6.52±0.03	0.1102	0.0011	0.0790
Hp (mg/dL)	31.93±0.25	30.51±0.18	0.0401	<0.0001	0.0454
Weight (kg)	120.27±0.78	113.37±1.70	<0.0001	<0.0001	0.9861
WH (cm)	90.62±0.15	87.86±0.38	<0.0001	<0.0001	0.6451
HW (cm)	27.90±0.07	27.26±0.16	<0.0001	<0.0001	0.7629

TC: type of calving; LG: length of gestation; BRD: Bovine Respiratory Disease; Hp: haptoglobin; WH: withers height; HW: hip width Descriptive analysis using PROC MEANS MEAN STDERR. MIXED test used for interaction analysis. Significant difference was considered when P≤0.05

Parity influenced BRD score punctuation, detecting higher values for young heifers from multiparous cows than for those from primiparous cows. In contrast, total protein and haptoglobin concentrations were higher in primiparous calves than in multiparous dams. These differences were more evident at T5, T7 and T30 (supplementary Tables 2 and 3).

Dystocia and parity affect weight, with low values observed in the offspring of primiparous and dystocic parturition dams. The length of gestation influenced all performance parameters: weight, withers height, and hip width, with lower values for heifers born prematurely than for term neonates.

The effects of season on the health and performance of Holstein heifers from weaning up to the 60th day are shown in Table 4. Seasonality influenced the fecal score, with a high average fecal score in the group of young heifers born in summer compared to calves born in the cold season. The effect of the season at birth on BRD score punctuation also revealed high BRD score punctuation in heifers born in the cold seasons (fall and winter). Seasonality at birth also affected all performance parameters, with greater development observed in offspring born in the cold season (fall and winter).

Table 3. Effect of parity on health and performance index in Holstein heifers from 1st up to 60th day after weaning

Variables	Primiparous	Multiparous	Parity	Times	Parity*times
Fecal score	0.24±0.01	0.25±0.01	0.7114	<0.0001	0.5882
BRD score	3.43±0.04	3.74±0.04	0.0001	<0.0001	0.4598
Protein (g/dL)	6.51±0.02	6.62±0.02	<0.0001	0.0011	0.8714
Hp (mg/dL)	3.66±0.25	3.06±0.18	0.0534	<0.0001	0.9028
Weight (kg)	117.80±1.01	120.34±1.01	0.0098	<0.0001	0.0831
WH (cm)	89.97±0.21	90.30±0.21	0.1825	<0.0001	0.8854
HW (cm)	27.77±0.09	27.81±0.09	0.7615	<0.0001	0.6650

BRD: Bovine Respiratory Disease; Hp: haptoglobin; WH: with height; HW: hip width. Descriptive analysis using PROC MEANS MEAN STDERR. MIXED test used for interaction analysis. A significant difference was considered when P≤0.05.

Table 4. Effect of season at birth on health and performance of Holstein heifers from 1st up to 60th day after weaning.

Parameters	Summer	Fall	Winter	Season	Times	Season x Times
Fecal score	0.43 ± 0.03	0.21 ± 0.01	0.16 ± 0.02	<0.0001	<0.0001	<0.0001
BRD score	3.39 ± 0.06	3.62 ± 0.04	3.69 ± 0.05	0.0286	<0.0001	0.0004
Protein (g/dL)	6.43±0.01	6.50±0.021	6.84 ±0.033	<0.0001	0.0007	<0.0001
Hp (mg/dL)	3.23±0.28	3.38±0.19	3.62±0.39	0.6682	<0.0001	0.0179
Weight (kg)	114.17±1.09	115.52±1.19	116.17±1.09	<0.0001	<0.0001	<0.0001
WH (cm)	90.01±0.22	88.60±0.23	92.65±0.27	<0.0001	<0.0001	0.1447
HW (cm)	27.18±0.10	27.23±0.10	29.46±0.12	<0.0001	<0.0001	0.0221

Bovine Respiratory Disease; Hp: haptoglobin; HW: withers height; RW: rump width. Descriptive analysis using PROC MEANS MEAN STDERR. MIXED test used for interaction analysis. A significant difference was considered when P≤0.05.

The results for the future reproductive parameters of the heifers are shown in Table 5. Maternal parity number influenced age at first artificial insemination and first parturition, observing precocity characteristics in the offspring of multiparous dams. Heifers born at term also exhibited more precocity than premature heifers. Finally, seasonality at birth affected pregnancy loss and age at first calving. Heifers born in winter had lower rates of pregnancy loss than those born in summer. In addition, these animals were more precocious than animals born during the cold seasons.

Table 5. Effects of maternal factors and seasonality on reproductive parameters in Holstein heifers

Parameters	Pregnancy losses %/n	Age at 1st AI (days)	Age at 1st calving (months)
		Type of calving	
Eutocic	12.26 (13/106)	14.24 ± 1.27	19.42 ± 9.67
Dystocic	10.71 (3/28)	14.28 ± 1.06	18.68 ± 10.25
P-value	0.92	0.50	0.57
		Number of calving	
Primiparous	11.26 (8/71)	14.42 ± 1.47	20.68 ± 8.88
Multiparous	12.69 (8/63)	14.08 ± 0.91	17.84 ± 10.45
P-value	0.99	0.05	0.08
		Length of gestation	
Term	12.17 (14/115)	14.19 ± 1.29	19.07 ± 9.81
Premature	10.52 (2/19)	14.51 ± 0.91	20.12 ± 9.72
P-value	0.85	0.07	0.98
		Seasonality at birth	
Summer	11.90 (42/49) [ab]	14.18 ± 2.00	23.04 ± 6.85[a]
Fall	7.04 (71/118) [b]	14.35 ± 0.86	17.83 ± 10.42[b]
Winter	28.57 (21/59) [a]	14.10 ± 0.90	19.01 ± 9.83[ab]

AI: artificial insemination. Differences were considered significant at $P<0.05$, as determined using the chi-square test. Dichotomic variables were analyzed using the chi-squared test. Tukey's test was used to identify differences between reproductive parameters according to seasonality. Different letters in the same column indicate statistically significant differences ($P\leq0,05$).

DISCUSSION

The present study sought to verify the effect of maternal factors and seasonality at birth on the health and performance of offspring, as well as to evaluate the long-term effects of these parameters on the future reproductive index.

Size at birth depends on the uterine environment responsible for transferring nutrients and oxygen from the dam to the fetus (Allen *et al*., 2002). Four aspects that affect the uteroplacental environment are important for cows: age, parity, dam size, and nutritional status (Kirchengast and Hartman, 2003).

The immaturity of dams during their first calving is commonly cited in the literature as a primary factor contributing to low birth weight. The competing nutritional demands for the heifer's own metabolic processes, colostrogenesis, and fetal development can restrict fetal growth during pregnancy. Adequate intrauterine nutrition plays a significant role in promoting offspring weight gain (Negrato and Gomes, 2013). Primiparous cows have lower placental weights and poorly developed arteries (Klewitz *et al*., 2015). Thus, placental viability at risk can cause changes in fetal growth and organ development (Reynolds *et al*., 2010). Primiparous cows tend to produce smaller calves, which may be at risk after birth because of their limited body energy reserves, hypothermia, and less-developed immune system. In our study, we did not observe low body weights at birth in calves from primiparous cows. Other causes of lower weight at birth are short gestation, changes in placentation, and genetic selection of bulls as donors of semen used in reproductive management (Wathes *et al*., 2008). Among these factors, only gestational length affected body weight at birth.

The negative consequences of short gestation start at birth and lower body weight compared to calves born at term, followed by low body weight, withers height, and hip width in the post-weaning phase, result in a delay in the first artificial insemination and subsequent first calving. Low body weight at birth in premature calves occurs due to the short gestation period. The effect of premature birth over a short period has already been described by Barrier (2013). Low body weight and reduced vitality in premature neonates result from a cascade of events that begin in fetal life. The development of the lungs and surfactant system occurs towards the end of pregnancy. Therefore, premature calving can lead to pulmonary immaturity and neonatal asphyxia. This problem is further compounded by delayed ingestion of maternal colostrum, which is crucial for the newborn's health. In addition, heifers experiencing these complications often exhibit slower daily weight gain, resulting in delayed weaning (Bleul, 2009). Premature birth and low birth weight result in a high risk of disease and are among the most important causes of mortality in bovine neonates (McCorquodale *et al*., 2013). McCorquodale *et al*. (2013) found that calves weighing less than 37 kg showed a 3.44-fold increase in mortality risk. We did not have a complete history of the offspring from birth up to the first calving, and the health data from calves in the pre-weaned period were not confident and were excluded due to the absence of a standardized protocol for disease screening and data recording. Despite this, long-term studies examining the effects of maternal factors on offspring life are scarce.

Term calves were not expected to have higher fecal and BRD scores in the post-weaning phase, in addition to a higher concentration of haptoglobin, than premature offspring. Haptoglobin is an acute-phase protein synthesized by the liver in response to various stressors, such as inflammation and acute, subclinical, or chronic diseases in calves (Ramos *et al*., 2021). We believe that the size of the individual housing where these calves were maintained near the weaning time was very small, and it could generate a stressful situation and high susceptibility to inflammation since offspring born at term presented high weight, withers height, and hip width.

Heifers born prematurely exhibited lower performance during the post-weaning period. This implies lower weight gain after weaning and subsequent weaning. Thus, these animals probably did not present compensatory weight gain to reach calves born at term, either at the time of weaning or at subsequent moments. Olson *et al*. (2009) reported that heifers born with lower weights were the premature daughters of primiparous dams. In our study, we observed a tendency for the delay of the first insemination in premature offspring, in addition to the delay of the first calving by approximately three months. According to Archbold *et al*. (2012), heifers that reach puberty with greater body weight calve earlier, thus emphasizing the reproductive and longevity benefits of body weight.

The frequency of dystocia observed in this study was 23%, and dystocia did not affect weight at birth, age at weaning, or health status of young Holstein heifers. There was only a slight difference in the body weights measured in the post-weaning phase, which did not affect the future reproductive performance of the offspring. Therefore, the classical clinical cascade characterized by neonatal asphyxia, failure of passive immune transfer, high occurrence of disease, and low development reported by calves with dystocia was not detected in our study (Wittum *et al*., 1994; Barrier *et al*., 2013; Murray *et al*., 2015). The prevalence of dystocia is approximately 23%; however, most cases are uncomplicated and can be successfully managed with or without the use of forceps. The dairy farm where this study was developed has adequate standard operating procedures to assist dams and neonates in the risk of dystocia, which could explain the low impact of dystocia on the short- and long-term lives of young heifers.

The number of calves did not affect weight at birth or age at weaning. Health parameters evaluated in the post-weaning period revealed high BRD scores in calves born to primiparous cattle; however, the frequency of BRD was similar between groups when qualitative analysis was performed. Total protein and haptoglobin were higher in young heifers from primiparous dams, with higher weights observed in the offspring of multiparous than in primiparous cattle. Overall, multiparous cows have higher body scores, and their glucose metabolism results in heavier offspring than that of primiparous cattle (Johanson and Berger, 2003). In contrast, small calves are at a high risk of mortality (McCorquodale *et al*., 2013). Heavier multiparous cattle achieve age at the first insemination and the first calving previously to primiparous offspring.

Seasonality also affects weight at birth and age at weaning. Calves born in fall had a lower weight at birth than those born in winter. Offspring from the winter season were weaned first, followed by calves from the fall and spring seasons. These events may be explained by the heat stress suffered by dams during the weather season before calving (summer). Heat stress at the end of gestation is associated with a reduction in dry-matter intake, uterine blood flow, and placental function, which results in impaired glucose and amino acid changes between dams and fetuses and low body weight of offspring at birth

(Linden *et al*., 2009). A long photoperiod in the late middle of gestation results in a higher concentration of prolactin with high colostrum and milk production, resulting in a decrease in nutrient availability to the fetus (García-Ispierto *et al*., 2009).

Another cause of low body weight at birth in cows subjected to heat stress is a shorter gestation period, since heat stress can anticipate delivery by up to four days, in addition to hyperthermia and delayed fetal growth (Laporta *et al*., 2017). Almoosavi *et al*., (2020) also found lower birth weights in calves exposed to intrauterine stress by heat, whereas weaning weights were similar to those in animals without thermal stress. The farm is situated in a hot and humid geographic region, characterized by an approximate duration of hot seasons lasting 5.9 months, with temperatures exceeding 29°C. Conversely, cool seasons persist for only 2.4 months annually. These environmental conditions can have numerous repercussions on pregnant cows, including decreased dry matter intake and colostrum quality. Furthermore, the heat directly affects the placenta and has consequential impacts on the calves (Linden *et al*., 2009).

Calving season also influenced offspring health parameters. Fecal sore punctuation was high in summer, whereas BRD score punctuation and haptoglobin concentrations were high during winter. However, offspring born in summer and autumn performed lower than those born in winter.

The study conducted had certain limitations that could have affected the outcomes. It is noteworthy to highlight that the field study was carried out on a highly productive dairy farm consisting of animals with a superior genetic standard. The study spanned a duration of six months and adhered to the requirements and protocols adopted by the farm, prioritizing the safety and integrity of their calves. This is a challenge commonly encountered when conducting research on commercial farms. However, it is crucial to note that this situation also provided valuable insights into the dynamic processes involved in heifer production.

One of these limitations was the variation in age at weaning, since the criterion used by the farm to start weaning was the weight estimated visually. Thus, the calves were weaned in different age groups, which may have influenced differences in nutritional management and contact with pathogens. Another limitation of the study was the housing arrangement for the animals following weaning. The calves were initially placed in a dynamic flow group ten days after weaning, and the group size increased to 20 calves shortly thereafter. Thus, it was not possible to assess the feed intake of individual post-weaning experimental units to assess the effect of maternal factors on performance. Diet after weaning was also a limiting factor, since the farm did not allow changes in the feeding management of these animals; therefore, the calves received two types of feed during the adaptation period, which may have affected the performance parameters.

CONCLUSIONS

Maternal factors had an impact on short- and long-term offspring; however, our data showed that season was the most important factor associated with body weight at birth, dynamics of disease in the post-weaning period, growth, and reproductive performance of the offspring. Hence, it is essential for future research to investigate heat stress and diverse maternity housing environmental conditions in Brazil, given its subtropical climate.

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