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ANIMAL REPRODUCTION

Metabolic, zootechnical, and health profile of Girolando calves conceived through *in vitro* fertilization

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ABSTRACT: This study determined the zootechnical, metabolic, and health performance of Girolando calves born with high or low birth weight, conceived through *in vitro* fertilization. The study was carried out on a commercial dairy farm located in Passos, Minas Gerais, Brazil. For this, a hundred Girolando calves were divided into two groups: The Control, which consisted of calves that were born weighing ≤ 35 kg; and high birth weight (HBW) calves, which were born weighing > 35 kg. The calves were monitored for zootechnical parameters; epidemiological indices, for diseases such diarrhea and pneumonia; as well as serum concentrations of aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase, gamma-glutamyl transferase, cholesterol, triglycerides, paraoxonase1, albumin, urea, and globulin. Calves from the HBW group had a higher general mortality rate, but no effects on the zootechnical performance or metabolism were observed. The results obtained allow us to conclude that Girolando calves generated by IVF and heavier at birth have a greater chance to present diseases such as omphalophlebitis, tympany, and bovine parasitic sadness, and have a higher rate of general mortality. Conversely, birth weight of the calves does not influence diarrhea or pneumonia, the zootechnical performance, or the metabolism.
Key words: neonates, bovine, metabolism, zootechnical performance, health.

Perfil metabólico, zootécnico e sanitário de bezerras Girolando concebidas por fertilização *in vitro*

RESUMO: Este estudo determinou o desempenho zootécnico, metabólico e saúde de bezerras Girolando nascidas com alto ou baixo peso, concebidas por fertilização *in vitro*. O estudo foi realizado em uma fazenda leiteira comercial localizada em Passos, Minas Gerais, Brasil. Cem bezerras Girolando foram divididas em dois grupos: Controle, que consistiu em bezerras que nasceram com peso ≤ 35 kg; e HBW, bezerras que nasceram com peso > 35 kg. As bezerras foram monitoradas quanto aos parâmetros zootécnicos; índices epidemiológicos para doenças como diarreia e pneumonia; bem como as concentrações séricas de aspartato aminotransferase, alanina aminotransferase, fosfatase alcalina, gama-glutamil transferase, colesterol, triglicérides, paraoxonase1, albumina, uréia e globulina. As bezerras do grupo HBW apresentaram maior taxa de mortalidade, mas nenhum efeito no desempenho zootécnico ou metabolismo foram observados. Os resultados permitem concluir que bezerras Girolando provenientes de FIV que nascem mais pesadas têm maior chance de apresentar doenças, como onfaloflebite, timpanismo e tristeza parasitária bovina, tendo uma maior taxa de mortalidade geral. Porém, o peso ao nascimento das bezerras não influenciou a ocorrência de diarreia ou broncopneumonia, o desempenho zootécnico e o perfil metabólico.
Palavras-chave: neonatos, bovino, metabolismo, desempenho zootécnico, saúde.

INTRODUCTION

The use of reproductive biotechnologies has been increasingly frequent in the Brazilian beef and dairy cattle farms, motivated by the necessity to meet the market demand and improve the genetic potential of herds (VIANA, 2019). *In vitro* fertilization (IVF) is a biotechnique that accelerates the process of genetic selection and enhances the participation of bovine females in the process of genetic improvement of herds. (VARAGO et al., 2008; BONILLA et al., 2014). However, the technique also has its drawbacks such as lower efficiency in embryo implantation, atypical placental development (BERTOLINI et al., 2004; SIQUEIRA et al., 2009), greater fetal development and, mainly, a higher birth weight (BONILLA et al., 2014).

Large offspring syndrome (LOS) is a fetal overgrowth condition in bovine animals, most often observed in offspring conceived with the use of reproductive technologies such as IVF and somatic cell nuclear transfer (SCNT). Different culture media cause transcript abundance changes of several developmentally important genes involved in cell–

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cell junctions, transport, RNA processing, and stress in bovine embryos (LI et al., 2019). Consequently, in addition to greater weight at birth, an abnormal enlargement of organs has been observed in animals with overgrowth, for example, in their hearts, livers, and kidneys (CHEN et al., 2013), which may cause metabolic changes in these animals.

Although, high birth weight may be associated with an increase in the average daily gain and height of calves (SWALI & WATHES, 2006), this condition may also be a risk factor for increasing dystocia, due to the incompatibility between the size of the calf and the mother's pelvis (PAPUTUNGAN et al., 2000). Consequences of dystocia may include neonatal asphyxia, metabolic and respiratory acidosis, reduced immunoglobulin absorption, increased susceptibility to diseases, and death (JACOBSEN et al., 2000).

High birth weight is associated with perinatal mortality in calves (JOHANSON & BERGER, 2003), having a great economic impact (MEYER et al., 2001; SCHILD et al., 2020). In Holstein cattle, it was demonstrated that lower birth weight tends to have a lower risk of mortality, otherwise, calves with around or above average birth weight have an exponentially increased risk of mortality (JOHANSON & BERGER, 2003). These facts support the hypothesis of this study that high birth weight IVF calves have a higher predisposition toward health disorders.

Although, other studies investigate the influence of birth weight on calf health (SWALI & WATHES, 2006; GLOVER et al., 2019), there are still a few studies that correlate this parameter with the performance and metabolic profile of neonates from IVF. Thus, due to the great importance of the Girolando breed for dairy production, as well as due to the increasing use of reproductive biotechnologies in dairy farms, an evaluation of the effects of these techniques on the health and initial zootechnical performance become important/ to contribute to the decision-making within the production system. In this sense, this study determined the influence of birth weight on the metabolic, zootechnical, and health profile of Girolando calves conceived through IVF.

MATERIALS AND METHODS

The study was conducted on a commercial dairy farm located in Passos, Southern Minas Gerais, Brazil. To conduct this, one hundred Girolando female calves, kept in a tropical (Argentinean) calf house system, were used. A shade cloth, a trough for feed supply, and a bottle for milk and water intake, were all present for individual use. The management of calves was described by WEILLER et al. (2021).

All calves were conceived through IVF, from a cross between the Holstein and Gir breeds, utilizing half Holstein–Gir donors (n = 51) and Gir donors (n = 49). For the IVF procedure, semen from nine Holstein bulls (bull "A" to "I") were used (A: 19 vs. 20; B: 7 vs. 6; C: 16 vs. 18; D:1 vs. 0; E:1 vs. 0: F: 1 vs. 2; G: 2 vs. 1; H: 3 vs.2, and I: 0 vs. 1), resulting in calves that were three-fourth Holstein–Gir (n = 51) and half Holstein–Gir (n = 49). All bulls used in this study had the expected difference in progeny positive for calving ease. The oocyte donors and recipients were cows from the same property, so all were subjected to the same climatic conditions. Recipients were primiparous (n = 55) or multiparous (two or more calvings, n = 45) cows Holstein–-Gir (half n = 23; three-fourths n = 69; five-eighths n = 4; seven-eighths n = 4). All recipients were cows presenting an average milk production of 20 liters/day, with body condition score between 2.5 and 3.5 (WILDMAN et al., 1982) at the moment of embryo transfer. The *in vitro* production system was the same throughout the study and fresh embryos were transferred from May to September 2017.

For the study, the animals were distributed into two groups, according to the birth-weight criterion. Given this, at birth, all calves were weighed using a tape measure for medium-sized animals, obtaining an average weight of 35.45 ± 4.6 kg and a median weight of 35.50 kg. Using the birth weights, the calves were included into two distinct groups, according to the average weight of Girolando females, which is 29.57 ± 4.2 kg at birth (OLIVEIRA & NOGUEIRA, 2006): Control (n = 50) — including calves that were born weighing 35 kg or less; and HBW group (n = 50) — including calves with a birth weight higher than 35 kg. For the composition of these two groups, the median was used as a reference measure. The bull semen, recipient parity, and the degree of blood of the Holstein–Gir were evenly distributed between the groups.

Assessing passive transfer of immunity

Failure of passive transfer of immunity (FPTI) was determined in the calves (n = 100) through assessment of their serum levels of total protein (TP). For this, blood was collected through jugular venipuncture, between 24 and 48 hours of life, using a vacuum system and tubes, without any anticoagulant (Vacuplast CRAL, São Paulo, Brazil). After collection, the samples were centrifuged for 10

minutes at a speed of 2183 x g to obtain the serum, and analyzed in an optical refractometer. To determine the occurrence of FPTI, the parameter of 5.5 g/dL was used as a cutoff point, as determined by BUCZINSKI et al. (2018).

Occurrence of diseases

All calves were monitored daily by the responsible Veterinarian of the study, from birth to 80 days of life, in order to diagnose diarrhea, respiratory, or other diseases (bloat, tick fever, and omphalophlebitis). For the determination of the presence of diarrhea, the feces were classified on a scale from 0 to 4 according to the methodology recommended (TEIXEIRA et al., 2015), with score 0 characterized as normal feces and score 4 characterized as profuse diarrhea, with watery and bloody feces. Whenever calves had a feces score ≥ 2, they were characterized to be suffering from diarrhea. Diagnosis of respiratory diseases was performed according to LOVE et al. (2014). Other than the cases of diarrhea and bronchopneumonia, the remaining diseases that occurred during the experimental period were all classified as "other diseases", and included cases of omphalophlebitis, ruminal tympany, and bovine parasitic sadness. The diseases were treated in accordance with the protocol determined by the farm Veterinarian, which was similar for both groups.

Based on the records, it was possible to determine: Morbidity (number of animals that became sick divided by the total number of animals), mortality (number of animals that died divided by the total number of animals), lethality (number of animals that died divided by the number of animals that had the disease), and recurrence (number of animals that had two or more diarrhea attacks over the course of the study).

Zootechnical assessments

The zootechnical evaluations were carried out on 41 randomly selected calves (Control: 22; HBW: 19). Body weight was determined at birth (between 24–48 hours), weekly, until 30 days of age, followed by evaluations on days 42, 60, and 80. Calf weights were estimated using a heart girth tape graduated in kilograms, placed vertically behind the forelimb (WOOD et al., 2015). The thoracic perimeter, withers height and width of the rump were measured using a tape measure. Assessments were performed weekly, up to 30 days of life (including birth), followed by the last assessment at 60 days. From the body weight assessment, the average daily gain (ADG) was determined.

Biochemical analysis

Total plasma proteins, albumin, triglycerides, cholesterol, and urea concentrations, as well as the activity of enzymes gamma-glutamyl transfererase (GGT), paraoxonase 1 (PON1), aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP) were evaluated in the same 41 calves (Control: 22; HBW: 19). For this purpose, blood was collected using a Vacutainer system and tubes, without anticoagulant (Vacuplast CRAL, São Paulo, Brazil), via the jugular vein, at the following times: At birth (between 24 and 48 hours) and on days 7, 14, 21, 28, and 60. All collections were performed in the morning, before food intake. After blood collection, all the samples were sent to the laboratory, centrifuged at 2183 x g, and immediately frozen for further analysis. Except for PON1, all samples were analyzed in an automatic biochemical analyzer Labmax Plenno (Labtest Diagnostica, Minas Gerais, Brazil) using commercial colorimetric kits from the same company. The procedures were performed according to the manufacturer's recommendation. To determine PON1 activity, a previously described protocol was used (BROWNE et al., 2007).

Statistical analysis

Body weight, thoracic perimeter, withers height, width of the croup, and biochemical results were analyzed, using the Analysis of Variance (ANOVA), with repeated measures, followed by the Tukey–Kramer multiple comparison test, considering the group, time of collection, and their interactions as fixed effects, and the animal as random effect. Data that did not have a normal distribution were transformed to log10 (i.e., PON1, GGT, and cholesterol).

Categorical variables such as FPIT, morbidity, mortality, lethality, and disease recurrence were assessed using the Chi-square test. The data obtained were analyzed using the NCSS 97 Statistical Program, being considered significant when $P < 0.05$. The relative risk was calculated (incidence in the HBW group/incidence in the control group) using a 95% confidence interval. Values were described as mean ± standard error.

RESULTS

There were no differences on failure in transfer of passive immunity between the Control and HBW groups (FPIT: 4.1% and 6.0%, respectively, $P = 0.66$). For both diarrhea and respiratory disease, there were no differences in morbidity between the

Control and HBW groups (P > 0.05). The general mortality rate was higher in HBW (P = 0.01). Calves in the HBW group were eight times more likely to die when compared with those in the Control group (RR: 8; 95% CI: 1.03–61.6; P = 0.01), and 3.4 times more likely to present other diseases (omphalophlebitis, ruminal tympany, and bovine parasitic sadness; RR: 3.4; 95% CI: 1.3–8.5; P = 0.004) (Table 1).

ADG showed interaction (Group*time, P = 0.01), and on day 80, the ADG of the Control group was lower than that of the HBW group (1.12 ± 0.05 vs. 1.38 ± 0.05 kg, P < 0.05); furthermore, the effect of time (P < 0.001) was observed. As expected, the body weight was higher in the HBW group every time it was evaluated (P < 0.05). The body weight and thoracic perimeter showed interaction (Group*Time, P < 0.001), effect of group (P < 0.001) and time (P < 0.001). The HBW group showed a higher weight and greater thoracic perimeter than the Control group every time they were evaluated (P < 0.05) (Figure 1).

The mean concentrations of total protein, albumin, globulins, AST, ALT, ALP, GGT, cholesterol, triglycerides, urea, and PON1, were not different between the HBW and Control groups during the evaluated period (P > 0.05, Table 2).

DISCUSSION

We investigated the hypothesis that IVF calves born with greater body weight were more susceptible to developing diseases. Surprisingly, there were no differences in the occurrence of diarrhea and respiratory disease. However, although, there is no chance of a higher incidence of illness, calves born with a birth weight greater than 35 kg were more likely to die.

The relationship between the calves' birth weight and survival, and the incidence of disease and zootechnical performance have been evaluated in a few studies. There is evidence that high birth weight is associated with perinatal mortality in calves (JOHANSON & BERGER, 2003), with a great economic impact (MEYER et al., 2001). Very heavy calves at birth can predispose cows to various degrees of dystocia; consequently, leading to other perinatal changes such as neonatal asphyxia, reduced immunoglobulin absorption, and increased susceptibility to diseases (JACOBSEN et al., 2000). IVF may be linked to the birth of heavier calves, and also may be associated with an increase in mortality (CAMARGO et al., 2010; BONILLA et al., 2014) corroborating the obtained results; although, we did not observe a high rate of FPTI.

According to BLOCK et al. (2003), 18% of calves born following embryo transfer using *in vitro* production were born dead or died within 24 hours of birth. Other studies have also reported increased incidence of stillbirths and neonatal mortality, ranging from 7.8% to 22.2% in calves obtained via IVF (KRUIP & DEN DAAS, 1997; NUMABE et al., 2000; VAN WAGTENDONK-DE LEEUW et al., 2000; BONILLA et al., 2014), which is in accordance with the 9% reported in this experiment. However, results demonstrated that not only IVF, but the birth weight of the calves produced by IVF can influence mortality. In this study, calves that were born with bodyweight > 35 kg had a higher mortality rate and were eight times more likely to die when compared to

Table 1 - Incidence and relative risk of diseases in Girolando calves conceived through *in vitro* fertilization with high birth weight.

	Total	Control	HBW	Relative risk	95%CI[1]	P value
Diarrhea morbidity	77.0%	76% (38/50)	78% (39/50)	1.0	0.8-1.2	0.812
Diarrhea recurrence	24.6%	23.6% (9/38)	25.6% (10/39)	1.1	0.4-2.3	0.842
Diarrhea mortality	3.0%	2.0% (1/50)	4.0% (2/50)	2.0	0.1-21.3	0.557
Diarrhea lethality	3.9%	2.6% (1/38)	5.1% (2/39)	1.9	0.2-20.6	0.606
Pneumonia morbidity	28.0%	24.0% (12/50)	32.0% (16/50)	1.3	0.7-2.5	0.339
Pneumonia mortality	3.0%	0.0% (0/50)	6.0% (3/50)	*	*	0.075
Pneumonia lethality	10.7%	0.0% (0/12)	18.7% (3/16)	*	*	0.147
Other diseases	22.0%	10.0% (5/50)[b]	34.0% (17/50)[a]	3.4	1.3-8.5	0.003
General mortality	9.0%	2.0% (1/50)[b]	16.0% (8/50)[a]	8.0	1.1-61.6	0.014

Control: constituted by calves that were born weighing ≤ 35 kg; HBW: calves that were born weighing more than 35 kg. Results obtained from the chi-square test, the differences being considered significant when P < 0.05. *Insufficient percentage to estimate the relative risk of diseases; [1]95% confidence interval.

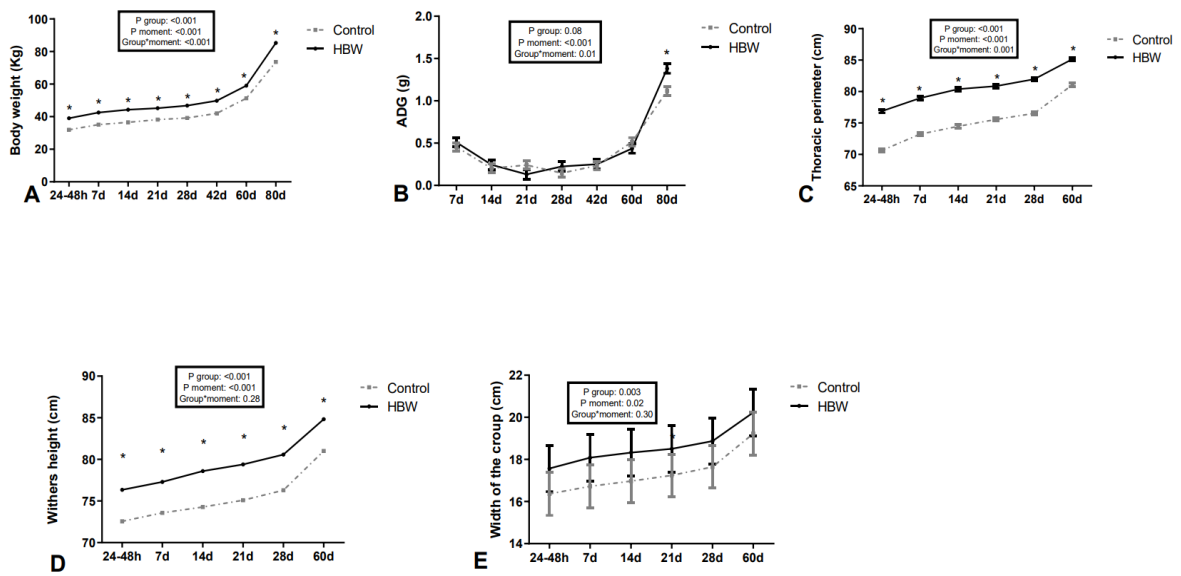

Figure 1 - Average weight (A), average daily gain (B), thoracic perimeter (C), withers height (D) and width of the croup (E) from birth to 60 or 80 days of age in Girolando calves conceived through *in vitro* fertilization and born with weight of 35 kg or less (Control) or with more than 35 kg (HBW).

*Moments when there was a significant difference ($P < 0.05$).

control calves. Despite this, there were no differences in the occurrence of diarrhea and respiratory disease between the Control and HBW groups, but there were a greater number of cases of other diseases, such as, omphalophlebitis, tympany, and bovine parasitic sadness. Between these diseases, the omphalophlebitis can be caused by structural changes in the navel, which are reported in individuals obtained through IVF (LARCHER et al., 2023), facilitating the entry of pathogens into the blood circulation and thus contributing to high mortality. Also, tympany may be associated with failure of the reticular groove reflex in very large calves with a low sucking reflex (BIRGEL JUNIOR, et al., 2011), as well as, macroglossia (enlarged tongue) which is a characteristic of LOS (CHEN et al., 2013), causes feeding difficulties, and thus contributing to mortality. Still, anaemia and other blood- and plasma-related conditions (erythrocyte and haemoglobin decrease), which are observed in calves obtained by reproductive biotechniques (MEIRELLES et al., 2009), may have contributed to the high morbidity due to bovine parasitic sadness and deaths.

It is known that satisfactory ingestion of high-quality colostrum is essential to protect neonates against pathogens during their first weeks of life (CHASE et al., 2008), as it increases the mechanisms of defense in the neonate (CORTESE, 2009). In this study, there was no difference between groups in the percentage of animals that presented with FPIT, therefore, the highest number of deaths in heavy calves cannot be credited to this. Over the 80 days of the study, we found a diarrhea morbidity of 77%, very similar to those 77.9% reported by WEILLER et al. (2020). The results are within the expected for the Brazilian reality (53.6–100%) (LANGONI et al., 2004).

Despite the high weight-related mortality, those animals that do not die perform better, as seen by greater weight gain, thoracic perimeter, and height. Directly related to puberty, age at first calving, and the higher productivity of the future cow, the females bovine growth is an important characteristic within the farm system (SHIVLEY et al., 2018). The relationship between birth weight and animal performance has been assessed in some studies. YAYLAK et al. (2015), using Holstein animals, demonstrated that the weaning weight was directly influenced by the animals' birth weight. In this context, animals that were born heavier also remained heavier for at least the first 15 life months (SWALI & WATHES, 2006). This was also observed in our

Table 2 - Biochemical parameters during the first 60 days of life of Girolando calves conceived through *in vitro* fertilization with high birth weight.

Parameter	Control	HBW	P group*time	P time†	P group
TPP[1] (g/dL)	6.28 ± 0.16	6.32 ± 0.18	0.291	<0.001	0.854
Albumin (g/dL)	2.75 ± 0.05	2.75 ± 0.05	0.686	<0.001	0.944
Globulin (g/dL)	3.44 ± 0.17	3.21 ± 0.18	0.238	<0.001	0.884
AST[2] (U/L)	39.30 ± 1.19	39.74 ± 1.32	0.863	<0.001	0.808
ALT[3] (U/L)	20.68 ± 1.05	19.57 ± 1.17	0.218	<0.001	0.485
GGT[4] (U/L)	295.65 ± 38.28	300.29 ± 42.88	0.897	<0.001	0.384
ALP[5] (U/L)	243.63 ± 15.46	235.46 ± 17.24	0.346	<0.001	0.726
Paraoxonase 1 (U/mL)	27.71 ± 2.60	22.96 ± 2.90	0.079	<0.001	0.431
Triglycerides (mg/dL)	21.34 ± 1.31	20.73 ± 1.46	0.977	<0.001	0.757
Cholesterol (mg/dL)	89.33 ± 4.36	91.22 ± 4.88	0.655	<0.001	0.852
Urea (mg/dL)	19.08 ± 1.16	19.70 ± 1.30	0.890	<0.001	0.727

Control: constituted by calves that were born weighing ≤ 35 kg; HBW: calves that were born weighing more than 35 kg. Data are represented by the mean ± standard error of the mean. Values of $P < 0.05$ were considered significant. † Time: collection realized at birth (between 24 and 48 hours) and on days 7, 14, 21, 28, and 60.
[1]TPP:Total plasma protein; [2]AST: Aspartate aminotransferase; [3]ALT:Alanine aminotransferase; [4]GGT: Gama glutamyl transferase; [5]ALP: Alkaline phosphatase.

study, where calves that were born heavier remained heavier throughout all assessments, as also those that were born taller, remained taller all times. Calves in this study had a medium birth weight greater than the one found by ALASSANE et al. (2018), in a study conducted in Africa, in which the birth weight of the Girolando females was 25.96 ± 0.70 kg, and heavier than 29.57 ± 4.4 kg, reported by OLIVEIRA & NOGUEIRA (2006), in Girolando calves. However, in this study, the authors did not specify the degree of blood Holstein–Gir.

FEUER et al. (2016) demonstrated that conception by IVF can reprogram metabolic homeostasis through metabolic, transcriptional, and epigenetic mechanisms, with lasting effects on adult growth. The reasons for the differences in mortality need to be clarified, as our study found no changes in different biochemical parameters between the two groups.

CONCLUSION

The results obtained in the current research allow us to conclude that Girolando calves from IVF that born heavier have a greater chance of the present diseases, such as, omphalophlebitis, tympany, and bovine parasitic sadness, and a higher general mortality rate. However, birth weight does not influence diarrhea or pneumonia, morbidity or mortality, the zootechnical performance, or metabolism of the animals.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the design and writing of the manuscript. All authors critically reviewed the manuscript and approved the final version.

BIOETHICS AND BIOSECURITY COMMITTEE APPROVAL

All procedures performed in the study involving animals followed the ethical standards of the Ethics Committee on Animal Experimentation (CEEA) at the Universidade Federal de Pelotas (UFPel), Pelotas, RS, Brazil, under registration number 14807.

REFERENCES

ALASSANE, Y. et al. Zootechnical performance of Girolando cattle at Kpinnou breeding farm, South-West of Benin Republic. **Journal of Advanced Veterinary and Animal Research** v.5, p.123-130, 2018. Available from: <https://www.banglajol.info/index.php/JAVAR/article/view/37156>. Accessed: Nov. 07, 2022. doi: 10.5455/javar.2018.e255.

BERTOLINI, M. et al. Evidence of increased substrate availability to in vitro-derived bovine foetuses and association with accelerated conceptus growth. **Reproduction**, v.128, p.341-354, 2004. Available from: <https://pubmed.ncbi.nlm.nih.gov/15333785/>. Accessed: Nov. 07, 2022. doi: 10.1530/rep.1.00188.

BIRGEL JUNIOR, E. H. et al. Clinical disorders observed during the first 30 days of life of cloned Zebu calf. **Acta Scientiae Veterinariae**, v.39 (Suppl 1), p.s243 - s252, 2011. Available from: <https://www.redalyc.org/pdf/2890/289060016030.pdf>. Accessed: Sep. 15, 2023.

BLOCK, J. et al. Use of insulin-like growth factor-I during embryo culture and treatment of recipients with gonadotropin releasing hormone to increase pregnancy rates following the transfer of in vitro produced embryos to heat-stressed, lactating cows. **Journal of Animal Science**, v.81, p.1590-1602, 2003. Available from: <https://pubmed.ncbi.nlm.nih.gov/12817508/>. Accessed: Nov. 07, 2022. doi: 10.2527/2003.8161590x.

BONILLA, L. et al. Consequences of transfer of an in vitro-produced embryo for the dam and resultant calf. **Journal of Dairy Science,** v.97, p.229-239, 2014. Available from: <https://pubmed.ncbi.nlm.nih.gov/24210495/>. Accessed: Nov. 07, 2022. doi: 10.3168/jds.2013-6943.

BROWNE, R. W. et al. Accuracy and biological variation of human serum paraoxonase 1 activity and polymorphism (Q192R) by kinetic enzyme assay. **Clinical Chemistry**, v. 53, p.310-317, 2007. Available from: <https://pubmed.ncbi.nlm.nih.gov/17185369/>. Accessed: Nov. 07, 2022. doi: 10.1373/clinchem.2006.074559.

BUCZINSKI S. et al. systematic review and meta-analysis of diagnostic accuracy of serum refractometry and brix refractometry for the diagnosis of inadequate transfer of passive immunity in calves. **Journal of Veterinary Internal Medicine**, v.32, p.474–483. 2018. Available from: <https://pubmed.ncbi.nlm.nih.gov/29210105/>. Accessed: Apr. 03, 2023. doi: 10.1111/jvim.14893.

CAMARGO, L. S. A. et al. Gestation length, birth weight and offspring gender ratio of in vitro produced Gyr (Bos indicus) cattle embryos. **Animal Reproduction Science**, v.120, p.10-15, 2010. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0378432010000485>. Accessed: Nov. 07, 2022. doi: 10.1016/j.anireprosci.2010.02.013.

CHASE, C. C. L. et al. Neonatal immune development in the calf and its impact on vaccine response. **Veterinary Clinics of North America: Food Animal Practice**, v.24, p.87-104, 2008. Available from: <https://pubmed.ncbi.nlm.nih.gov/18299033/>. Accessed: Nov. 07, 2022. doi: 10.1016/j.cvfa.2007.11.001.

CHEN, Z. et al. Large offspring syndrome: a bovine model for the human loss-of-imprinting overgrowth syndrome Beckwith-Wiedemann. **Epigenetics**, v.8, p.591–601, 2013. Available from: <https://www.tandfonline.com/doi/full/10.4161/epi.24655>. Accessed: May, 10, 2023. doi: 10.4161/epi.24655.

CORTESE, V. S. Neonatal immunology. **Veterinary Clinics of North America: Food Animal Practice**, v.25, p.221-227, 2009. Available from: <https://pubmed.ncbi.nlm.nih.gov/19174291/>. Accessed: Nov. 07, 2022. doi: 10.1016/j.cvfa.2008.10.003.

GLOVER, I. D. et al. Little association between birth weight and health of preweaned dairy calves. **Veterinary Record**, v.184, p.477-477, 2019. Available from: <https://pubmed.ncbi.nlm.nih.gov/30824602/>. Accessed: Nov. 07, 2022. doi: 10.1136/vr.105062.

JACOBSEN, H. et al. Ease of calving, blood chemistry, insulin and bovine growth hormone of newborn calves derived from embryos produced in vitro in culture systems with serum and co-culture or with PVA. **Theriogenology**, v.54, p.147-158, 2000. Available from: <https://pubmed.ncbi.nlm.nih.gov/10990356/>. Accessed: Nov. 07, 2022. doi: 10.1016/S0093-691X(00)00333-2.

JOHANSON, J. M.; BERGER, P. J. Birth weight as a predictor of calving ease and perinatal mortality in Holstein cattle. **Journal of Dairy Science**, v.86, p.3745-3755, 2003. Available from: <https://www.sciencedirect.com/science/article/pii/S0022030203739812>. Accessed: Nov. 07, 2022. doi: 10.3168/jds.S0022-0302(03)73981-2.

KRUIP, T. A. M.; DEN DAAS, J.H.G. In vitro produced and cloned embryos: effects on pregnancy, parturition and offspring. **Theriogenology**, v.47, p.43-52, 1997. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0093691X9600338X>. Accessed: Nov. 07, 2022. doi: 10.1016/S0093-691X(96)00338-X.

LANGONI, H. et al. Contribution to the study of diarrhea etiology in neonate dairy calves in São Paulo state, Brazil. **Brazilian Journal of Veterinary Research and Animal Science**, v.41, p.313-319, 2004. Available from: <https://www.scielo.br/j/bjvras/a/gtGGmsrzSjGBBDSRvdQCQsn/?format=pdf&lang=en>. Accessed: Nov. 07, 2022. doi: 10.1590/S1413-95962004000500004.

LARCHER, L. et al. Ultrasound diagnosis of placental and umbilical cord anomalies in singleton pregnancies resulting from in-vitro fertilization. **Placenta**, v.131, p.58-64, 2023. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0143400422004672>. Accessed: Sep. 15, 2023. doi: 10.1016/j.placenta.2022.11.010.

LI, Y. et al. Overgrowth syndrome. **The Veterinary Clinics of North America. Food Animal Practice**, v.35, p.265-276, 2019. Available from: <https://pubmed.ncbi.nlm.nih.gov/31103180/>. Accessed: May, 21, 2023. doi: 10.1016/j.cvfa.2019.02.007.

LOVE, W. J. et al. Development of a novel clinical scoring system for on-farm diagnosis of bovine respiratory disease in pre-weaned dairy calves. **PeerJ**, v.2, e238, 2014. Available from: <https://pubmed.ncbi.nlm.nih.gov/24482759/>. Accessed: Nov. 07, 2022. doi: 10.7717/peerj.238.

MEIRELLES, F. V. et al. Delivery of cloned offspring: experience in Zebu cattle (Bos indicus). **Reproduction, Fertility and Development**, v. 22, p. 88–97, 2009. Available from: <https://www.publish.csiro.au/rd/rd09229>. Accessed: Sep. 15, 2023. doi: 10.1071/RD09229.

MEYER, C. L. et al. Phenotypic trends in incidence of stillbirth for holsteins in the United States. **Journal of Dairy Science**, v.84, p.515-523, 2001. Available from: <https://pubmed.ncbi.

nlm.nih.gov/11233037/#:~:text=The%20percentage%20of%20stillborn%20calves,6.6%25%20from%201985%20to%201996.>. Accessed: Nov. 07, 2022. doi: 10.3168/jds.S0022-0302(01)74502-X.

NUMABE, T. et al. Birth weight and birth rate of heavy calves conceived by transfer of in vitro or in vivo produced bovine embryos. **Animal Reproduction Science,** v.64, p.13-20, 2000. Available from: <https://pubmed.ncbi.nlm.nih.gov/11078963/>. Accessed: Nov. 07, 2022. doi: 10.1016/S0378-4320(00)00190-1.

OLIVEIRA, D. J. C.; NOGUEIRA, G. P. Curvas de crescimento de bezerros da raça girolando. **Arquivos de Ciências Veterinárias e Zoologia UNIPAR**, v.9, p.1-6, 2006. Available from: <https://revistas.unipar.br/index.php/veterinaria/article/view/31#:~:text=As%20m%C3%A9dias%20observadas%20em%20machos,118%C2%B17%2C93%20cm>. Accessed: Nov. 07, 2022.

PAPUTUNGAN, U. et al. Effects of sire birth weight on calving difficulty and maternal performance of their female progeny. **Asian Australasian Journal of Animal Sciences**, v.13, p.729-732, 2000. Available from: <https://koreascience.kr/article/JAKO199923443163822.page>. Accessed: Nov. 07, 2022. doi: 10.5713/ajas.2000.729.

SCHILD, C. O. et al. A survey of management practices that influence calf welfare and an estimation of the annual calf mortality risk in pastured dairy herds in Uruguay. **Journal of Dairy Science**, v.103, p.9418-9429, 2020. Available from: <https://pubmed.ncbi.nlm.nih.gov/32773303/>. Accessed: Apr. 03, 2023. doi: 10.3168/jds.2020-18177.

SHIVLEY, C. B. et al. Preweaned heifer management on US dairy operations: Part VI. Factors associated with average daily gain in preweaned dairy heifer calves. **Journal of Dairy Science**, v.101, p.9245-9258, 2018. Available from: <https://www.sciencedirect.com/science/article/pii/S0022030218305149>. Accessed: Nov. 07, 2022. doi: 10.3168/jds.2017-14022.

SIQUEIRA, L. G. B. et al. Pregnancy rates and corpus luteum–related factors affecting pregnancy establishment in bovine recipients synchronized for fixed-time embryo transfer. **Theriogenology**, v.72, p.949-958, 2009. Available from: <https://pubmed.ncbi.nlm.nih.gov/19709722/>. Accessed: Nov. 07, 2022. doi: 10.1016/j.theriogenology.2009.06.013.

SWALI, A.; WATHES, D. C. Influence of the dam and sire on size at birth and subsequent growth, milk production and fertility in dairy heifers. **Theriogenology**, v.66, p.1173-1184, 2006. Available from: <https://pubmed.ncbi.nlm.nih.gov/16647111/>. Accessed: Nov. 07, 2022. doi: 10.1016/j.theriogenology.2006.03.028.

TEIXEIRA, A. G. V. et al. Effect of crofelemer extract on severity and consistency of experimentally induced enterotoxigenic Escherichia coli diarrhea in newborn Holstein calves. **Journal of Dairy Science**, v.98, p.8035-8043, 2015. Available from: <https://pubmed.ncbi.nlm.nih.gov/26298758/>. Accessed: Nov. 07, 2022. doi: 10.3168/jds.2015-9513.

VAN WAGTENDONK-DE LEEUW, A. M. et al. Effects of different reproduction techniques: AI, MOET or IVP, on health and welfare of bovine offspring. **Theriogenology**, v.53, p.575-597, 2000. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S0093691X99002599>. Accessed: Nov. 07, 2022. doi: 10.1016/S0093-691X(99)00259-9.

VARAGO, F. C. et al. Produção in vitro de embriões bovinos: estado da arte e perspectiva de uma técnica em constante evolução. **Revista Brasileira de Reprodução Animal**, v.32, p.100-109, 2008. Available from: <http://cbra.org.br/portal/publicacoes/rbra/2008/rbraaj2008.html>. Accessed: Nov. 07, 2022.

VIANA, J. Statistics of embryo production and transfer in domestic farm animals. **Embryo Technology Newsletter**, v.36, p.8-25, 2019. Available from: <https://www.iets.org/Portals/0/Documents/Public/Committees/DRC/IETS_Data_Retrieval_Report_2019.pdf>. Accessed: Nov. 07, 2022.

WEILLER, M. A. A. et al. The occurrence of diseases and their relationship with passive immune transfer in Holstein dairy calves submitted to individual management in southern Brazil. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia,** v.72, p.24-30, 2020. Available from: <https://www.scielo.br/j/abmvz/a/v8RtgSpzMKbsjd9TgD3scnG/>. Accessed: Nov. 07, 2022. doi: 10.1590/1678-4162-11482.

WEILLER, M. A. A. et al. Zootechnical and health performance of Holstein x Gir crossbred calves. **Tropical Animal Health and Production**, v.53, p.1-9, 2021. Available from: <https://pubmed.ncbi.nlm.nih.gov/33543399/>. Accessed: Nov. 07, 2022. doi: 10.1007/s11250-021-02601-w.

WILDMAN, E. E. et al. A dairy cow body condition scoring system and its relationship to selected production characteristics. **Journal of Dairy Science**, v.65, p.495-501, 1982. Available from: <https://www.sciencedirect.com/science/article/pii/S0022030282822236>. Accessed: May, 21, 2023. doi: 10.3168/jds.S0022-0302(82)82223-6.

WOOD, S. et al. Comparison of visual assessment and heart girth tape measurement for estimating the weight of cattle in clinical practice. **The Veterinary Journal**, v.203, p.337-338, 2015. Available from: <https://pubmed.ncbi.nlm.nih.gov/25648775/>. Accessed: Nov. 07, 2022. doi: 10.1016/j.tvjl.2014.12.034.

YAYLAK, E. et al. Some environmental factors affecting birth weight, weaning weight and daily live weight gain of Holstein calves. **Turkish Journal of Agriculture-Food Science and Technology**, v.3, p.617-622, 2015. Available from: <http://www.agrifoodscience.com/index.php/TURJAF/article/view/392>. Accessed: Nov. 07, 2022. doi: 10.24925/turjaf.v3i7.617-622.392.