Turkish Journal of Veterinary and Animal Sciences

http://journals.tubitak.gov.tr/veterinary/

Research Article

Turk J Vet Anim Sci
(2023) 47: 34-41
© TÜBİTAK
doi:10.55730/1300-0128.4266

Influence of temperature-humidity index, calf sex, and parity on gestation length in Holstein cows

Lazoumi OUARFLI[1,2,*], **Abdelmadjid CHEHMA**[3]

[1]Department of Agricultural Sciences, Faculty of Natural and Life Sciences and Earth Sciences, University of Ghardaia, Algeria
[2]Laboratory for the Valorization and Conservation of Arid Ecosystems, Ghardaia, Algeria
[3]Laboratory of Saharan Bio-Resources Preservation and Valorization, University of Kasdi Merbah, Algeria

Received: 21.07.2022 • **Accepted/Published Online:** 08.01.2023 • **Final Version:** 10.02.2023

Abstract: The present study aimed to analyse the gestation length (GL) variability in locally born purebred Holstein dams (n = 1047), in a private farm, under Saharan climate. The overall GL mean was 278.73 ± 6.67 days. A general linear model revealed that the GL was significantly affected by calf sex ($p = 0.035$) with a minor increase of 0.19% in males, dam parity ($p = 0.016$) and calving season ($p < 0.0001$) including the shortest lengths recorded in heifers and during heat stress period. Moreover, a negative regression (–1.96%) in recent years was recorded in GL by the influence ($p = 0.01$) of years of birth, breeding, and calving of cows. Our findings show that cows that were inseminated and gave birth during the cold season (temperature-humidity index, THI < 74) had 11.54 days longer ($p = 0.048$) gestation period compared to animals that were inseminated and gave birth during the hot season (THI > 84). Similarly, the association ($p = 0.003$) between dam parity and calf sex revealed that the GL of multiparous cows that gave birth to male calves was higher (3.07 days) than that of male calves from heifers. The findings can contribute to a better understanding of the environmental and animal factors association's effects on GL in Holstein cows under hyperarid zone and assisting in the adequate management of pregnant females.

Key words: Temperature-humidity-index, calf sex, parity, cow, gestation length

1. Introduction

Gestation length (GL) is a physiological trait characteristic of the species and breed and important for foetal and mammary gland development [1]. Furthermore, GL is defined as the interval from conception to subsequent parturition [2], and it is closely related to the reproductive period [3], while affecting the productive and reproductive performance of cattle. The accurate prediction of parturition can help dairy farmers to comply with the specific nutritional, health, and management needs of pregnant females during gravidity [2].

Previous studies indicated that high summer temperatures can accelerate calving and shorten GL [4,1]. Tao and Dahl [5] also reported that shortened GL and low birth weight were due to heat stress, which compromised placental development and led to foetal hypoxia, malnutrition, and foetal growth retardation. In addition, Tomasek et al. [6] and Haile-Mariam and Pryce [7] confirmed that the GL is shorter in nulliparous than in multiparous dams. Furthermore, male calves are carried 1–2 days longer than female calves [7]. In addition, single calving is associated with a longer GL than twin calving [8].

The purpose of this investigation was to explore the relationship between temperature-humidity index, parity, and calves' sex, and gestation length in Holstein cattle born and reared in northern Algerian Sahara.

2. Materials and methods

No ethical approval was obtained because this study only involved data collection from the farm manager.

2.1. Animal and herd management

Data for this study were gathered from 1047 Holstein dairy cows in the Ghardaia region (32° 41′ 06.7″ N latitude and 4° 44′ 10.8″ E longitude), over a period of 22 years (January 1995 to December 2017). The cows were housed in a free-stall building, including a bedding area where cows can ruminate and rest, and a shaded area (metal roofs) of 15 m^2 per head, whereas the calving area (20 m^2 of the free space per cow provided) had straw bedding. Otherwise, a total mixed ration (TMR) offered to animals, consisting of roughage and commercial concentrate feed (ratio: 40%; 60%), the dry matter consumed (23 kg), total energy (34.56 Mcal), protein intake (2190 g), and a total of DM% (40%), was fed to all the animals involved in the study.

* Correspondence: lazoumi.ouarfli@univ-ghardaia.dz

This work is licensed under a Creative Commons Attribution 4.0 International License.

Heifers were bred at the age of 18.7 months; thus, the first calvings were at the age of 28.8 months. The reproductive traits of females are shown in Table 1. The mean service period, open days, days from first to last AI, and calving interval were 80, 143, 63, and 419 days, respectively. In addition, the overall conception rate was 33.5%, and animals were inseminated 1.87 times in average until pregnancy.

All females (n = 1047) were free of tuberculosis and brucellosis. A total of 976 females (heifers = 291, primaparous = 215 and multiparous = 470) were inseminated 12 h after the detection of oestrus by the farm manager. Seventy-one animals (heifers = 21, primaparous = 19, and multiparous = 31) were inseminated by using an intramuscular injection of 100 µg of GnRH (i.e., 2 ml of CYSTORELINE® solution) at D0, 25 mg of PGF2α (i.e. 5 mL of DINOPROST® solution) 7 days later, and GnRH 48 h after the PGF2α injection, and AI occurred 16–18 h after the GnRH injection.

Pregnancy was diagnosed by transrectal palpation after day 45 of pregnancy, or using ultrasonography (ultrasound scanner "My-A001-N" made in China by Guangzhou Maya Equipment Co., Ltd.) from day 25 to 30 of pregnancy by the farm veterinarian.

2.2. Climatic factors

The equation describing the temperature and humidity index (THI) according to Mader et al. [9] is THI = (0.8 × AT°) + [(%RH / 100) (AT°-14.4)] + 46.4, where %RH represents relative humidity, and AT represents ambient temperature expressed in Celsius centigrade was used to describe climatic factors.

2.3. Statistical analysis

Statistical analyses were performed using Minitab® 18.1 (Minitab, Inc., in the United States and other countries). The normality of the dependent variable (GL) was tested using the Kolmogorov–Smirnov and Anderson-Darling tests, followed by the "Bonferroni" test for equality of variances and the "Levens" test for equality of error differences. The analysis of variance by the general linear model (GLM) procedure with a difference of $p < 0.05$ was considered statistically significant.

3. Results

3.1. Factors influencing gestation length

The study involved 1047 animals of which 312 heifers (29.80%), 234 primiparous (22.35%) and 501 multiparous (47.85%). Male calves were recorded in 49.37% of parturitions, female calves in 47.46% of cases, and twin calves in 3.15% of births. Out of twin calves, 36.36% were males, 18.18% were females, and 45.46% were of mixed sex. In our study 56% of animals were artificially inseminated during the THI < 74, 20.34%, 16.52% during the THI period (75 to 78), (79 to 83), respectively, and 7.35% during the THI season > 84, which resulted with 44.12% of calvings during the period of thermo-neutrality (THI < 74), 8.50%, 15.09% during the THI period (75 to 78), (79 to 83), respectively, and 32.28% of calvings during the severe thermal stress (THI > 84) (Table 2).

The GLM was used to analyse the relationship between GL of Holstein dams and variation factors. The minor difference (–0.55 days) of GL between the calf sexes was ($p = 0.035$). Following the dam parity, a significant increase ($p = 0.025$) in the GL was recorded in multiparous dams (+1.35 days). Interestingly, there were also substantial differences ($p = 0.0001$) in the GL of calves sired multiparous grand dams cows than primiparous grand dams cows of (+2.36 days). Furthermore, there was a high significant difference (+5.64 days, $p < 0.0001$) between the calving at THI < 74 and the calving at THI > 84. In addition, we found that the frequency of twin births and average GL according to dams parity (nulliparous, primiparous, and multiparous) as (6.06%, 18.18%, and 75.76%) and (270.5 ± 0.7 days, 270 ± 6.16 days, and 278.12 ± 9.24 days).

As shown in Figure 1, there was a significant difference in GL according to the variation of dam's birth year (1992–2014); ($p = 0.006$), dam's breeding year (1994–2017); ($p = 0.007$) and dam's calving year (1995–2016); ($p < 0.0001$) with an average difference of (–5.52 days), (–5.05 days),

Table 1. Effects of dam parity on some reproductive traits in Holstein dairy cows (1995–2017).

Reproductive traits	Dam parity		
	Nulliparous	Primiparous	Multiparous
Days from calving to 1stAI	/	82.7	79.6
Days from calving to last AI	/	150.5	139.8
Days from 1stAI to last AI	/	67.8	60.3
Calving interval	/	427	415
NAI/FAI	1.43	1.95	1.99
Conception rate (fecundate AI per number AI) (%)	54.21	30.75	27.26

Table 2. The fixed effects of THI, sex calf, dam and grand dam parity, breeding type and twinning on GL.

	N	Mean	StDev	95% CI (Lower ; Upper)	p-value
Calf sex					
Male	517	279.08	6.7	(278.51 ; 279.66)	0.035
Female	497	278.53	6.42	(277.95 ; 279.12)	
Twin	33	276.18	9.06	(273.91 ; 278.46)	
Dam parity					
Nulliparous	312	277.97	6.01	(277.23 ; 278.71)	0.016
Primiparous	234	278.49	6.53	(277.64 ; 279.34)	
Multiparous	501	279.32	7.07	(278.73 ; 279.90)	
THI at breeding					
< 74	584	278.96	6.91	(278.43 ; 279.51)	0.543
[75–78]	213	278.26	6.44	(277.36 ; 279.16)	
[79–83]	173	278.45	6.39	(277.45 ; 279.45)	
> 84	77	278.89	6.07	(277.40 ; 280.39)	
THI at calving					
< 74	462	281.32	5.97	(280.77 ; 281.88)	0.0001
[75–78]	89	281.45	5.71	(280.18 ; 282.71)	
[79–83]	158	276.16	5.77	(275.21 ; 277.11)	
> 84	338	275.68	6.45	(275.03 ; 276.33)	
Grand dam parity					
Multiparous dam	445	280.09	6.87	(279.48 ; 280.71)	0.0001
Primiparous dam	602	277.73	6.34	(277.20 ; 278.25)	
Breeding type					
EDAI	976	278.67	6.61	(278.252 ; 279.09)	0.255
TAI	71	279.61	7.48	(278.052 ; 281.16)	
Twin status					
Singleton	1014	278.82	6.57	(278.41 ; 279.23)	0.025
Twin	33	276.18	9.06	(273.91 ; 278.46)	

StDev: standard deviation, EDAI: AI on detected oestrus, TAI: timed artificial insemination

and (–3.9 days), i.e. an average regression per year of the order of (–1.96%), (–1.78%), and (–1.36%), respectively.

3.2. Factors' interaction effects on gestation length

It has been found (Figure 2) that the GLs of multiparous dams calved in season (THI<74), (THI = 75–78), (THI = 79–83), and (THI > 84) were higher (p = 0.053) than those recorded in the nulliparous dams in the order of (+ 8.51 days), (+ 8.51 days), (+ 8.51 days), and (+ 5.25 days), respectively. Furthermore, there was 1.8 days of increase of GL (p = 0.045) associated with multiparous dams inseminated by timed AI versus those inseminated on oestrus detection. However, a reduction of GL (–3.51 days) was observed in primiparous dams inseminated on oestrus detection compared with programmed AI. The interaction (p = 0.048) between THI at calving and THI at breeding effects on GL resulted an increase (+12.36 days) in cows inseminated and calved in (THI > 74) against those inseminated at (THI > 74) and calved at (THI = 79–83). Moreover, dams inseminated and calved in (THI < 84) had a longer GL (+7.02 days) than those inseminated at (THI < 84) and calved at (THI > 74).

In Figure 3, there was a clear trend of decrease (p = 0.003) in the GL of male calves from nulliparous dams (–3.07 days) comparing to the multiparous; similarly, the GLs of female calves were shorter than those born to multiparous cows (–2.55 days).

From the data in Figure 4, it was apparent that the GL of male calves sired multiparous grand dams (+ 2.86 days)

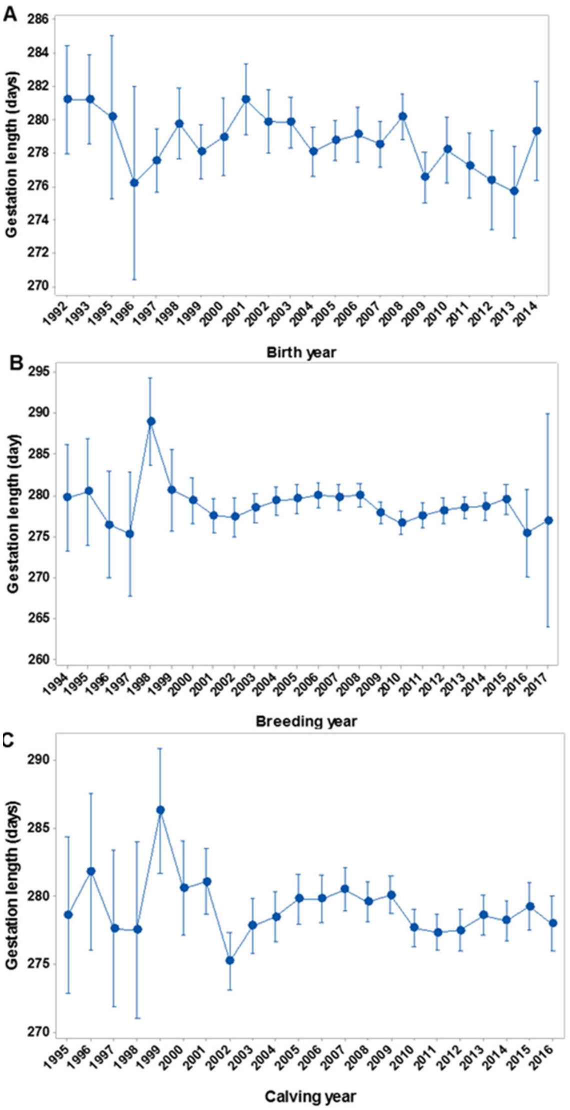

Figure 1. Interval plot of Holstein cow' GL for dam's birth year (A), dam's breeding year (B), and dam's calving year (C).

more than those issued from nulliparous grand dams, also, in female calves from multiparous grand dams (+ 1.44 days) versus those primiparous.

Otherwise, the GL of calves born from nulliparous, primiparous, and multiparous dams sired from multiparous cows were longer ($p = 0.026$) than those sired from primiparous dams in the order of +1.03 days, +2.09 days, and +3.15 days, respectively.

4. Discussion

The current study found that the average GL of Holstein females (278.73 days) was similar to that reported by Kašná et al. [10]. However, it was higher than those recorded by Vieira-Neto et al. [1] (+ 2.73 days) and Scanavez and Mendonça [11] (+ 3.83 days). Moreover, it was slightly lower than those found by Sobek et al. [12] (–1.17 days) and Kamal et al. [13] (–1.27 days).

4.1. Effect of THI at breeding on gestation length

In this study, the THI at breeding did not show any significant effect on the GL. Fifty-six percent of fecundate inseminations occurred in the period (THI < 74) between November and March. This outcome is contrary to that of Norman et al. [2], who found that the Holstein females inseminated in the first half of the year had a longer GL. This result may be explained by the fact that environmental changes in the temperate zone might affect GL more than in the subtropical zone [6]. Similarly, Hansen [14] claimed that embryo survival does not depend on maternal heat stress beyond the 7th day of pregnancy. Hence, it could conceivably be hypothesised that there are the deleterious photoperiodic effects on endocrine function in cattle [15]. In particular, high circulating progesterone (P4) concentrations shortly after conception are associated with increased conceptus growth in dairy and beef cattle [16]. However, low concentrations of (P4) can also lead to implantation failure [17]. Plasma (P4) concentrations can be increased or decreased depending on whether the heat stress is acute or chronic and on the metabolic state of the animal [18]. The present study raises the possibility that heat stress had no effect on plasma (P4) concentrations [19], which is contrary to Ronchi et al. [20], who reported that plasma (P4) concentrations were lower in heat-stressed Holstein heifers.

4.2. Effect of THI at calving on gestation length

The most interesting finding was that the decreasing in GL of Holstein dams (nulliparous, primiparous, and multiparous) calved during the warm season (THI > 84), These results were in good agreement with other studies conducted in temperate zones [21,6], which have shown that the calving at hot periods had a negative correlation with the GL. This consistency may be because the climate and food availability were favourable for the survival and growth of many wild bovine species' offspring in their natural habitat under temperate conditions [22]. It seems possible that these results are due to the inability of the developing foetus to control its body temperature independently of the mother [23]. Therefore, the reducing of GL by a few days during heat stress shortens the period of rapid foetal growth, resulting in reduced birth weight [24]. Thus, calves from heat-stressed dams had lower weaning weights. According to these data, we can infer that the calves undergoing heat stress in utero are likely to have a smaller adult body size and higher fat reserves [24]. Furthermore, Vieira-Neto et al. [1] relied on the possibility that heat stress promotes the maturation of the hypothalamic-pituitary-adrenal axis and the release of cortisol by the foetus, leading to earlier calving compared to cool-season calving.

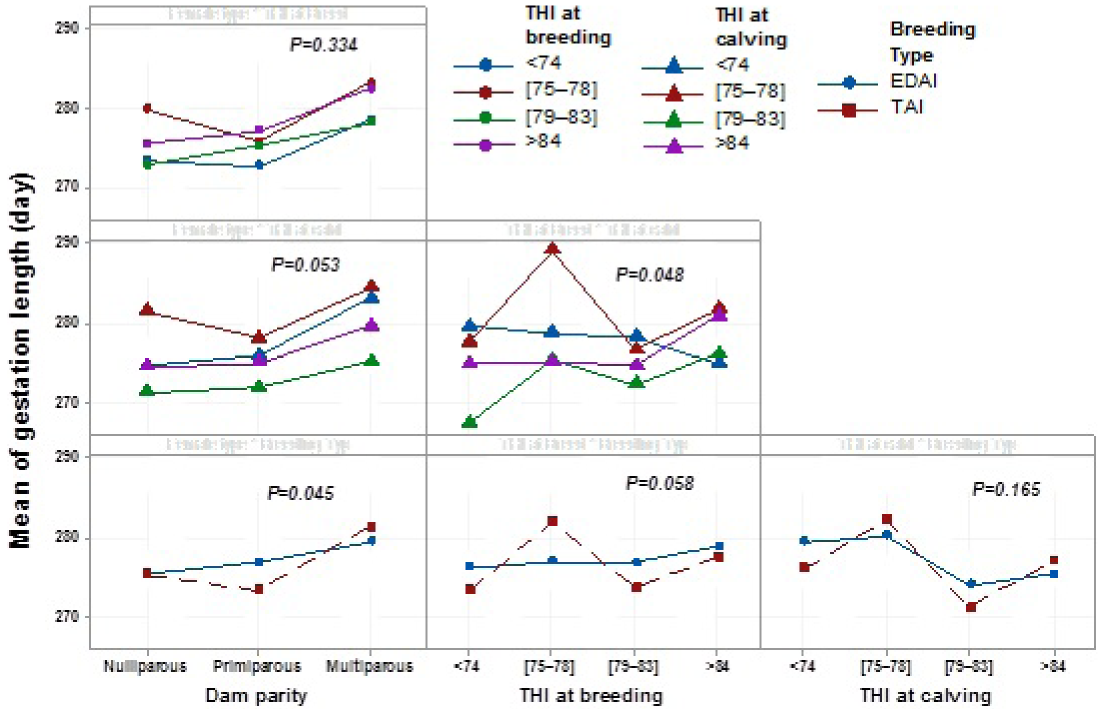

Figure 2. Interaction plot (THI at breeding × THI at calving × Dam parity × Breeding type) for GL.

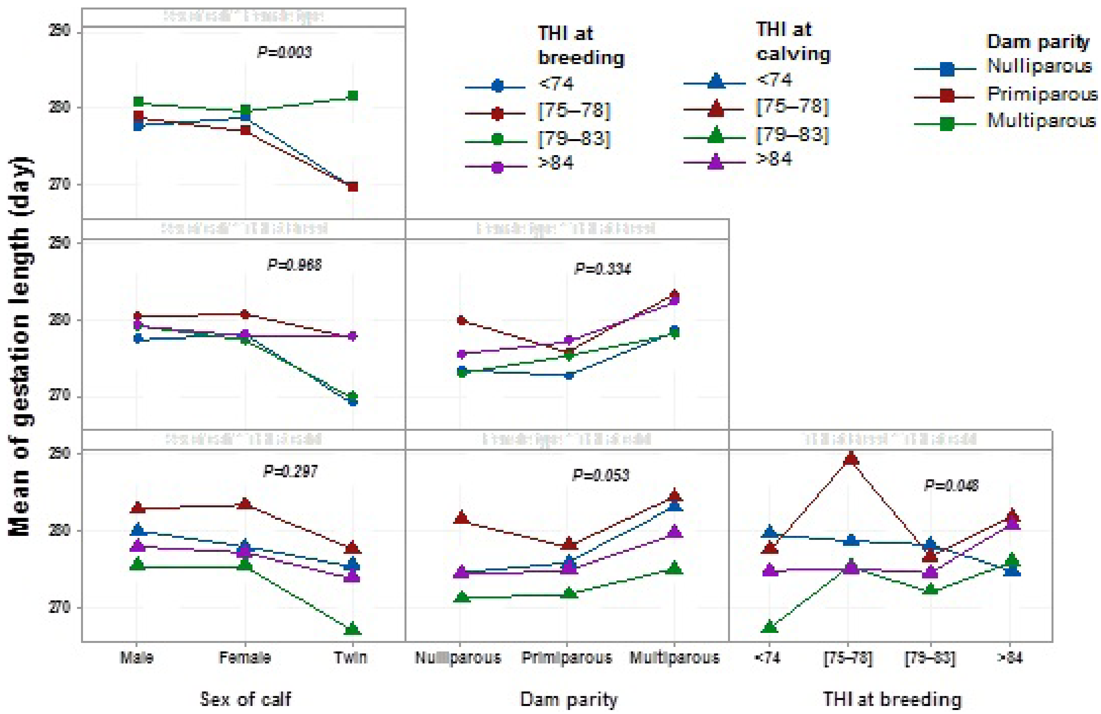

Figure 3. Interaction plot (THI at breeding × THI at calving × Sex of calf × Dam parity) for GL.

4.3. Effect of female parity on gestation length

Our results indicate that gestation length of primiparous and nulliparous is much shorter than gestation length of multiparous cows, and is supported by previous studies of [25,1,26,10,6]. We speculate that differences can be a result of different concentrations of a circulating P4 hormone

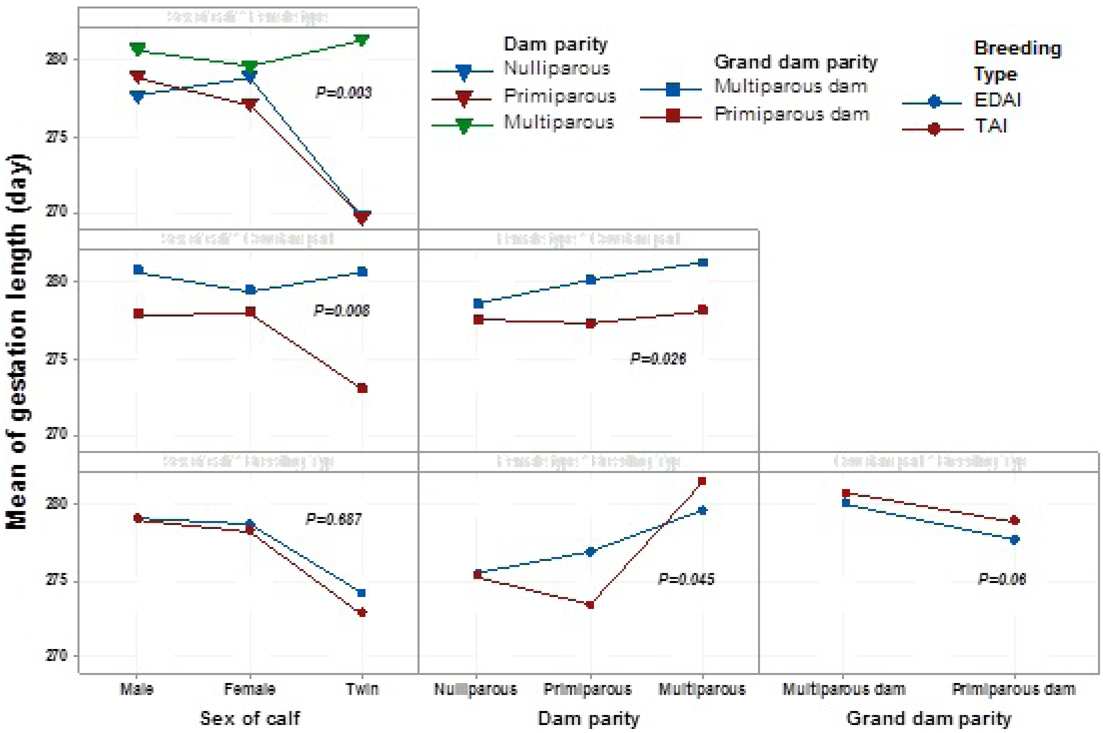

Figure 4. Interaction plot (Sex of calf × Dam parity × Breeding type × Grand dam parity) for GL.

since [27] and [28] already reported that high-producing multiparous dams have a larger volume of luteal tissue but lower circulating P4 concentrations than nulliparous ones.

We found a nonsignificant effect of the interaction between dam parity and THI at breeding on GL of females. These results are likely to be related to the noninfluence of heat stress on plasma levels of (P4) in females exposed to heat in a climatic chamber during the second half of the oestrous cycle [19]. However, the short GL of primiparous cows is probably related to calf weight [4,29]. These differences can be explained in part by that the primiparous cows are smaller than multiparous cows, having less space to accommodate the calf in the abdominal cavity at the end of gestation, which could create potential stress for the foetus and alter blood flow and oxygen availability, thus stimulating the activity of the hypothalamic-pituitary-adrenal axis [1].

4.4. Effect of calf sex on gestation length

On the question of the influence of calf sex on GL, this study found that the development of male calves during gestation was longer than that of females. These results reflect those of Silva Del Río et al. [30] and Echternkamp et al. [8], who also found that the male calves are usually carried 1–2 days longer than females. They observed combination between calf sex and dam parity and its influence on GL. For this purpose, we found that male and female calves from multiparous dam had +3.07 days and + 2.55 days, respectively than those from nulliparous dam, it might be explained by McClintock et al. [31], who reported that heifers carried male calves longer than female calves (0.6 day), as did lactating cows (0.9 day). Besides, Matthews and Challis [32] reported that calving is triggered by increased foetal glucocorticoid concentrations due to maturation and activation of the foetal hypothalamic-pituitary-adrenal axis. In this regard, Vieira-Neto et al. [1] estimated that the definitive development of this axis takes longer in males and results in a longer GL than in females.

4.5. The effect of twins on gestation length

Another finding was that the GL of twins was significantly shorter (–2.64 days) than that of singletons in Holstein cows, which were lower than those reported by Norman et al. [2] (–4.6 days) and Tomasek et al. [6] (–5.2 days). Furthermore, a direct effect of maternal parity on the GL of twins was observed in the current study, we found a difference in twins' GL ($p = 0.032$) between dam categories (nulliparous, primiparous, and multiparous). This outcome is contrary to that of Tomasek et al. [6], who found that the twins had the same GL in cows and heifers. In accordance with the present results, the high frequency of twins in multiparous (75.76%), dairy cows were, however, at a higher risk of twinning due to their higher frequency of multiple ovulations [33] compared to heifers [34]. In particular, Sartori et al. [35] reported that the rate of double ovulation was higher during the warmer months, given that "bizygote" twinning accounts for 95% of twin births in Holstein cattle [36]. In addition, the increased rate of twin births has also been reported in dairy cows given GnRH or PGF2α before conception [37].

4.6. Effect of birth, breeding, and calving year on gestation length

The analysis of the year effect has shown a decline in GL of Holstein cows in recent years. These results corroborate the ideas of Norman et al. [2], who found a difference in GL of Holstein cattle across years, confirming the importance of dam birth, conception, and calving years on GL. A possible explanation for these results may be that the global warming in latest years had a negative impact on the reproductive functions of Holstein cows, especially in hot environments. This study supports evidence from previous observations of Kašná et al. [10], who reported that the effect of calving year as a fixed factor explains only 1% of the total variability, which influences the GL of Holstein cows. In general, the year of calving has a significant effect on reproductive parameters, which may be related to annual changes in husbandry and environmental factors. In addition, the farmer' economic viewpoint and management practices contributed to these changes [38].

5. Conclusion

The aim of the present research was to examine the impact of the factors on the GL of Holstein dairy cattle in a Saharan context. This study has found that, generally, the GL of pregnant females was strongly affected by calf sex, dam parity, and especially heat stress conditions at parturition and their interaction. The findings of this study suggest that it can contribute to appreciate the variation of GL of Holstein cows in hot arid conditions, according the calf sex, the dam parity, and the intensity of heat stress during late gestation in order to predict the calving date of the cows.

The accuracy of calving prediction in the study area can help dairy industry managers in establishing adequate rations corresponding to the nutritional requirements in the final stage of gestation.

Conflict of interest

We certify that there are no conflicts of interest with any financial organization regarding the material discussed in the manuscript.

References

1. Vieira-Neto A, Galvao KN, Thatcher WW, Santos JEP. Association among gestation length and health, production and reproduction in Holstein cows and implications for their offspring. Journal of Dairy Science 2017; 100 (4): 3166-81. https://doi.org/10.3168/jds.2016-11867
2. Norman HD, Wright JR, Kuhn MT, Hubbard SM, Cole JB et al. Genetic and environmental factors that affect gestation length in dairy cattle. Journal of Dairy Science 2009; 92: 2259-2269. https://doi.org/10.3168/jds.2007-0982
3. Silveira D, Souza F, Brauner C, Ayres D, Silveira F et al. Body condition score of Nelore cows and its relation with mature size and gestation length. Livestock Science 2015; 175: 10-17. http://dx.doi.org/10.1016/j.livsci.2015.02.013
4. Hansen M, Lund M S, Pedersen J, Christensen LG. Gestation length in Danish Holsteins has weak genetic associations with stillbirth, calving difficulty, and calf size. Livestock Production Science 2004; 91: 23-33.
5. Tao S, Dahl GE. Heat stress impacts during late gestation on dry cows and their calves. Journal of Dairy Science 2013; 96: 4079-4093. https://doi.org/10.3168/jds.2012-6278
6. Tomasek R, Rezac P, Havlicek Z. Environmental and animal factors associated with gestation length in Holstein cows and heifers in two herds in the Czech Republic. Theriogenology 2017; 87: 100-107. https://doi.org/10.1016/j.theriogenology.2016.08.009
7. Haile-Mariam M, Pryce JE. Genetic evaluation of gestation length and its use in managing calving patterns. Journal of Dairy Science 2019; 102 (1): 476-87.
8. Echternkamp SE, Thallman RM, Cushman RA, Allan MF, Gregory KE. Increased calf production in cattle selected for twin ovulations. Journal of Animal Science 2007; 85: 3239-48.
9. Mader TL, Davis MS, Brown-Brandl T. Environmental factors influencing heat stress in feedlot cattle. Journal of Animal Science 2006; 84: 712-719.
10. Kašná E, Zavadilová L, Krupa E, Krupová Z, Kranjčevičová A. Evaluation of gestation length in Czech Holstein cattle. Czech Journal of Animal Science 2020; 65: 473-481.
11. Scanavez AL, Mendonça LG. Gestation Length and Overall Performance in the Subsequent Lactation of Dairy Cows Conceiving to Holstein, Jersey, or Angus Semen: An Observational Study, Kansas Agricultural Experiment Station Research Reports 2018; 4: Iss. 10. https://doi.org/10.4148/2378-5977.7713
12. Sobek Z, Nienartowicz-Zdrojewska A, Różańska-Zawieja J, Siatkowski I. The evaluation of gestation length range for different breeds of Polish dairy cattle. Biometrical Letter 2015; 52 (1): 37-45.
13. Kamal M, Van Eetvelde M, Depreester E, Hostens M, Vandaele L et al. Age at calving in heifers and level of milk production during gestation in cows are associated with the birth size of Holstein calves. Journal of Dairy Science 2014; 97 (9): 5448-5458.
14. Hansen PJ. Reproductive physiology of the heat-stressed dairy cow: implications for fertility and assisted reproduction. Animal Reproduction 2019; 16: 497-507. https:// doi. org/ 10. 21451/ 1984- 3143- AR2019- 0053

15. Dahl GE, Auchtung TL, Kendall PE. Photoperiodic effects on endocrine and immune function in cattle. Reproduction 2002; Suppl 59: 191-201.

16. Carter F, Forde N, Duffy P, Wade M, Fair T et al. Effect of increasing progesterone concentration from Day 3 of pregnancy on subsequent embryo survival and development in beef heifers. Reproduction, Fertility and Development 2008; 20: 368-375.

17. Lamming GE, Royal MD. Ovarian hormone patterns and subfertility in dairy cows. BSAP Occasional Publication 2001; 26 (1): 105-118. https ://doi.org/10.1017/S0263 967X0 0033620

18. Khodaei-Motlagh M, Zare Shahneh A, Masoumi R, Derensis F. Alterations in reproductive hormones during heat stress in dairy cattle. African Journal of Biotechnology 2011; 10 (29): 5552-5558.

19. Wilson SJ, Marion RS, Spain JN, Spiers DE, Keisler DH et al. Effects of controlled heat stress on ovarian function of dairy cattle. I. Lactating cows. Journal of Dairy Science 1998; 81: 2124-2131.

20. Ronchi B, Stradaioli G, Verini-Supplizi A, Bernabucci U, Lacetera N et al . Influence of heat stress or feed restriction on plasma progesterone, oestradiol-17b, LH, FSH, prolactin and cortisol in Holstein heifers. Livestock Production Science 2001; 68: 231-241.

21. Wright EC, Boehmer BH, Cooper-Prado MJ, Bailey CL, Wettemann RP. Effect of elevated ambient temperature at parturition on duration of gestation, ruminal temperature, and endocrine function of fall-calving beef cows. Journal of Animal Science 2014; 92: 4449-4456.

22. Jainudeen MR, Hafez ESE. Cattle and Buffalo. In: Hafez ESE, Hafez B (editors). Reproduction in Farm Animals. 7th ed. Baltimore: Lippincott Williams and Wilkins; 2000. pp. 159-71.

23. Laburn H, Faurie A, Mitchell D. The thermal physiology of the ruminant fetus. pp. 295-310 in Ruminant Physiology: Digestion, Metabolism, Growth and Reproduction. P. B. Cronjé, ed. CABI Publishing, Wallingford, UK. 2000.

24. Dahl GE, Tao S, Monteiro APA. Effects of late-gestation heat stress on immunity and performance of calves. Journal of Dairy Science 2016; 99: 3193-3198.

25. Nogalski Z, Piwczyński D. Association of length of pregnancy with other reproductive traits in dairy cattle. Asian-Australian Journal of Animal Science 2012; 25 (1): 22-27. http://dx.doi.org/10.5713/ajas.2011.11084

26. Jamrozik JJ, Fatehi G, Kistemaker J, Schaeffer LR. Estimates of genetic parameters for Canadian Holstein female reproduction traits. Journal of Dairy Science 2005; 88: 2199-2208.

27. Sartori R, Haughian JM, Shaver RD, Rosa GJM, Wiltbank MC. Comparison of ovarian function and circulating steroids in estrous cycles of Holstein heifers and lactating cows. Journal of Dairy Science 2004; 87: 905-920.

28. Wolfenson D, Inbar G, Roth Z, Kaim M, Bloch A et al Follicular dynamics and concentrations of steroids and gonadotropins in lactating cows and nulliparous heifers. Theriogenology 2004; 62: 1042-55.

29. Villarroel A, Lane VM . Effect of systematic parturition induction of long gestation Holstein dairy cows on calf survival, cow health, production, and reproduction on a commercial farm. Canadian Journal of Veterinary Research 2010; 74 (2): 136-144.

30. Silva Del Río N, Stewart S, Rapnicki P, Chang YM, Fricke PM. An observational analysis of twin births, calf sex ratio, and calf mortality in Holstein dairy cattle. Journal of Dairy Science 2007; 90: 1255-1264.

31. McClintock, Beard K, Gilmour A, Goddard. Relationships between calving traits in heifers and mature cows in Australia. Interbull Bulletin 2003; 31: 102-106.

32. Matthews SG, Challis JRG. Regulation of the hypothalamo-pituitary-adrenocortical axis in fetal sheep. Trends in Endocrinology and Metabolism 1996; 7: 239-246.

33. Wiltbank MC, Fricke P, Sangsritavong MS, Sartori R, Ginther OJ. Mechanisms that prevent and produce double ovulations in dairy cattle. Journal of Dairy Science 2000; 83: 2998-3007.

34. Rivera H, Lopez H, Fricke PM. Use of intravaginal progesterone releasing inserts in a synchronization protocol before timed AI and for synchronizing return to estrus in Holstein heifers. Journal of Dairy Science 2005; 88: 957-968.

35. Sartori R, Haughian JM, Shaver RD, Rosa GJ, Wiltbank MC. Comparison of ovarian function and circulating steroids in estrous cycles of Holstein heifers and lactating cows. Journal of Dairy Science 2004; 87: 905-920.

36. Silva del Rı´o NB, Kirkpatrick W, Fricke PM. Observed frequency of monozygotic twinning in Holstein dairy cattle. Theriogenology 2006; 66: 1292-1299.

37. Kinsel ML, Marsh WE, Ruegg PL, Etherington WG. Risk factors for twinning in dairy cows. Journal of Dairy Science 1998; 81: 989-993.

38. Galon N, Zeron Y, Ezra E. Factors Affecting Fertility of Dairy Cows in Israel. Journal of Reproduction and Development 2010; 56: Suppl, S8-S14.