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Eight year longitudinal study on cattle reproductive parameters concerning forty-three farms in the Northern of Algeria

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Abstract

A longitudinal study was carried out between February 2007 to September 2015 in Algiers province and 3 neighboring provinces namely Blida, Boumerdes and Tipaza. It included 492 cows from 43 farms (42 private farms, and one farm from State technical livestock institute), the farm size varied from 3 to 115 dairy cows, including the control lot (T) without retained placenta, the number of cows having aborted was thirty (30) cows.

Six reproductive parameters were analysed in this study: the calving-1st heat interval (CFHI), the calving-1st insemination interval (CFII), the calving-fertilizing insemination interval (CCI), the success rate in 1st heat insemination (CR1IA), the percentage of cows requiring 3 or more inseminations to be pregnant or those not pregnant after two inseminations (%3IA) and the percentage of cows culled for infertility (CRI).

The main factors affecting cow reproductive performances were the body condition score (BCS), the type of mating (Artificial insemination versus natural mating), occurrence of reproductive and metabolic disorders. Furthermore, the main causes of culling were infectious diseases like IBR.

Keywords: cows, reproductive performances, Algiers and surrounding provinces, Artificial insemination, fertility, abortion agents.

1. Introduction

Reproduction is a key factor to guarantee the efficiency of cattle production. Poor reproductive performance is responsible of economic losses due to reduced production, prolonged calving interval and extra costs to improve the persistence of lactation and reproductive traits (**Strapáková et al., 2016; Kumar et al., 2017; Niozas et al., 2019**). Cow reproduction is modulated by different aspects of management, including differences within and between breeds in production, nutrition and farming practices. The reproductive efficiency of a breeding cow is modulated by factors such as age at first calving, calving interval and number of services per calving (**Bujko et al., 2013; Dochi et al., 2010; Nuraddis and Ahmed, 2017**).

The decrease in fertility observed in livestock in recent decades, and the increasing requirements of livestock farmers, have made periodic control of reproduction essential to urgently identify and solve problems in reproductive efficiency. Traditionally, the main diagnostic methods for reproductive monitoring in cattle included rectal palpation, inspection of vaginal discharge and vaginoscopy (**Quintela et al., 2012**).

It is well known that improving the cow reproductive performances has a direct impact on the profitability of cattle farming. The reproductive efficiency and profitability of the dairy farm are maximized when the average calving Interval ranges from 12 to 13 months.

Figueroa (2019) conducted research on "the effect of body condition score on reproductive efficiency. It was concluded that cows that have suboptimal body conditions, will have reproductive problems regarding calving interval, while a good body condition positively influences calving and reproductive process.

GutilloParrado and MeloColina (2020) studied the relationship between the main reproductive parameters and reproductive efficiency, whose objective was determining the "factors that influence both the beginning and the outcome of reproductive events both in the female and in the male." They showed that the relevant factors for reproductive efficiency were related to breed, environment, management, nutrition and health, both in beef and dairy cattle. Nonetheless, nutrition remains the factor that greatly impact this performance (**Macheboeuf et al 1993, Keady et al 2001, Kaouche et al 2015a, Kaouche et al 2015b)**.

2. Materials and methods

2.1. Ethical statement

This study was approved by the scientific council of High National Veterinary School, Algiers, Algeria.

2.2. Study zone

The study was undertaken in Algiers province and in 3 neighboring provinces namely Blida, Boumerdes and Tipaza. It was carried out on 43 farms (42 private, and 1 farm from State technical livestock institute), the size of the herds varied from 3 to 115 dairy cows, the study was carried out on 492 dairy cows, including the control lot (T) without retained placenta, the number of cows having aborted was 30, serology was also performed to investigates the abortion causing causes.

2.3. Type of study and data collection

In this work, a longitudinal study was carried out between February 2007 to September 2015. The initial sample size (n) was calculated using the formula provided by Dohoo et al., 2009).

$$n = \frac{1.96^2 \, (P_{exp})(1-P_{exp})}{e^2} \qquad (1)$$

With :

P_{exp}: theoretical success rate in 1st insemination. e: absolute precision.

Therefore, the minimum sample size (n) to select for a theoretical first insemination success rate of 64% (Mouffok et al., 2019) and an absolute precision of 5% is 354 cows.

As a result, data from 492 cows, selected at random, were collected from 43 (42 private and 1 farm from technical livestock institute) breeders, spread over 4 provinces (Algiers, Blida, Boumerdes, Tipaza). The herd size of the selected farms ranged from 3 to 115 cattle.

In this study, each cow was followed from calving until fertilization or culling due to infertility (≥4 inseminations).

Data likely to impact reproductive performance such as cow characteristics (breed, lactation rank and body condition), mating type and season were collected by structured questionnaire with closed questions. While the data relating to reproductive and health disorders of cows were collected by clinical examinations, which consisted of:

D0: day of the first examination,

1st visit 48 hours after the call (general examination: temperature measurement, possible treatment)

2nd visit: D7 (same protocol as visit 1)

3rd visit: D15 (blood test for serology, control of uterine involution, examination of vaginal secretions)

4th visit: D21 (control of uterine involution, examination of vaginal secretions)

5th visit: (control of uterine involution, examination of vaginal secretions + biopsy for histological study = 10 cows per lot)

6th visit: (BCS assessment, control of uterine involution, examination of vaginal secretions + examination of the ovaries)

7th visit: (control of uterine involution, examination of vaginal secretions, examination of the ovaries)

The assessment of the body condition score (BCS body condition score) was carried out by the same operator and following the method described by Hanzen (2009), scores ranging from 0 to 5 were assigned.

This technique was done twice at the time of delivery and 6 weeks later to observe the evolution of the BCS which is a reflection of the energy balance of the animal.

2.4. Reproductive performance parameters

Six reproductive parameters were analysed in this study: the calving-1st heat interval (CFHI), the calving-1st insemination interval (CFII), the calving-fertilizing insemination interval (CCI), the success rate in 1st heat insemination (CR1IA), the percentage of cows requiring 3 or more inseminations to be pregnant or those not pregnant after two inseminations (%3IA) and the percentage of cows culled for infertility (CRI).

2.5. Statistical analysis

A descriptive analysis was used, first, to study the data collected in this work. Quantitative variables were presented by their means and standard deviations, while categorical variables were presented as absolute frequencies and percentages.

A multivariate generalized linear model (GLM precisely Analysis of Variance or ANOVA) was used to study the impact of cow characteristics (breed, lactation rank and body condition score), reproductive management by the breeder (type of mating and calving season), reproductive disorders (calving mode, uterine involution and vaginal health situation) and health disorders (Q fever, Chlamydia, IBR and salmonellosis) on reproductive performance following: CFHI, CFII, CCI, CR1IA, %3IA and CRI.

The linear regression model was used to analyse the first three reproductive parameters (CFHI, CFII and CCI). While for the last three reproduction parameters (CR1IA, %3IA and CRI), a logistic regression model was used.

Finally, for these two types of model, a series of steps was carried out to select the final model for each reproduction parameter:

1. A univariate analysis was carried out, during which the relationship between reproductive performance and each explanatory variable was tested separately, using the likelihood ratio test (LRT). Variables with p-value < 0.25 (with an α error risk of 5%) were retained for the multivariate analysis (Mickey and Greenland, 1989).
2. A linearity test was carried out for the continuous variables, which were retained in step i, using the LRT test (Zhang, 2016a). When the LRT test indicates the absence of a linear trend, the quantitative variable is transformed into categorical variables.
3. The multi-co-linearity of the variables selected in the univariate analysis (step i) is tested by the variance inflation factor (VIF). Variables with a VIF < 10 were retained for the multivariate analysis (Dohoo et al., 2009).
4. A final multivariate model is constructed in this step for each breeding performance parameter. The selection of the best model was carried out using the Akaike Information Criterion (AIC) (Akaike, 1998), using the bottom-up stepwise variable selection method (from an empty model) (Zhang , 2016b). The model with the lowest AIC value was chosen. All second-order interactions between the explanatory variables were tested in the final model. The assumptions of normality and equality of variances of the residuals for the linear regression model were checked graphically. The general goodness of fit of the logistic regression model was verified by the Hosmer-Lemeshow test (Hosmer and Hjort, 2002).
5. The assumptions of normality and equality of variances of the residuals for the linear regression model were checked graphically. The general goodness of fit of the logistic regression model was verified by the Hosmer-Lemeshow test (Hosmerand Hjort, 2002).

Statistical analyses were performed using R software (version 3.4.0) (R Development Core Team, 2016).

3. Results et discussion

3.1. Descriptive analysis

In this work, the average of CFHI (the calving-1st heat interval (CFHI) was 87.5 ± 25.4 days, The CFII (the calving-1st insemination interval (CFII) was 93.2 ± 23 .7 days and CCI (the calving-fertilizing insemination interval (CCI), was 107.1 ± 29 days (Table 1).

The results concerning the CFII (calving interval – 1st insemination) are more extended compared to the standards, in fact Wattiaux (2006) estimates that the interval should be between 45 and 70 days postpartum.

Regarding the calving-fertilizing insemination interval (CCI), in the case of the present study, it was 107.1 ± 29 days, which is relatively fit the standards. Indeed, Cauty and Perreau (2003) consider that this interval should be less than 110 days.

The CR1IA (the success rate at 1st insemination (CR1IA) was 52.8% (n=260).This rate remains below the standards, in fact Seegers and Malher (1996) estimate that this rate must be greater than 60%, it is higher than those reported by Bouzebda et al (2006) who found a rate ranging between 31 and 39%, It should be noted that this rate depends on several factors relating to the energy balance during this period reflected by the loss of body condition whose intensity and duration go against an adequate resumption of the reproductive cycle and therefore impacts the conception rate and the quality of heat detection (El Jaouhari 2007). and at the time of deposit of the semen in the genital tract in relation to the time of heat and the place of deposit of the semen (Saumand 2001). Also, it can be linked to the quality of the semence or the quality of its conservation or even to the quality of the thawing protocol (Seegers 1996).

However, the %3IA (the percentage of cows requiring 3 or more inseminations to be pregnant or those not pregnant after two inseminations (%3IA) was 24.8% (n=122). (The CRI the percentage of cows culled due to infertility (CRI) is 8.5% (n=42) (Table 1).

These results seem to be acceptable, this is explained by the variations in BCS in the period of the first 6 weeks after calving, a period during which significant variations in BCS have a negative impact on reproductive results, in this case the variation is around from a point which remains compatible with good reproduction performance.

In our study, the cross breed was the most dominant with 33.7% (n=166). The Holstein and Montbéliard breeds represented 20% (n=102) of the workforce respectively. However, the Brown Atlas local race was the least common with 11.6% (n=57) (Table 1).

Regarding parity, 29.1% (n=143) of cows are primiparous compared to only 3% (n=15) which are in the 5^{th} lactation rank or more, which is relatively good for dairy cattle farms and which shows a correct herd renewal rate, which has the effect of promoting performance. The average difference in body condition score between calving and 6 weeks after was 0.93 ± 0.4 (Table 1) (the BCS of the cows varied from x to y).The parity of the cows in the present study and the differences in BCS somewhat explain the relatively good reproductive results.It was observed that 83.3% (n=410) of cows had a normal cycle, while dystocia and abortions accounted for 10.6% (n=52) and 6.1% (n=30) respectively. This percentage of normal calving can be explained by good drying off management (**Cattaneo et al., 2023**), particularly from a nutritional point of view, as proof of the relatively good evolution of the BCS at the start of lactation. Indeed, Drying off is crucial to optimize remodelling and renewal of the mammary gland secretory tissue, but represents a stressful event, involving several changes in daily routine, diet and metabolism (**McCubbin et al., 2022**). This dystocia can be partly explained by the presence of cows with excessive BCS at the time of parturition, on the other hand due to cows which have given birth more than 5 times, which is relatively normal.

During the third visit (which was carried out 15 days after calving), uterine physiological involution was recorded in 37.4% (n=184) of cows, which is relatively good (put reference figure) compared to only 16.9% (n=83) having had metritis or endometritis, which is relatively significant and could be explained by hygiene around calving which does not seem to be controlled, in fact around calving requiring the separation of cows in a place prepared for the event, therefore clean, calm, with clean, dry and abundant bedding is not always achieved and leads to infection problems. Vaginal examination revealed that 63.4% (n=312) of cows had a score of 0 and 16.2% (n=80) had a score of 3 (discharge containing more than 50% pus) (Table 1), which is relatively high and reflects the recurring problem of hygiene in farms

The majority of cows (59.8%) in our study were fertilized by artificial insemination. The distribution of the village season shows that breeders calved 31.2% (n=153) of their cows during the spring (Table 1). As in other countries, dairy cattle are more frequently bred by artificial insemination as compared to beef cattle (**Martin et al, 2010).**

The distribution of cows in the different treatment batches is more or less homogeneous, it varies from 9% (n=44) for batch 9 (Control without delivery and without treatment) to 14.2% (n=70) for lot 2 (the lot must be defined) (Table 1). (lot 2= délivrance+oblets)

The estimated prevalence of Q fever, Chlamydia disease, IBR and salmonellosis were respectively: 2.2%, 19.1%, 25%, 4% and 13.4% (Table 1). They represents the main abortion causing pathogens in cattle worldwide (**Dereje et al., 2024**).

Table 1. Results of the descriptive analysis of reproductive performance indicators, cow characteristics, health and reproductive disorders, treatment lots and reproductive management.

Variable	Indicator	Value
Reproductive performance indicators		
Calving interval - 1st heat	Mean (SD[1])	87,5 (25,4)
(CFHI) (days)	Mean (SD[1])	93,2 (23,7)
Calving interval - 1st	Mean (SD[1])	107,1 (29)
insemination (CFII) (days)	n (%)	260 (52,8)
Calving interval -	n (%)	122 (24,8)
fertilizing insemination	n (%)	42 (8,5)
(CCI) (days)		
Success rate in 1st year		
insemination (CR1IA)	n (%)	57 (11,6)
Percentage of cows requiring 3	n (%)	166 (33,7)
inseminations or more to be	n (%)	66 (13,4)
gravid or non-gravid	n (%)	101 (20,5)
after two inseminations (%3IA)	n (%)	102 (20,8)
Lactation rank		
1	n (%)	143 (29,1)
2	n (%)	147 (29,9)
3	n (%)	129 (26,2)
4	n (%)	58 (11,8)
> = 5	n (%)	15 (3)
ΔBSC^2	Mean (SD)	0,93 (0,4)

Table 1. Results of the descriptive analysis of reproductive performance indicators, cow characteristics, health and reproductive disorders, treatment lots and reproductive management. (Continued)

Variable	Indicateur descriptive	Valeur
Reproductive problems		

Last calving event		
Abortion	n (%)	30 (6,1)
Dystocia	n (%)	52 (10,6)
Physiological	n (%)	410 (83,3)
Uterine involution		
Physiological	n (%)	184 (37,4)
Subinvolution	n (%)	225 (45,7)
Metritis	n (%)	83 (16,9)
Vaginal examinassion		
0	n (%)	312 (63,4)
1	n (%)	49 (10)
2	n (%)	51 (10,4)
3	n (%)	80 (16,2)
Reproductive management		
Mating type		
Artificial insemination	n (%)	294 (59,8)
Natural mating	n (%)	198 (40,2)
Last calving Season		
Autumn	n (%)	103 (21)
Winter	n (%)	112 (22,8)
Spring	n (%)	153 (31,2)
Summer	n (%)	123 (25)
Treatment lots		
1	n (%)	53 (10,8)
2	n (%)	70 (14,2)
3	n (%)	45 (9,1)
4	n (%)	58 (11,8)
5	n (%)	48 (9,8)
6	n (%)	66 (13,4)
7	n (%)	46 (9,3)
8	n (%)	62 (12,6)
9	n (%)	44 (9)

Table 1. Results of the descriptive analysis of reproductive performance indicators, cow characteristics, health and reproductive disorders, treatment batches and reproductive management. (Continued).

Variable	Descriptive indicator	Valeur
Health status of cows		
Q fever	n (%)	11 (2,2)

Chlamydia	n (%)	94 (19,1)
IBR	n (%)	125 (25,4)
Salmonellosis	n (%)	66 (13,4)

[1]SD : Standard deviation
[2]Δ BSC :BCS difference between calving and 6 weeks after

3.2. Multivariate analysis

3.2.1. Calving-1st heat interval (CFHI)

The results in Table 2 show that there was a significant effect of the difference in body condition score between calving and 6 weeks after, vaginal examination score and mode of calving on CFHI.Cows having lost between 0.5 and 1 point and more than one point in body condition score had on average a significantly higher CFHI of 10.27 (95% CI: 6.45; 14.08) and 46 (95% CI), respectively. : 40.99; 51.01) days compared to cows which lost less than 0.5 points (Table 2). These results could be explained by the fact that cows which show a significant drop in their BCS, expend a lot of energy at the start of lactation and suffer from hypoglycaemia, which does not allow a better resumption of reproduction and therefore the expression of heat unlike those who experience a lesser reduction in their BCS. It is well known that BCS evacuation is an easy, cheap, reliable method to estimate cow endogenous energy balance. Furthermore, this method fits for large-scale studies (**Ayres et al., 2009; Limai and Simon, 2022**). Cows with a score 2 on vaginal examination had, on average, 10.57 (95% CI: 4.64; 16.51) days more in CFHI compared to cows with score 0 (Table 2). This can be explained by the fact that the reproductive system needs more time to defend itself against infection, which will also require energy expenditure to defend against infection, and therefore will be subtracted from the reproductive axis, which explains these delays between healthy animals and infected animals. Abortion significantly reduces, on average, -10.45 (95% CI: -17.65; -3.25) CFHI days compared to physiological calving. However, we observed that there was not a significant difference in CFHI between physiological and obstructed calving (P-value = 0.52) (Table 2). Abortion remains the most devastating and costly issue in livestock, directly influencing their productive and reproductive performances (**Dereje et al., 2024**)

Table 2. Regression coefficients of the final model related to calving-first heat interval (CFHI).

Variable	Catégorie	Moyenne ± SD[1]	β (95% CI)[2]	P-value	R^2
Δ BSC[3]	<= 0,50	74.08 ± 15.41	Référence		0.44
	] 0,50 – 1]	84.59 ± 20.52	10.27 (6.45 ; 14.08)	< 0.001	
	> 1	121.22 ± 23.06	46 (40.99 ; 51.01)	< 0.001	
Score d'examen vaginal	0	84.49 ± 23.1	Référence		
	1	85.27 ± 26.51	-0.33 (-6.32 ; 5.65)	0.91	
	2	102.08 ± 28.06	10.57 (4.64 ; 16.51)	< 0.001	
	3	91.62 ± 28.2	4.62 (-0.29 ; 9.54)	0.06	
Mode de vêlage	Physiologique	87.32 ± 24.85	Référence		

	Avortement	77.67 ± 23.14	-10.45 (-17.65 ; -3.25)	0.004
	Dystocique	95.04 ± 29.11	-1.94 (-7.94 ; 4.06)	0.52

[1]SD : Ecart-type.

[2]β : Coefficient de régression ; IC : intervalle de confiance.

[3]Δ BSC :Difference in body condition score between calving and 6 weeks after.

3.2.2. Calving-1st insemination interval (CFII)

It was found that the difference in body condition score between calving and 6 weeks after, treatment batch, mating type and vaginal examination score had a significant effect on CFII (Table 3). The loss between 0.5 and 1 point and more than 1 point in the body condition score increased respectively on average CFII by 8.98 (95% CI: 5.25; 12.71) and 40.03 (95% CI: 34.85; 45.21) days compared to a loss of less than 0.5 points (Table 3). Indeed it is clear that cows which lose less condition place less strain on their reserves and find themselves more quickly in a positive energy balance, which allows a better resumption of reproductive activity and therefore consequently reduces the calving interval 1st insemination, it is also clear that animals which have not had an infection of their genital tract have a greater chance of resuming normal reproduction, as do cows infected and treated and which have seen the state of their reproductive system improve following treatment. Indeed, **Luiz et al (2021**) showed the strong relationship between BCS and cow fertility.

Table 3. Regression coefficients of the final model concerning calving-first insemination interval (CFII) .

Variable	Category	Mean ± SD[1]	β (95% CI) [2]	P-value	R^2
Δ BSC[3]	<= 0,50	81.44 ± 16.6	Reference category		0.41
	] 0,50 – 1]	90.6 ± 19.22	8.98 (5.25 ; 12.71)	< 0.001	
	> 1	122.49 ± 22.41	40.03 (34.85 ; 45.21)	< 0.001	
Treatment lots	9	85.18 ± 21.96	Reference category		
	1	92.83 ± 31.69	-3.05 (-10.97 ; 4.86)	0.44	
	2	96.3 ± 20.5	5.06 (-2.03 ; 12.16)	0.16	
	3	98.42 ± 27.35	4.8 (-3.23 ; 12.82)	0.24	
	4	95.4 ± 23.12	3.48 (-3.76 ; 10.72)	0.34	
	5	101.25 ± 24	10.44 (2.46 ; 18.42)	0.01	
	6	90.86 ± 22.05	4.69 (-2.49 ; 11.87)	0.19	
	7	90.15 ± 22.19	4.51 (-3.09 ; 12.1)	0.24	
	8	88.18 ± 18.18	1.56 (-5.56 ; 8.68)	0.66	
Insemination =	Artificial	96.17 ± 24.61	Reference category		
mating	Natural	88.73 ± 21.70	-3.97 (-7.39 ; -0.55)	0.02	
Vaginal Score	0	90.34 ± 22.07	Reference category		
examination	1	94.18 ± 24.31	3.46 (-2.56 ; 9.48)	0.25	
	2	104.8 ± 25.26	8.52 (2.46 ; 14.58)	0.006	
	3	96.19 ± 26.36	2 (-2.98 ; 6.98)	0.43	

[1]SD : Standard deviation

[2]β : Regression Coefficient; C.I : Confidence Interval

[3]Δ BSC : Difference in body condition score between calving and 6 weeks after.

Regarding the impact of the treatment, we observe that only cows in batch 5 (having received oblets and PGF2 alpha) had a significantly higher CFII (10.44, 95% CI: 2.46; 18.42) compared to lot 9 “control” (Table 3). Likewise, multiple comparisons of the effect of treatment batches by Tukey post-hoc test show that batch 5 had a significantly higher CFII compared to batches 1 (having received oblets) and 8 (oblets + PGF1 and 1')) (figure 1).

The use of natural mating significantly reduces, on average, -3.97 (95% CI: -7.39; -0.55) CFII days compared to artificial insemination. Cows with a score of 2 on vaginal examination had, on average, 8.52 (95% CI: 2.46, 14.58) days more in CFII compared to cows with score 0 (Table 3). Heifers and cows respond extremely well to the MGA/PGF2α system. PGF2α, GnRH and progestin are the most important hormonal treatments for estrus synchronization. The main limitation of estrus synchronization programs lies in their inability to induce potentially fertile estrus and ovulation in non-cycling livestock (**Fesseha and Dega, 2020**)

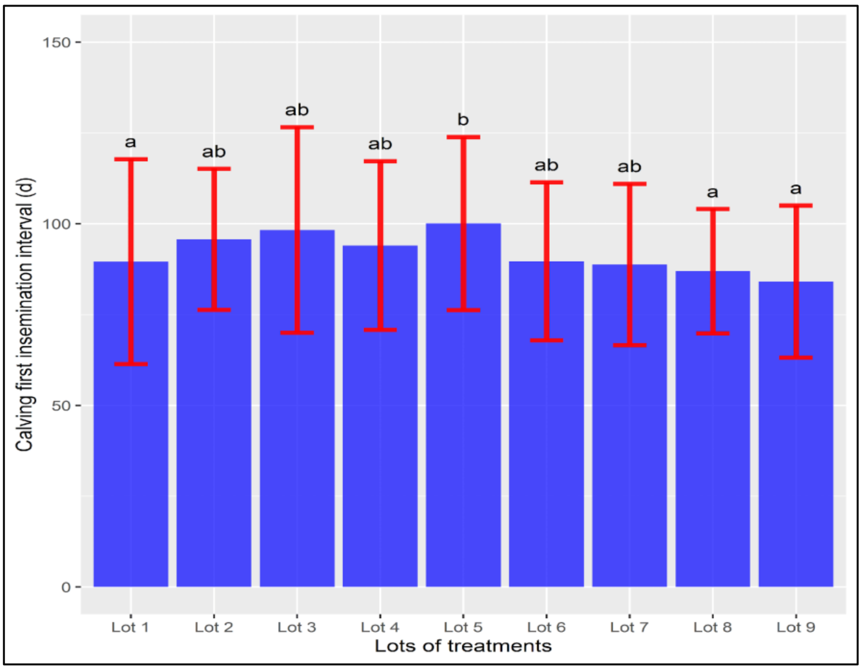

Figure 1. Mean and standard deviation of calving-first insemination interval (CFII) per treatment lot. Bars marked with different lowercase letters are significantly different ($P < 0.05$).

3.2.3. Calving-fertilizing insemination interval (CCI)

The results of the CCI model show that the loss of body condition score between calving and 6 weeks later was positively correlated with this reproductive parameter. Indeed, cows that lost between half and one point had, on average, 9.05 (95% CI: 3.99; 14.1) more days in CCI compared to those that lost less than half a point. However, the loss of more than one point increased significantly from 40.03 (95% CI: 34.85; 45.21) CCI days to a loss of less than 0.5 points (Table 4).

This is explained by a better energy balance in cows which lose less condition, in fact these cows very quickly find a positive energy balance favourable to fertilization, the cows which lose 1 point and more suffer in addition to the negative balance of periods of subclinical and sometimes even clinical ketosis which have an unfavourable effect on the resumption of the reproductive cycle and on the results of fertilization. **Luiz et al (2021)** have demonstrated the importance and practicability of BCS evaluation in the cow reproduction monitoring.

Naturally bred cows had, on average, a significantly reduced CCI of -16.12 (95% CI: -20.8; -11.44) days compared to artificially inseminated cows (Table 4). Animals which are the subject of natural breeding have better responses on the one hand because the bull better detects the cows to be used for reproduction, in addition the bull's ejaculate contains many more spermatozoa which allows more high chances of fertilization

Cows with metritis had, on average, a higher CCI of 11.06 (95% CI: 4.11; 18.01) days compared to cows with physiological uterine involution (Table 4).

It is clear that cows which have infections of the reproductive tract require time to clear this apparatus for a better resumption of reproduction.

Table 4. Regression coefficients of Calving first fertilizing insemination interval (CCI) model.

Variable	Catebory	Mean ± SD[1]	β (95% CI)[2]	P-value	R^2
Δ BSC[3]	<= 0,50	95.64 ± 22.98	Reference category		0.29
	] 0,50 – 1]	106.37 ± 26.85	9.05 (3.99 ; 14.1)	< 0.001	
	> 1	134.49 ± 29.65	33.83 (26.81 ; 40.85)	< 0.001	
Type of mating	Artificial	115.2 ± 30.61	Reference category		
	Natural	96.06 ± 22.55	-16.12 (-20.8 ; -11.44)	< 0.001	
Uterine involution	physiological	99.93 ± 25.08	Reference category		
	Sub-involution	108.85 ± 29.25	4.69 (-0.35 ; 9.74)	0.06	
	Metritis	119.11 ± 32.66	11.06 (4.11 ; 18.01)	0.002	

[1]SD : Standard deviation.

[2]β : Coefficient of regression ; IC :Confidence interval

[3]Δ BSC Difference in body condition score between calving and 6 weeks after.

3.2.4. First insemination success rate (CR1IA)

The introduction of artificial insemination (AI), particularly in dairy cattle, revolutionized animal reproduction procedures from the 20th century onwards (**Hunter et al., 2021).**

In this study, only the type of mating had a significant effect on CR1IA. Breeders who use natural mating for the reproduction of their cows had a significantly higher CR1IA (OR = 2.79, 95% CI: 1.93; 4.08) compared to those who used artificial insemination.It is obvious that cows which are the subject of natural mating have a greater chance of being fertilized at the first breeding compared to those artificially inseminated, for the reasons mentioned above, sperm concentration of ejaculate and better selection by the bull of cows ready for reproduction. Numerous factors like parity, insemination timing, insemination procedures, reproductive disorders (dystocia, metritis, and retained placenta), greatly influence the conception rate (**Tadesse et al., 2022**).

3.2.5. Percentage of cows requiring 3 or more inseminations to be pregnant or those not pregnant after two inseminations (%3IA)

The results in Table 5 show that the variables type of mating, season of last calving and uterine involution have a significant impact on the % 3IA. Naturally bred cows are less likely to have three or more inseminations compared to those that have been artificially inseminated (OR = 0.13, 95% CI: 0.06; 0.25) this is explained as explained above, by the concentration in spermatozoa and the detection of heat and therefore of cows to be put into reproduction. According to **Baruselli et *al* (2018)**, artificial insemination (A.I) is inadequate to the farm conditions, it can reduce reproductive efficiency by increasing the calving to conception interval and, thus, increasing the calving interval as compared to natural mating (NM)

Calving in winter significantly increases the risk of having three or more inseminations (OR = 2.2, 95% CI: 1.006; 4.98) compared to calving in autumn, during winter cows experience periods of relatively low temperatures and direct part of the energy to fight against the cold, in addition the cows are generally in stables and express their heat less well, sometimes they are tied which accentuates the problems of heat detection. However, there was a significant difference in %3IA between spring, summer and autumn. Indeed environmental and weather conditions, mainly temperature and humidity, exert a strong effect in / on cow productivity (**Stojnov et al., 2024)**. Cows suffering from metritis are more likely to have three or more inseminations compared to cows with physiological uterine involution (OR = 2.31, 95% CI: 1.08; 4.91) (Table 5). It is clear that cows with metritis require a period of clearance of their apparatus, during this clearance period they experience failures to breed. Indeed several factors like mating type, timing of insemination and farming practices affect the cow fertility rate (**Haadem et al., 2023**).

Table 5. Odds ratios (OR) and their 95% confidence intervals of the final model regarding percentage of cows requiring 3 or more inseminations to be pregnant or those not pregnant after two inseminations.

Variable	Category	%3IA[1]	OR (95% CI)[2]	P-value
Type of mating	Artificial	27.4%	Reference category	
	Natural	4.73%	0.13 (0.06 ; 0.25)	< 0.001
Season of last calving	Autumn	14.1%	Reference category	
	Winter	24.5%	2.2 (1.006 ; 4.98)	0.049
	Spring	19.3%	1.37 (0.65 ; 2.98)	0.42
	Summer	13.1%	0.78 (0.34 ; 1.83)	0.56
Uterine Involution	Physiological	12.3%	Reference category	
	Sub-involution	19.8%	1.53 (0.84 ; 2.84)	0.16
	Metritis	25%	2.31 (1.08 ; 4.91)	0.03

[1]%3IA : Percentage of cows requiring 3 or more inseminations to be pregnant or those not pregnant after two inseminations.

[2]OR : Odds-ratio ; CI : Confidence Interval.

3.2.6. Percentage of cows culled for infertility (CRI)

Recording the factors responsible for culling helps to identify many issues affecting the farm from cow-level to herd-level (**Yanga and Jaja, 2022**). The loss of one point in the body condition score significantly increases the probability of being discharged for infertility (OR = 1.8, 95% CI: 1.81; 2.99). Breeders who use natural mating have a significantly lower percentage of cows culled for infertility compared to those who use artificial insemination

(OR = 0.33, 95% CI: 0.14; 0.70), this is in relation to the fact that these cows have a greater chance of being impregnated than those bred by artificial insemination, that is to say greater concentration of sperm in the ejaculate and problems with detecting heat. Finally, cows affected by infectious bovine rhinotracheitis (IBR) have a greater risk of being culled for infertility compared to cows free of this disease (OR = 1.99, 95% CI: 1.01; 3.89) (Table 6), in fact this condition has a debilitating effect on the animal, in addition it can affect the reproductive system and therefore directly impact the reproductive results. In fact, IBR is a leading source of economic losses, causing abortion, retained placenta, metritis, infertility both in bull and cow, and various respiratory or genital infections (**Graham, 2013**).

According to **Weigel et al (2019),** the most frequently recorded reasons for culling at the cow-level include old age, mammary and foot diseases, metabolic diseases or disorders, respiratory diseases, infectious (like IBR) and non-infectious diseases, injury, infertility, and accidents.

Table 6. Odds ratios (OR) and their 95% confidence intervals of the final model of the percentage of cows culled for infertility (CRI).

Variable	Category	CullR[1]	OR (95% CI)	P-value
Δ BSC[3]	*[4]	*[4]	1.87 (1.81 ; 2.99)	0.008
Type of mating	Artificial	11.6	Reference category	
	Natural	4.05	0.33 (0.14 ; 0.70)	0.007
IBR	No	7.08	Reference category	
	Yes	12.8	1.99 (1.01 ; 3.89)	0.048

[1]CullR: Percentage of cows culled for infertility.
[2]OR: Odds ratio; CI: confidence interval.
[3]Δ BSC: difference in body condition score between calving and 6 weeks after.
[4]: No categories for the variable ΔBSC, because it has a linear effect on the percentage of cows culled for infertility. The correlation coefficient (ρ) between these two variables is 0.14.

4. Conclusion

Cattle diseases, along with poor farming practices, are responsible for significant production losses both in dairy and beef farms. A large part of these losses can be avoided by improving hygienic conditions, mastering artificial insemination, and the good handling of the transition period from drying up to new conception. The periodic control and evaluation of reproductive parameters, such as the success rate of artificial insemination, the calving interval, the duration of uterine involution, optimize cattle production efficiency. In our study, it turns out that poor body condition, the occurrence of infectious diseases such as metritis and IBR, and bad handling of artificial insemination, are the main causes of the deterioration in cattle productivity.

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